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Abkürzungen

AEE: Akzeptanz, Effektivität, Effizienz

BMBF: Bundesministerium für Bildung und Forschung

CFIR: Consolidated Framework for Implementation Research

CISSM: Clinical Information Systems Success Model

EBN: Evidence-based Nursing

ELSI: Ethical, Legal, Social Implications

DIPSA: Development of an Evaluation Framework for Health Information Systems

DNT: Digital Nursing Technologies (= digitale Pflegetechnologien)

DTIP: Digitale technologische Innovationen in der Pflege

PIZ: Pflegeinnovationszentrum

RCT: Randomised Controlled Trial

IKT: Informations- und Kommunikationstechnologien

MAST: Model for Assessment of Telemedicine

NASSS: Nonadoption, Abandonment, Scale-up, Spread, and Sustainability

NWA: Nutzwertanalyse

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

TRL: Technology Readiness Levels

Zusammenfassung

Digitalen Pflegetechnologien (DNT) wird das Potenzial zugesprochen, die Pflege zum Positiven zu verändern. Neben einer grundsätzlichen Offenheit für das Thema existieren in der Pflege auch kritische Stimmen, die das Potenzial von DNT, zu Verbesserungen vorhandener Probleme beizutragen, infrage stellen. Das Potenzial von DNT und die damit einhergehenden Veränderungen in der Pflege zu analysieren, ist mithilfe einer wissenschaftlichen Evaluation möglich. Diese kumulative Dissertation hat daher eine Aufarbeitung des Wissensstands zum Thema Evaluation und Bewertung von digitalen Pflegetechnologien zum Gegenstand. Dazu wurde ein Methodenmix bestehend aus einem Scoping Review, einem Critical Review, einem Expertenworkshop, sowie einem Overview durchgeführt. Als übergreifende Fragestellung wurde untersucht, wie eine umfassende Evaluation und Bewertung von digitalen Pflegetechnologien ermöglicht werden kann und anhand welcher Kategorien und Kriterien dies geschehen müsste.

Zur Beantwortung der Forschungsfrage wurde eine Analyse der bisher wissenschaftlich evaluierten DNT und den dazu verfügbaren Erkenntnissen in der Forschungsliteratur durchgeführt. Außerdem wurde eine Strukturierung des Felds bezogen auf den Teilbereich der Wirksamkeitsforschung vorgenommen und ein neues Modell zur Erfassung von Wirksamkeit von DNT erarbeitet. Abschließend wurden verfügbare Evaluationsframeworks für DNT recherchiert, untersucht und verglichen, sowie deren Stärken und Schwächen analysiert.

Als Ergebnis kann berichtet werden, dass eine umfassende Evaluation und Bewertung von DNT ermöglicht werden kann durch (1) die Evaluationen vielversprechender, spezifischer DNT in den Bereichen Akzeptanz, Effektivität und Effizienz auf einem hohen Evidenzniveau in realen Anwendungssettings, (2) die (Wirksamkeits-)Evaluation von DNT in verschiedenen, in dieser Arbeit herausgearbeiteten Outcome-Bereichen auf verschiedenen Ebenen zur Identifikation von wirksamen DNT, und (3) die kritische Auswahl und Nutzung von strukturierten Evaluationsframeworks anhand der in dieser Arbeit erarbeiteten Kriterien und die Einordnung und Strukturierung des Evaluationsvorhabens anhand der in dieser Arbeit herausgearbeiteten Evaluationsbereiche, durch vorab festzulegenden Evaluations- und Bewertungsperspektiven. Die Gesamtarbeit beschreibt als Referenzrahmen übergeordnete Evaluationsbereiche und Methoden, sowie Perspektiven, die zukünftig für die Evaluation von DNT genutzt werden sollten. Aufkommende Fragen können in diesen neu geschaffenen Referenzrahmen eingeordnet werden und der Kontext für die Erforschung von DNT wird besser verständlich. Der eröffnete Referenzrahmen hilft anderen Forscher:innen dabei, kleinteiligere Forschungsfragen unter einer neuen Perspektive zu bearbeiten.

Summary

Digital nursing technologies (DNT) have the potential to change nursing for the better. In addition to an openness for the topic, there are also critical voices in nursing that question the potential of DNT to contribute to an improvement of existing problems. Analysing the potential of DNT and the associated change in nursing care is possible with the help of a scientific evaluation. This cumulative dissertation therefore contains an inventory of the state of knowledge on the topic of evaluation and assessment of digital nursing technologies. For this purpose, a method mix consisting of a scoping review, a critical review, an expert workshop and an overview was carried out. The overarching question examined was how a comprehensive evaluation and assessment of digital nursing technologies can be made possible and which categories and criteria should be used to do this.

An analysis of the DNT that have been scientifically evaluated to date and of the available research findings was carried out to answer the research question. In addition, a structuring of the field related to the sub-area of effectiveness research on DNT was carried out and a new model for recording the effectiveness of DNT was developed. Finally, available evaluation frameworks for DNT were researched, examined and their strengths and weaknesses analysed.

As a result, it can be reported that a comprehensive evaluation and assessment of DNT can be enabled by (1) evaluating promising, specific DNT in the areas of acceptance, effectiveness and efficiency at a high level of evidence in real application settings, (2) the (effectiveness) evaluation of DNT in different outcome areas identified in this work at different levels to identify effective DNT, and (3) the critical selection and use of structured evaluation frameworks based on the criteria elaborated in this thesis and the classification and structuring of the evaluation project based on the evaluation areas elaborated in this thesis, through evaluation and assessment perspectives to be defined in advance. The overall work describes as a frame of reference overarching evaluation areas and methods, as well as perspectives that should be used in future evaluations of DNT. Emerging questions can be placed in this newly created frame of reference and the context for research on DNT becomes more comprehensible. The opened frame of reference helps other researchers to address smaller research questions from a new perspective.

Vorbemerkung

Die vorliegende Dissertation setzt sich aus den folgenden Einzelarbeiten (Publikationen in Erstautorenschaft und Alleinautorenschaft) zusammen:

- Krick, T., Huter, K., Domhoff, D., Schmidt, A., Rothgang, H. & Wolf-Ostermann, K. (2019). Digital technology and nursing care: a scoping review on acceptance, effectiveness and efficiency studies of informal and formal care technologies. BMC Health Services Research, 19 (400).
- Krick, T., Huter, K., Seibert, K., Domhoff, D. & Wolf-Ostermann, K. (2020). Measuring the effectiveness of digital nursing technologies: development of a comprehensive digital nursing technology outcome framework based on a scoping review. BMC Health Services Research, 20 (1), 243.
- Krick, T. (2021). Evaluation frameworks for digital nursing technologies: analysis, assessment, and guidance. An overview of the literature. BMC Nursing, 20 (1), 146.

Darüber hinaus sind folgende Publikationen, die in einem Peer-Review-Verfahren begutachtet und in wissenschaftlichen internationalen Fachzeitschriften publiziert wurden, mit Beteiligung von Tobias Krick entstanden:

- Gliesche, P., Krick, T., Pfingsthorn, M., Drolshagen, S., Kowalski, C. & Hein, A. (2020). Kinesthetic Device vs. Keyboard/Mouse: A Comparison in Home Care Telemanipulation. Front Robot AI, 7, 561015.
- Huter, K., Krick, T. & Rothgang, H. (2022). Health economic evaluation of digital nursing technologies: a review of methodological recommendations. Health Econ Rev, 12 (1), 35.
- Huter, K., Krick, T., Domhoff, D., Seibert, K., Wolf-Ostermann, K. & Rothgang, H. (2020). Effectiveness of Digital Technologies to Support Nursing Care: Results of a Scoping Review. Journal of Multidisciplinary Healthcare., 13, 1905–1926.
- Seibert, K., Domhoff, D., Huter, K., Krick, T., Rothgang, H. & Wolf-Ostermann, K. (2020). Application of digital technologies in nursing practice: Results of a mixed methods study on nurses' experiences, needs and perspectives. Zeitschrift für Evidenz, Fortbildung und Qualität im Gesundheitswesen.

In diesem Abschnitt werden weitere Beiträge mit Themenrelevanz für diese Dissertation von Tobias Krick gelistet (Bücher, Buchbeiträge und sonstige Publikationen):

- Domhoff, D., El Ali, A., Huter, K., Krick, T., Stratmann, T.C., Wolf-Ostermann, K. & Rothgang, H. (2018). Digitale, automatisierte Analyse von Literaturdatenbanken in Public

Health und Pflegewissenschaft – Quantitative Textanalyse großer Ergebnismengen mittels Topic Modeling. Eine Darstellung am Beispiel neuer Technologien in der Pflege. In: Boll, S., Hein, A., Heuten, W. & Wolf-Ostermann, K. (Hrsg.), Zukunft der Pflege. Tagungsband der 1. Clusterkonferenz 2018 „Innovative Technologien für die Pflege“ (S. 190–195). Oldenburg: OFFIS – Institut für Informatik.

- Klawunn, R., Walzer, S., Zerth, J., Anika, H.-S., Schepputat, A., Forster, C., Müller, S., Dierks, M.-L. & Krick, T. (2021). Auswahl und Einführung von Pflegetechnologien in Einrichtungen der Pflegepraxis – Erfahrungen aus den vier Pflegepraxiszentren und dem Pflegeinnovationszentrum des „Clusters Zukunft der Pflege“. In: Bettig, U., Frommelt, M., Maucher, H., Schmidt, R. & Thiele, G. (Hrsg.), Digitalisierung in der Pflege. Auswahl und Einsatz innovativer Pflegetechnologien in der geriatrischen Praxis (S. S. 37–70). Heidelberg: Medhochzwei.
- Krick, T., Zerth, J., Rothgang, H., Klawunn, R., Walzer, S. & Kley, T. (2023). Pflegeinnovationen in der Pflegepraxis – Erkenntnisse aus dem „Cluster Zukunft der Pflege“. Berlin: Springer Gabler (im Erscheinen).

1 Einleitung: Digitale Pflegetechnologien – Eine Einordnung

Digitale Pflegetechnologien umfassen einen weiten Bereich unterschiedlicher und in diverse Technologie-Kategorien einordbarer Einzeltechnologien. Die Bandbreite reicht von robotischen Systemen, virtueller Realität, Tracking-Systemen und digitaler Entscheidungsunterstützung bis zu Informations- und Kommunikationstechnologien (IKT) und weiteren Technologien (Krick et al. 2019).

Was in der Pflege neu und ungewohnt erscheint, ist in anderen gesellschaftlichen und wirtschaftlichen Bereichen bereits zur Normalität geworden. So nutzt die Autoindustrie in Deutschland bereits seit 1970 hydraulische Roboter in ihren Werkanlagen (Babel 2021) und smarte Sensoren spielen in der „Industrie 4.0“ in den unterschiedlichsten Bereichen wie Logistik oder Fertigung bereits eine relevante Rolle (Mehta & Senn-Kalb 2021). Auch in der Pflege spricht man bereits von einer „Pflege 4.0“, welche durch ein Fortschreiten von technologischen Innovationen gekennzeichnet sein soll, die das Potenzial haben sollen, Prozesse, das Berufsbild, oder das Selbstverständnis der Pflege zu verändern (Schneider et al. 2020). Ein Zitat aus der Pflegepraxis vermittelt jedoch einen anderen Eindruck: „Wir reden über die Pflege 4.0, aber die Praxis ist erst bei 2.0 angekommen“ (Merda et al. 2017, S. 85). Wir bewegen uns im Bereich der digitalen Pflegetechnologien im Jahr 2023 in einem Spannungsfeld zwischen Wunsch und Wirklichkeit.

Neuen Technologien wird sowohl im wissenschaftlichen (Archibald & Barnard 2018; Zöllick et al. 2020) als auch im politischen Diskurs (Maier et al. 2019) das Potenzial zugesprochen, zu Verbesserungen im Pflegealltag beitragen zu können. Auch Befragungen in der Pflegepraxis zeigen eine grundsätzliche Offenheit gegenüber neuen Technologien, insbesondere, wenn sie die Arbeitseffizienz erhöhen, zu einer Zeitersparnis führen oder die Qualität der Pflege verbessern können. Der Wunsch nach einer verbesserten technologischen Unterstützung bei direkten Pflegeaufgaben, um die körperliche Belastung und den psychischen Stress zu reduzieren, ist vorhanden (Seibert et al. 2020). Der Grund für diesen Wunsch nach Unterstützung wird in der öffentlichen Debatte insbesondere den in der Pflege existierenden Herausforderungen durch den demographischen Wandel, wie dem Mangel an qualifiziertem Personal und einer daraus resultierenden medizinisch-pflegerischen Unterversorgung, zugeschrieben (Hergesell 2019a; Hülsken-Giesler et al. 2022). Die hohe politische Relevanz dieser Herausforderungen zeigt auch die Förderlinie „Mensch-Technik-Interaktion“ des Bundesministeriums für Bildung und Forschung, bei der zwischen 2008 und 2018 ein Fördervolumen von circa 149 Millionen Euro in den Gesundheits- und Pflegesektor investiert wurde (Fehling

2019). Für die Jahre 2022 bis 2025 sind weitere 70 Millionen Euro Fördervolumen jährlich in der Förderlinie „Miteinander durch Innovation“ geplant (BMBF 2020).

Digitale Pflegetechnologien sehen sich allerdings andererseits aktuell ebenso starker Kritik ausgesetzt, die an sie gestellten Anforderungen in der realen Anwendung nicht erfüllen zu können (Hergesell 2019a). Hergesell kritisiert in seinen Ausführungen, dass digitale Pflegetechnologien insbesondere deshalb als Lösungsstrategie zur Bewältigung der Folgen des demographischen Wandels in der Pflege herangezogen werden, weil sie rein semantisch mit der „persuasiv-positiven Bedeutungskonnotation von ‚Innovationen‘ als ‚Allheilmittel‘ für jegliche Art von Problemen“ (Hergesell 2019a, S. 249) in Frage kämen und digitale Pflegetechnologien aktuell nur ein diskursiv zugeschriebenes Potential zur Lösung der Probleme hätten (Hergesell 2019a; Hergesell 2019b).

Auch Erhebungen aus der Praxis zeigen, dass neben vorhandener Euphorie und Offenheit auch immer noch eine gewisse Skepsis gegenüber bestimmten digitalen Unterstützungssystemen vorhanden ist (Rösler et al. 2018). So wird beispielsweise die Übernahme sozialer oder emotionaler Unterstützungsleistungen bei zu Pflegenden durch Technologien in der Studie von Kuhlmey et al. (2019) von den befragten 355 Pflegekräften kritisch gesehen. Eine körperliche Unterstützung oder Unterstützung im Bereich der Dokumentation wird hingegen positiver bewertet.

Ein Blick auf die aktuellen Nutzungszahlen von digitalen Pflegetechnologien zeigt, dass sie sowohl in der stationären Langzeitpflege (Sebastião et al. 2020) als auch in der ambulanten Pflege und der Pflege im Krankenhaus (Rösler et al. 2018) noch keine weite Verbreitung gefunden haben. Vielen Pflegekräften sind neue Technologien zwar grundsätzlich bekannt, aber nur wenige haben aktuell einen praktischen Zugang dazu, wie beispielsweise die Befragung von Kuhlmey et al. (2019) aufzeigt.

Rein faktisch können digitale Pflegetechnologien zum aktuellen Zeitpunkt also noch keiner wissenschaftlichen Erprobung im größerem Umfang in der Pflegepraxis unterzogen worden sein. Das postulierte Potenzial von digitalen Pflegetechnologien muss also in den kommenden Jahren einer genaueren Prüfung und Bewertung unterliegen, um entweder aufzuzeigen, dass sie als Lösungen für bestimmte Probleme in der Pflege in Frage kommen oder eben nicht.

Hierfür ist eine systematische, wissenschaftliche Evaluation und Bewertung von digitalen Pflegetechnologien in der realen Anwendung die methodische Voraussetzung.

Das vorliegende **Rahmenpapier** beinhaltet daher die Aufarbeitung des Wissenstands zum Thema der wissenschaftlichen Evaluation von digitalen Pflegetechnologien und bildet durch die Kombination der enthaltenen Einzelarbeiten einen neuen Referenzrahmen für die qualitativ hochwertige Evaluation von digitalen Pflegetechnologien.

Es beginnt im ersten Kapitel mit einer literaturbasierten theoretischen Einleitung und Einordnung des Gegenstands und des Hintergrunds zu digitalen Pflegetechnologien und deren Bewertung und Evaluation. Anschließend wird die in diesem Zusammenhang bearbeitete Forschungsfrage der Dissertation vorgestellt, sowie Erläuterungen zur methodischen Herangehensweise gegeben. In den Kapiteln zwei bis vier wird die Essenz der Einzelarbeiten vorgestellt. Hierbei nähert sich diese Forschungsarbeit der Fragestellung durch eine Analyse der bisher in der wissenschaftlichen Literatur evaluierten digitalen Pflegetechnologien (Kapitel zwei), durch eine Strukturierung des Felds bezogen auf den Teilbereich der Wirksamkeitsmessung (Kapitel drei) und durch eine Aufarbeitung vorhandener Evaluationsframeworks für den Bereich der digitalen Pflegetechnologien (Kapitel vier). Anschließend werden in Kapitel fünf die Ergebnisse dieser Arbeit vor dem Hintergrund des existierenden Forschungskontexts diskutiert und eine Einordnung der Arbeit in den größeren Kontext der Forschungsfrage vorgenommen. Im abschließenden Kapitel sechs werden Schlussfolgerungen aus den Erkenntnissen dieses Rahmenpapiers gezogen und konkrete Empfehlungen gegeben. Außerdem wird beschrieben, wie mit Hilfe von wissenschaftlichen Evaluationen mehr Wissen zu digitalen Pflegetechnologien generiert werden kann und worauf dabei in der zukünftigen Forschung zu achten ist.

1.1 Gegenstand

In diesem Abschnitt sollen zunächst grundlegende Begrifflichkeiten dieser Arbeit definiert und der Gegenstand der Arbeit genauer erläutert werden. Der Gegenstand der vorliegenden kumulativen Promotion teilt sich in zwei in Verbindung stehende, aber getrennt voneinander zu betrachtende Teile (I) digitale Pflegetechnologien (in dieser Arbeit auch als DNT bezeichnet – abgeleitet aus dem Englischen „Digital Nursing Technologies“) und (II) deren Bewertung und Evaluation.

1.1.1 (I) Digitale Pflegetechnologien

Der erste Teil des Gegenstands umfasst die digitalen Pflegetechnologien. Um genauer zu verstehen, was hierbei untersucht werden soll, ist zunächst zu klären, was unter den einzelnen Begriffen, die den Untersuchungsgegenstand ausmachen, in der Literatur beschrieben und für diese Arbeit abgeleitet wird. Im Anschluss daran wird eine Arbeitsdefinition aufgestellt.

1. Hinter dem Begriff **„digital“** verbirgt sich in erster Linie die digitale Schaltung, die nach dem Prinzip der Darstellung von Informationen mit den Werten 0 und 1 aufge-

baut ist. Das benannte Prinzip wird als Zweiwertigkeit bezeichnet. Digitale Schaltungen steuern und regeln technischen Geräte, indem sie Informationen abfragen und anhand von Regeln Entscheidungen treffen (Gehrke et al. 2016).

2. Eine **„Technologie“** wird von Rogers (2003) in zwei Komponenten unterteilt: Hardware und Software. Er weist darauf hin, dass unter dem Begriff Technologie/Technik häufig nur die Hardwarekomponente betrachtet wird (am Beispiel der Pflegerobotik wäre dies die gesamte Aktorik und Sensorik). Jedoch sei die Software, und somit das Sammeln und Verarbeiten von Informationen, ebenso wichtig oder bilde sogar den deutlich wichtigeren Anteil der Technologie ab. Ein Technologie besteht also aus Hardware und/oder Software und ist nach Rogers (2003) ein Werkzeug (Tool), welches zur Erreichung einer bestimmten Problemlösung oder Bedürfnisbefriedigung existiert.
3. Aus soziologischer Sicht kann **„Technik“** auch als „zeitlich wiederholbare Form […], die sozial als Vermittler zwischen Wünschen und Wirklichkeit eingesetzt wird“ (Rammert 2016, S. 58), definiert werden. Rammert betont besonders, dass Technik neben der Hardware auch „symbolisch kulturelle Artefakte“ einschließe (Rammert 2016, S. 58). Technik könnte im soziologischen Verständnis von Rammert als eigenständige Entität bezeichnet werden, welche in gesellschaftlichen soziokulturellen Prozessen integriert ist. Verwirrend sein kann, dass die Begriffe Technologie und Technik im deutschsprachigen Raum häufig synonym verwendet werden. Im Englischen wird in erster Linie der Begriff „Technology“ verwendet. Der Begriff „Technologie“ bezeichnet jedoch auch die Wissenschaft von der Technik. Dies kann zu einer gewissen Abgrenzungsproblematik führen (Friesacher 2010). Es sei darauf hingewiesen, dass die Begriffe in dieser Arbeit synonym verwendet werden.

Arbeitsdefinition:

Digitale Pflegetechnologien sind Hardware und/oder Software(-Erzeugnisse), die anhand von bestimmten Regeln Entscheidungen treffen. Dies beinhaltet insbesondere informationstechnisch vernetzte und/oder mit Sensorik ausgestattete (digitale) Entwicklungen, die

- pflegende Personen oder die Organisation von pflegerischem Handeln unterstützen,
- dazu beitragen, dass Personen so in ihrer sozialen, physischen und/oder psychischen Eigenständigkeit unterstützt werden, dass auf direkte pflegerische Unterstützung vor Ort verzichtet werden kann,
- die Ausbildung, den Wissenstransfer und die Kompetenzentwicklung von Personen unterstützen.

Die Unterstützung kann sich sowohl auf professionelle und informelle Pflegepersonen als auch auf Pflegebedürftige, deren Angehörige und sonstige Bezugspersonen beziehen (angelehnt an Krick et al. (2020, S. 3)).

Diese Definition wurde aufbauend auf den Erkenntnissen der in dieser Arbeit enthaltenen Artikel entwickelt und geht in ihrer Spezifität auf den in Krick et al. (2020) definierten Begriff der „Digital Nursing Technologies" (DNT) zurück. Im Laufe der Arbeit wird auch auf den im Titel bereits verwendeten Begriff der „Innovation" bzw. auf die so bezeichneten digitalen technologischen Innovationen in der Pflege eingegangen und eine Abgrenzung zum Begriff der DNT vorgenommen.

1.1.2 (II) Die Rolle von Evaluationen in der Bewertung von digitalen Pflegetechnologien

Der zweite Teil des Untersuchungsgegenstands beschäftigt sich mit der Evaluation und Bewertung von DNT. Die Begriffe „Evaluation" und „Bewertung" werden im alltäglichen Sprachgebrauch häufig synonym verwendet, was für die Verwendung und Abgrenzung in dieser Arbeit ungünstig ist. Der Begriff „Evaluation" meint in dieser Arbeit einerseits ein „nachprüfbares Verfahren" zur Bewertung einer digitalen Pflegetechnologie und gleichzeitig die Durchführung des Prozesses einer methodisch kontrollierten und verwertungsorientierten Informationssammlung zu einer DNT (angelehnt an Kromrey (2012, S. 105-106)). Das Ergebnis der Evaluation und die damit einhergehende Einordnung der Ergebnisse anhand begründeter Kriterien wird in dieser Arbeit als „Bewertung" bezeichnet. Diese Bewertung dient weniger dem theoretischen Erkenntnisgewinn, sondern im Sinne eines empirisch-wissenschaftlichen Handelns in erster Linie dazu, die Erkenntnisse über den zu evaluierenden Gegenstand (DNT) für praktische Zwecke nutzbar zu machen (Kromrey 2012).

Grundsätzlich kann die Evaluation und Bewertung von digitalen Pflegetechnologien darauf aufbauend vier Zielfunktionen erfüllen (angelehnt an Stockmann (2002, S. 3-4)):

(1) Die Gewinnung von Erkenntnissen über die digitale Pflegetechnologie zur Ableitung von spezifischen Handlungen (zum Beispiel die Weiterentwicklung der Technologie)
(2) Die Kontrolle der digitalen Pflegetechnologie (im Sinne einer Zielerreichung zum Beispiel zur Ableitung von Steuerungsentscheidungen)
(3) Die Nutzung der Erkenntnisse zu einer digitalen Pflegetechnologie, um dadurch einen besseren Umgang mit der Technologie zu ermöglichen (Lernfunktion).
(4) Die Legitimierung von Entscheidungen im Zusammenhang mit einer digitalen Pflegetechnologie (beispielsweise Investitionsentscheidungen)

Auf die neuen Erkenntnisse zum Thema Evaluation von DNT aus dieser Arbeit wird in den Kapiteln zwei bis vier näher eingegangen.

1.2 Hintergrund und Forschungsstand

Die folgenden Abschnitte beschreiben den Forschungsstand und den theoretischen Diskurs zu digitalen Pflegetechnologien. Dabei werden die substanziellen zusätzlichen Erkenntnisse durch die in dieser Arbeit enthaltenen Artikel außen vorgelassen, da diese in den Abschnitten zwei bis vier erläutert werden.

1.2.1 Forschung und Diskurs zu digitalen Pflegetechnologien und deren Evaluation

Digitale Pflegetechnologien verändern die Pflege. Mit dieser Aussage ist gemeint, dass das Vorhandensein von digitalen Pflegetechnologien auf verschiedenen Ebenen zu Veränderungen führt, oder mit Veränderungen im Zusammenhang steht. In der Forschungsliteratur werden DNT sowohl auf der Mikro-, der Meso- als auch auf der Makroebene in einem Veränderungskontext diskutiert (Schneider et al. 2020). Für jede dieser Ebenen sollen im Folgenden beispielhaft Veränderungen aufgezeigt werden, die im Zusammenhang mit DNT stehen.

Veränderungen auf der Mikroebene betreffen individuell handelnden Personen – hier kann eine DNT beispielsweise einen individuellen Nutzen für eine Person erzeugen (zum Beispiel für Pflegekräfte oder zu pflegende Person), indem sie einen Arbeitsschritt vereinfacht oder eine Entlastung herbeiführt. Die DNT greift dabei jedoch in den erlebten (Arbeits-)Alltag ein und verändert ihn. Diese Veränderungen passieren in einem komplexen soziotechnischen System (Zerth et al. 2021), was sich am Beispiel der Akzeptanz einer DNT aufzeigen lässt. Ob eine DNT im Alltag akzeptiert wird, hängt unter anderem vom Alter, Bildungsstand oder von den bisherigen Erfahrungen einer Person mit der Technologien ab (Jacobs et al. 2019). Außerdem steht die Akzeptanz stark in Verbindung mit den Eigenschaften der Technologie selbst, insbesondere der wahrgenommenen Nützlichkeit (Holden et al. 2016). Die Auswirkungen einer Veränderung auf der Mikroebene müssen also in einem sehr individuellen Zusammenhang betrachtet werden.

Die Mesoebene umfasst Veränderungen für Organisationen und Einrichtungen. Dort können beispielsweise veränderte Arbeitsstrukturen und -prozesse auftreten. Die DNT muss hier entweder in einen Prozess integriert werden oder sorgt im Rahmen der Einführung für einen komplett neuen Prozess mit neuen Aufgabenteilungen. DNT greifen hierbei in organisational-pflegerische Routinen ein (Greenhalgh 2008). Diese Routinen treten als sich wiederholende, erkennbare Muster voneinander abhängiger Handlungen auf, an denen mehrere Akteure beteiligt sind (Feldman & Pentland 2003). Ungeeignete und unpassende Technologien können diese Routinen negativ beeinflussen (Greenhalgh 2008). Gleichzeitig muss berücksichtig werden, dass das Ausmaß des Eingriffs in die pflegerische Routine wahrscheinlich im Zusammenhang mit der Akzeptanz und der Verbreitung von DNT steht (Greenhalgh et al. 2017; Klawunn et al. 2021).

Die Makroebene bezeichnet die „nationalstaatliche und die supranationale Regulierungsebene der Gesundheitspolitik“ (Rosenbrock & Gerlinger 2014, S. 16). Für digitale Pflegetechnologien können sich hier beispielsweise spezifische Finanzierungsmechanismen oder Vergütungsregelungen ändern oder neue Regularien zur Einführung beschlossen werden, welche weitreichende Auswirkungen auf eine der anderen Ebenen haben können (Schneider et al. 2020). Unklar ist zum Zeitpunkt der Arbeit beispielsweise, wie in Zukunft digitale Pflegetechnologien in der stationären Langzeitpflege nachhaltig finanziert werden sollen. Für ambulante und stationäre Pflegeeinrichtungen stehen aktuell nur Fördermittel für Digitalisierungsprojekte zur Verfügung. Einrichtungen können dabei einmalige Zuschüsse bei der Anschaffung von digitalen Pflegetechnologien und damit verbundener Schulungen von bis zu 40 Prozent der Gesamtkosten erhalten. Der maximale Zuschuss beträgt 12.000 Euro (Theobald 2022). An der Realität der fortlaufenden Kosten des Betriebs von digitalen Pflegetechnologien und deren Administration geht der Förderbetrag jedoch völlig vorbei.
Die beispielhafte Aufzählung von Veränderungen, die im Zusammenhang mit der Existenz von DNT stehen, zeigt auf, wie umfänglich die Analyse von DNT und deren Auswirkungen auf verschiedenen Ebenen ist.
Über die Art der Veränderungen, welche DNT im Pflegesystem verursachen, gibt es seit vielen Jahren einen kontroversen Diskurs. So genannte „Technikoptimisten“ betrachten digitale Pflegetechnologien in diesem Diskurs als positive Ergänzung der Pflege und als Teil des sozialen Fortschritts, wohingegen „Technikromantiker“ (auch Technikpessimisten) Technologien als unvereinbar mit der Pflegekultur ansehen und sie als Ausdruck einer maskulinen Kultur und als Wiederholung bestehender sozialer Ungleichheiten ablehnen (Sandelowski 1997). Technikoptimisten sind grundsätzlich davon überzeugt, dass Technik gezielt zum Wohle der zu Pflegenden eingesetzt werden kann. Die Extremform des Technikoptimismus sieht eine optimale Pflege sogar nur unter Einbezug von Technologien als möglich an. Die größte Befürchtung im technikpessimistischen Diskurs ist hingegen die Befürchtung, dass technische Geräte die pflegerische Tätigkeit ersetzen könnten (Hülsken-Giesler 2007). Aus der technikpessimistischen Perspektive geht auch der Kritikpunkt hervor, dass Technologien keine neut-

ralen Objekte seien, sondern im Zeitverlauf die Pflegepraxis, die Werte und das Umfeld verändern, oftmals ohne dass diese Veränderung erkannt werden (Barnard 1997). Technologien könnten so beispielweise zu einer Dehumanisierung der Pflegearbeit beitragen (Hülsken-Giesler 2007). Die tief verwurzelte philosophisch-anthropologische Komponente bei der Betrachtung von digitalen Pflegetechnologien kann man gut an der Beschreibung von Remmers (2015, S.11) beobachten, der das Aufeinandertreffen von Pflege und Technik als „Kollisionen zweier unvereinbarer Eigenlogiken“ beschreibt: „einer Logik persönlicher Zuwendung und Hilfe, die nur wenig formalisierbar ist, und einer gegenläufigen Logik von Ökonomie sowie planender Verwaltung und Organisation.“
Bei der Betrachtung dieser gegensätzlichen Blickrichtungen ist auffällig, dass digitale Pflegetechnologien – eingebettet in ein soziales Konstrukt – abhängig von der angewendeten Denklogik und auf Grund ihrer Auswirkungen ihre positiven Eigenschaften zugeschrieben bekommen oder kritisiert werden. Nicht die DNT per se führt daher zu Veränderungen, sondern der soziale Kontext, der bei der Nutzung einer digitalen Pflegetechnologie in einem spezifischen Anwendungssetting entsteht, und die Interpretation und Bedeutung, die der Nutzung der Technologie zugeschrieben wird. Die Kritik, dass DNT zu einer Dehumanisierung in der Pflege beitragen, hängt beispielsweise in starkem Maße davon ab, wie wir (als Gesellschaft oder Person) menschenwürdige Pflege definieren und in welchem Zusammenhang digitale Pflegetechnologien damit in Zukunft stehen könnten (Barnard & Sandelowski 2001). Je nach Nutzung und Interpretationsweise könnten digitale Pflegetechnologien auch zu einer humaneren Pflege beitragen, indem sie beispielsweise Freiräume für mehr menschliche Interaktionen schaffen.

Aus den vorangegangenen Beschreibungen ist bereits hervorgegangen, dass die Einführung von DNT nicht nur an einer spezifischen Stelle zu Veränderungen führt, sondern eingebettet ist in ein größeres soziales Konstrukt, bestehend aus Einzelpersonen, Organisationen und einer übergeordneten gesellschaftlichen Ebene. Auf all diesen Ebenen kann eine DNT theoretisch zu Veränderungen führen oder mit Veränderungen im Zusammenhang stehen. Diese Veränderungen können positiv, negativ oder neutral sein und wie sie eingeordnet werden, hängt unter anderem maßgeblich von dem zugrundeliegenden Denkparadigma (zum Beispiel Technikoptimismus versus Technikpessimismus), dem Verfahren zur Bewertung (systematisch und methodisch kontrolliert versus unsystematisch und methodisch unkontrolliert) und den genutzten Bewertungskriterien (vorab definierte Bewertungskriterien versus subjektive Bewertung ohne Bewertungskriterien) ab.
Zum aktuellen Zeitpunkt existiert keine umfängliche Übersicht darüber, wie diese Veränderungen auf allen Ebenen systematisch analysiert und bewertet werden können. Hier stellt sich

deshalb die Frage, wie genau mithilfe einer Evaluation diese Veränderungen aufgezeigt und bewertet werden können.

Veränderungen analysieren

Eine Möglichkeit, die Analyse der Veränderungen durch digitale Pflegetechnologien im Rahmen einer Evaluation auf den verschieden Ebenen handhabbarer zu machen, ist die Einteilung in spezifischere Evaluationsbereiche und Perspektiven. Schneider et al. (2020) teilen die Untersuchung der Veränderungen durch digitale Pflegetechnologien auf den Pflegeprozess beispielsweise nach dem Strukturmodell von Beikirch (2015) ein. Untersucht werden kann in diesem Zusammenhang, welche Auswirkungen digitale Pflegetechnologien für Pflegekräfte auf den Prozess der strukturierten Informationssammlung, die individuelle Maßnahmenplanung, die Durchführung der Pflegemaßnahme und die Evaluation des Prozesses haben. Lutze et al. (2021) betrachten die Auswirkungen einer DNT für Pflegekräfte unter den Gesichtspunkten der planmäßigen Routinearbeit, der wissensbasierten Arbeit und der Interaktionsarbeit. Aus der Perspektive der Pflegebedürftigen existiert für die Nutzenermittlung von digitalen Pflegetechnologien eine Einteilung in die Bereiche Selbstständigkeit, Teilhabe, Sicherheit und Schutz, sowie Selbstbestimmung und Wohlbefinden (Lutze et al. 2019). Für alle genannten Bereiche sind wiederum Unterkategorien vorhanden oder denkbar und unterschiedliche Outcomes sowie Instrumente notwendig, um Veränderungen messen oder beurteilen zu können. Es existierte jedoch keine Übersicht in der Literatur, die umfänglich Evaluationsbereiche, verschiedene Perspektiven, Instrumente oder Outcome-Bereiche benennt, welche für digitale Pflegetechnologien grundsätzlich genutzt werden können.

Wenn man die Literatur zur Evaluation von digitalen Pflegetechnologien betrachtet, dann ist außerdem erkennbar, dass hier ein Phänomen existiert, welches der allgemeinen Forschungslogik inhärent ist – und welches dadurch beim Wissen über digitale Pflegetechnologien eine große Lücke hinterlässt. Digitale Pflegetechnologien werden immer „nur" aus einem bestimmten Blickwinkel und mit einer sehr engen Fragestellung erforscht. So konzentriert man sich beispielsweise nur auf die Akzeptanz (Honekamp et al. 2019) einer spezifischen Technologie oder untersucht ausschließlich die Effektivität (Sahota et al. 2014) – statt für eine Technologie eine umfängliche Analyse unterschiedlicher Evaluationsbereiche durchzuführen. Dies ist einerseits mit der Kleinteiligkeit von Forschungsfragen begründbar, die, um ein bestimmtes Thema handhabbar und erforschbar zu machen, meist auf spezifische Teilbereiche fokus-

siert sein müssen. Andererseits ist eine umfängliche Testung von Technologien, die viele Evaluationsbereiche abdeckt, aus Gründen der personellen und finanziellen Ressourcen, die dafür notwendig wären, eher unwahrscheinlich.
Diese Tatsachen führen jedoch dazu, dass die größeren Zusammenhänge einzelner Technologien im Pflegekontext auf verschiedenen Ebenen nicht in einen entsprechenden Gesamtkontext gesetzt werden können.
Als Beispiel für die Problematik dieser Vorgehensweise wird an dieser Stelle eine Studie von Honekamp et al. (2019) zur Erfassung der Akzeptanz von 120 Senior:innen in einer betreuten Wohneinrichtung gegenüber Pflegerobotik dargestellt. Zur Erfassung der Akzeptanz wurden den Bewohner:innen bebilderte Szenarien mit einer Szenario-Beschreibung vorgelegt und dann eine schriftliche Befragung durchgeführt. Eine direkte Konfrontation mit den Robotern war aus Ressourcengründen nicht möglich. Im Anschluss wurde ein Fragebogen mit 30 Items auf Grundlage des Technology-Usage-Inventory (Kothgassner et al. 2013) von den Senior:innen beantwortet. Ziel der Untersuchung war es, „Hinweise zu generieren, unter welchen Bedingungen und in welchen Situationen der Einsatz von Pflegerobotern in Krankenhäusern auf Akzeptanz oder Skepsis von SeniorInnen trifft“ (Honekamp et al. 2019, S. 62). Studien vergleichbarer Art ohne konkreten Technikeinsatz (Beiter et al. 2020), mit Vorhandensein der Technologien im Alltag (Jacobs et al. 2019) oder in einem Testsetting (Baisch et al. 2018) gibt es einige. Jedoch stellt sich die Frage, inwiefern sich eine Aussage zur Akzeptanz der Technologie ohne ein Verständnis für das Zusammenspiel der Veränderungen durch die Technologie im konkret erforschten Setting überhaupt beurteilen lässt. Die wissenschaftliche Aussagekraft derartiger Befragungen ist sehr begrenzt – sie kann maximal als erste Einschätzung zur Meinungsbildung gegenüber einer Technologie dienen. Die gemessene grundsätzliche Haltung eines Individuums gegenüber einer Technologie besitzt zwar laut Diffusionstheorie nach Rogers (2003) eine relativ dauerhafte Konsistenz, in der längerfristigen Anwendung einer Technologie kann die Grundhaltung allerdings entweder bestätigt oder wieder verworfen werden. Da sich viele digitale Pflegetechnologien noch in einer frühen Entwicklungsphase befinden und noch nicht viele dauerhaft in der Praxis angekommen sind (Lutze et al. 2019), können Akzeptanzstudien folglich oft nur mit frühphasigen Technologien durchgeführt werden. Aussagen zur Akzeptanz einer Technologie sind dann meist nur eine Momentaufnahme, da sich Technologien und deren Anwendungen im Zeitverlauf der Entwicklung verändern.

Außerdem ist zu beachten, dass bei den benannten Studien das Ergebnis der Untersuchung mit unterschiedlichen Vorgehensweisen und Methoden dennoch mit dem gleichen Begriff „Akzeptanz“ benannt wird. Diese Verallgemeinerung der Begrifflichkeit ist höchst problematisch, weil die Aussagekraft der unterschiedlichen Herangehensweisen und das, was tatsächlich gemessen oder erhoben wird, unter einem breit gefassten Akzeptanzbegriff zusammengefasst und dann in verallgemeinernden Aussagen als das Gleiche nach außen getragen werden. Abhilfe schaffen könnte hier zumindest die Unterscheidung nach verschiedenen Akzeptanzarten wie von Kollmann (1998) mit den Begriffen **Einstellungsakzeptanz** (nach kognitiver Kenntnisnahme der Existenz einer Innovation, ohne sie zu testen und vor dem Erwerb der Innovation), **Handlungsakzeptanz** (nach ersten Erfahrungen mit der Innovation, aber vor dem Erwerb) und **Nutzungsakzeptanz** (im Einsatz nach dem Erwerb einer Innovation) beschrieben.

Man könnte davon ausgehen, dass das für Akzeptanz beschriebene Problem bei der Effektivitätsforschung durch eine sehr enge Fragestellung und einen klaren Effektivitätsbegriff bezogen auf spezifische Outcomes und bei hohem Evidenzniveau weniger vorhanden ist. Ein Beispiel zeigt jedoch auch hier auf, dass die größeren Zusammenhänge bei der Effektivitätsforschung selbst bei Studien auf hohem Evidenzniveau eine wichtige Rolle spielen. Sahota et al. (2014) führten zur Erforschung der Effektivität eines Drucksensors in Verbindung mit einem Funkrufempfänger im akutstationären Pflegesetting eine randomisierte kontrollierte Studie (RCT) durch. Untersucht werden sollte unter anderem, ob die Technologie die Anzahl der Stürze am Bett reduziert. Dazu wurden 1.839 Patient:innen in zwei Gruppen eingeteilt (n = 918 in der Kontroll- und n = 921 in der Interventionsgruppe). Das Ergebnis war: Es gab keinen signifikanten Unterschied zwischen den beiden Gruppen bezogen auf die Anzahl der Stürze am Krankenbett. Die Studie erwähnt die Vorgehensweise der Intervention nur am Rand. Der Sensor registriert das Aufstehen der Patient:innen aus dem Bett und das Funkrufsystem benachrichtigt die Pflegekraft darüber. Man muss daraus schlussfolgern, dass, um einen Sturz zu verhindern, die Pflegekraft in dem Moment der Benachrichtigung die Möglichkeit haben muss, nach dem:der Patient:in zu sehen und bei Notwendigkeit einzugreifen. Es wurde allerdings nicht untersucht, wie oft dies geschehen ist. Zur Auswertung der Sturzhäufigkeit in den zwei Gruppen wurde das zentrale (verpflichtende) Unfallmeldesystem ausgewertet. Die Studie benennt zwar die Art der Auswertung als Problem, reflektiert jedoch nicht, dass ein Kontrollieren der Handlung der Pflegekraft im Moment der Benachrichtigung deutlich mehr Klarheit hätte bringen können. Die Kontrolle der Umsetzung bzw. Umsetzbarkeit des Teils der Intervention, der nicht direkt durch die Technologie geschehen kann, sondern eher organisatorisch oder prozessualer Natur ist, könnte hier als zentrale Herausforderung für jede Art von Studie genannt werden. Für eine solche Kontrolle der Umsetzung, beispielsweise durch das Begleiten der Pflegekraft, wäre ein hoher Ressourcen- und Zeitaufwand notwendig – jedoch

wäre es für das Verständnis der Wirkung der Technologie-Mensch-Kombination wichtig, diesen Faktor zu kontrollieren, um eine Aussage über die gesamte Intervention treffen zu können. Die Kontrolle der Durchführung durch eine Person wäre allerdings auch wieder selbst ein Eingriff in die Studie, denn dies könnte die Handlungen der Pflegekraft und damit die Aussagekraft der Studie verändern. Für einen fairen Vergleich sollten RCTs zudem gleiche Rahmenbedingungen aufweisen und die Gruppen sich ausschließlich in der Intervention unterschieden – ein Begleiten der Nicht-Interventionsgruppe wäre damit ebenso notwendig, um gleiche Bedingungen herzustellen (Windeler et al. 2008).
Am Ende konkludiert die Studie von Sahota et al. (2014) mit der Aussage, dass Drucksensoren mit Funkrufempfängern die Rate der Stürze am Patientenbett nicht reduzieren konnten. Diese Aussage ist so nicht korrekt. Denn der Sensor kann die Stürze ohnehin nicht beeinflussen. Erst die Handlung der Pflegeperson hätte einen Sturz verhindern können. Hochwertige Studien müssen zur Effektivitätsmessung also immer auch prozessuale und nicht-technologische Faktoren der Technologie-Mensch-Kombination untersuchen, um eine Aussage über die Technologie treffen zu können. Denn in fast jedem Fall der Technologienutzung ist auch eine Veränderung der menschlichen Handlung enthalten. Die aktuelle Forschung konzentriert sich allerdings häufig eher auf die Mensch-Technik-Interaktion – also die Evaluation der direkte Nutzung der Technologie durch den Menschen und die Ergebnisse, die dies erzeugt (BMBF 2015; Seeling & Blotenberg 2017).

Neben Einzelstudien zu digitalen Pflegetechnologien existieren auch Übersichtsarbeiten, die einzelne Fragestellung zu bestimmten Technologiebereichen (Arditi et al. 2012; Bemelmans et al. 2012; Brandt et al. 2012; Bright et al. 2012; Blum et al. 2015) oder verschiedene Technologien bezogen auf eine spezifische Zielgruppe wie die Überlebenden eines Schlaganfalls (Aldehaim et al. 2016) untersuchen. Auch in diesen Fällen liegt der Fokus der Arbeiten meist auf einzelnen Outcome-Bereichen für bestimmte Technologiebereiche wie der Effektivität von sozialer Robotik (Bemelmans et al. 2012), der Akzeptanz einer elektronischen Patientenakte (Kruse et al. 2015) oder der Effizienz assistiver Technologien zur Unterstützung von Menschen mit Demenz (Bowes et al. 2013). Mit den Übersichtsarbeiten lassen sich generelle Aussagen zu Technologiekategorien und den entsprechenden Outcome-Bereiche treffen, jedoch lassen sich die Zusammenhänge der Technologie-Mensch-Kombination, die auf der Mikroebene relevant sind und innerhalb der Einzelstudien beobachtbar sind, nicht mehr so leicht nachvollziehen.

Implementierung und Prozesse

Die Implementierung einer digitalen Pflegetechnologie, die ausgelösten Veränderungen in der Pflegepraxis und die Messung von einzelnen Outcomes sollten immer zusammen betrachtet werden. Diskussionen im Rahmen des „Clusters Zukunft der Pflege“ deuten in die Richtung, dass digitale Pflegetechnologien, welche bestehende Prozesse stärker beeinflussen bzw. verändern, eine geringere Akzeptanz bei den Pflegenden haben (Klawunn et al. 2021). Eine Voraussetzung für den Erfolg von DNT könnte also sein, möglichst wenig in die vorhandenen Prozesse einzugreifen. Zu beachten ist allerdings, dass soziale Innovationen (unabhängig von Technologien), zum Beispiel in Form von Prozessveränderungen, ohnehin stattfinden (Rösler et al. 2018). Eine digitale Pflegetechnologie, die heute in die Prozesse passt, muss morgen nicht zwangsläufig weiterhin in die Prozesse passen. Partizipative Vorgehensweisen bei der Einführung von Technologien in der Pflege werden als Lösung dieser Problematik an vielen Stellen gefordert (Zettl & Trübswetter 2018; Obser & Schroll-Würdig 2020; Sebastião et al. 2020; Helmig et al. 2021), insbesondere wenn die Verwendung der DNT nur mit einer stärkeren Anpassung gewohnter Prozesse gelingen kann (Lutze et al. 2021). Die Aussage über die Zusammenhänge von Prozessveränderungen und dem Erfolg von digitalen Pflegetechnologien deckt sich auch mit umfänglichen Analysen von Greenhalgh et al. zur Diffusion von Innovationen in Gesundheitsorganisationen (Greenhalgh et al. 2004; Greenhalgh et al. 2017). Laut Greenhalgh et al. (2017) ist es wahrscheinlicher, dass eine bestimmte Innovation aufgegriffen wird, wenn durch die aktuelle Situation ein starker Handlungswunsch für einen Wandel besteht, die Innovation gut zum System passt (das heißt die Innovation gut zu bestehenden Arbeitsabläufen und Routinen passt), breite Unterstützung für die Innovation (und wenig Widerstand dagegen) besteht, sowie eine systematische Bewertung der Auswirkungen durchgeführt werden kann.

Mit dem CFIR-Framework (Damschroder et al. 2009) existiert hierzu bereits eine umfängliche wissenschaftliche Aufarbeitung möglicher Zusammenhänge und Rahmenbedingungen die beim Einführungsprozess von komplexen Interventionen in Einrichtungen des Gesundheitswesen relevant sind. Das Framework zeigt auf in welchem sozialen Gefügen sich die Einführung von komplexen Interventionen bewegt. Das Gelingen oder der Misserfolg der Einführung hängt laut CFIR-Framework beispielsweise von den Charakteristiken der Individuen ab, welche die Technologie verwenden sollen, oder steht im Zusammenhang mit den strukturellen Merkmalen des Einführungssettings (Inner und Outer Setting). Außerdem spielen die spezifischen Charakteristiken der Intervention und die Charakteristiken des Einführungsprozesses eine Rolle (Damschroder et al. 2009). Ob der Einführungsprozess gelingt und die digitale

Pflegetechnologie damit überhaupt das Potenzial erhält, positive Auswirkungen zu verbreiten, hängt, wie auch an anderer Stelle bereits beschrieben, stark von der Komplexität der Technologie(-Nutzung) und der Integrierbarkeit in die Prozesse ab (Greenhalgh et al. 2017; Obser & Schroll-Würdig 2020). Das am Anfang dieses Kapitels erwähnte Beispiel der Effektivität einer Drucksensorik zur Prävention von Stürzen am Bett von Sahota et al. (2014) kann auch hier als Beispiel herangezogen werden. Selbst wenn die Pflegekraft eine Benachrichtigung erhält, dass eine zu pflegende Person das Bett verlassen hat, so stellt dies noch lange nicht sicher, dass auch in diesem Moment (im Rahmen des Prozesses) die Kapazität besteht, einen Sturz zu verhindern, weil aktuell möglicherweise eine andere Aufgabe ausgeführt werden muss.

Eine ausführlichere Aufarbeitung zum Thema Komplexität von DNT und den damit im Zusammenhang stehenden Herausforderungen findet sich im nächsten Kapitel.

Digitale Pflegetechnologien und Evidence-based Nursing

An dieser Stelle soll aufbauend auf den vorangegangenen Beschreibungen noch einmal die Wichtigkeit der Nutzung von Evidenz bei der Einführung und Bewertung von digitalen Pflegetechnologien betont werden. Wenn sich die Nutzung von DNT zu einer alltäglichen Handlungsweise in der Pflege entwickeln soll, dann müssen für die Nutzung der Technologien die gleichen Standards von Evidence-based Nursing (EBN) gelten, wie für alle weiteren Vorgehensweisen in der Pflegepraxis.

> *„Evidence-based Nursing ist die Nutzung der derzeit besten wissenschaftlich belegten Erfahrungen Dritter im individuellen Arbeitsbündnis zwischen einzigartigen Pflegebedürftigen oder einzigartigem Pflegesystem und professionell Pflegenden." (Behrens et al. 2016, S. 25)*

Diese Denkweise stützt sich auf die Annahme, dass Pflege durch eine wissensbasierte Vorgehensweise eine höhere Qualität aufweist, Pflegekräfte dadurch professioneller werden und mehr Verantwortung für die eigenen Handlungen übernehmen können (Roes et al. 2013). Die durch Forschung erzeugten Erkenntnisse (zu digitalen Pflegetechnologien) können und sollten demnach das pflegerische Handeln beeinflussen. Roes et al. (2013) weisen darauf hin, dass bei steigender Qualität der Forschung eine höhere Chance auf bessere Outcomes existiere, wenn die Umsetzung der Evidenz stimmig geschehe. Die evidenzbasierte Implementierung, also „die Integration evidenzbasierter Interventionen in einem spezifischen Setting" (Roes et al. 2013, S. 198), in der Pflege spielt für digitale Pflegetechnologien also eine entscheidende Rolle.

Es stellt sich nun die Frage, wie weit die Pflegepraxis beim Thema der evidenzbasierten Implementierung von digitalen Pflegetechnologien bereits ist und wo aktuell noch Herausforderungen bestehen. Eine Analyse von van Achterberg et al. (2008) kommt zu dem Schluss, dass in der Literatur diskutierte Konzepte für den Erfolg von Technologieimplementierungen wie das Wissen, die Einstellungen und Routinen von Pflegekräften, der soziale Einfluss und organisatorische Merkmale zwar relevante Oberkategorien seien, diese Konzepte allerdings immer im spezifischen Einzelfall genauer analysiert werden sollten, um für die Umsetzung einer Implementierungsstrategie relevante Determinanten herauszufinden. Diesen Schritt zu übersehen oder „abzukürzen" sei verlockend, werde aber wahrscheinlich zu einer erfolglosen Umsetzung führen (van Achterberg et al. 2008, S. 307). Es besteht also eine Differenz zwischen wissenschaftlich aufgearbeiteten, theoretischen Konzepten und ihrer tatsächlichen Umsetz- und Anwendbarkeit – hin dazu, dass sich eine evidenzbasierte Implementierung in der Pflege immer auch an den tatsächlichen Gegebenheiten orientieren muss und Konzepte angepasst werden müssen.

Evidence-based Nursing stößt zusätzlich in der realen Umsetzung an weitere Grenzen, die auch für die evidenzbasierte Einführung von Technologien relevant sind. So berichtet eine systematische Übersichtsarbeit von Ayoubian et al. (2020) darüber, dass eine Barriere für die Nutzung von Evidenz in der Pflege die Verfügbarkeit ist. Wo keine Evidenz vorhanden oder verfügbar ist, kann auch keine Evidenz genutzt werden. Dies ist insbesondere für die Einführung von digitalen Pflegetechnologien erwähnenswert, da aufgrund der Frühphasigkeit vieler Technologien zum aktuellen Zeitpunkt noch keine übersichtliche, vollumfängliche und systematische Evidenz zu einzelnen Technologien existieren kann (Lutze et al. 2019).

Ein zweites relevantes Hindernis ist das Nichtvorhandensein von organisatorischen und personellen Ressourcen, um das vorhandene Wissen in der Pflegepraxis umzusetzen (Ayoubian et al. 2020). Selbst wenn also qualitativ hochwertige Evidenz für die Einführung von DNT in der Pflegepraxis vorhanden sein sollte, kann diese in der Praxis an bestimmte Umsetzungsgrenzen stoßen und dann nicht ihre volle Wirkung entfalten.

Systematisierung von Evidenz

Ein wichtiger Schritt zur Schaffung von Evidenz im Bereich der digitalen Pflegetechnologien ist die Aufarbeitung und Systematisierung von vorhandenem Wissen zu einem Überblick für relevanten Technologiegruppen und spezifische Technologien. Im Bereich der DNT widmen sich bereits einige Arbeiten der Erstellung von Übersichten über Methoden und Vorgehensweisen zur Schaffung von Evidenz. So liefern beispielsweise Lindwedel et al. (2016) einen Überblick über verschiedene potenziell nutzbare Instrumente zur Messung von Akzeptanz oder Effektivität von digitalen Pflegetechnologien, jedoch geben sie keine konkreten Handlungsempfehlungen und in der Übersicht mangelt an es an der Darstellung bereits verwendeter Instrumente im Zusammenhang mit der Pflege.

Für einzelne Evaluationsbereiche existieren Handreichungen, wie das MAST-Manual zur Evaluation von telemedizinischen Anwendungen (Kidhom et al. 2010) oder Ansätze zur Entscheidung bei der Auswahl zwischen verschiedenen Technikalternativen mittels Nutzwertanalyse (NWA) (Elsbernd et al. 2014). Es existieren außerdem vereinzelt übergreifende Evaluationsframeworks, die eine übersichtlichere Darstellung von verschiedenen Evaluationsbereichen und -inhalten liefern sollen, wie das NASSS-Framework (Greenhalgh et al. 2017) oder das DIPSA-Framework (Stylianides et al. 2018). Jedoch stellt sich die Frage, welches dieser Frameworks wirklich geeignet ist und genügend Hilfestellung liefert, um geplante Evaluationsvorhaben zu spezifischen digitalen Pflegetechnologien in der Forschungspraxis durchzuführen.

Eine systematische Aufarbeitung vorhandener Systematisierungsschemata (Frameworks) zur Evaluation von digitalen Pflegetechnologien mit konkreten Empfehlungen zur Auswahl und Anwendung der Evaluationskonzepte fehlte bislang in der Literatur.
Neben der Aufarbeitung solcher Systematisierungsschemata im Bereich Evaluation ist es für die Evidenzermittlung gleichermaßen relevant für einzelne DNT Studien mit einer methodisch hochwertigen Vorgehensweise durchzuführen und die Ergebnisse dieser Studien systematisch zusammenzuführen, wie dies beispielsweise Ekeland et al. (2010) für den Bereich der Telemedizin im Rahmen eines Systematic Reviews gemacht haben.
Erst durch das Zusammenführen der so gesammelten Evidenz kann ein Überblick über das große Ganze für eine Kategorie von digitalen Pflegetechnologien geschaffen werden. Dabei spielt allerdings nicht nur die Effektivität eine Rolle, sondern viele weitere Aspekte, wie die Akzeptanz und weitere Veränderungen, die DNT in der Pflegepraxis auslösen. In der Literatur fehlte bisher der Überblick über das „große Ganze" – eine Aufarbeitung des Wissensstands zum Thema Evaluation und Bewertung von digitalen Pflegetechnologien ist daher Teil dieser Arbeit.

1.2.2 Komplexität bei der Evaluation von digitalen Pflegetechnologien

Digitale Pflegetechnologien bewegen sich in einem komplexen soziotechnischen Raum (Zerth et al. 2021) und sorgen in diesem für Veränderungen. Dabei steht das Ausmaß und die Aus-

prägung der Veränderungen unter anderem in Verbindung mit den Individuen, die die Technologie anwenden, dem vorhandenen Setting inklusive der Strukturen und Prozesse, dem Einführungsprozess und den Charakteristiken der Technologie (Damschroder et al. 2009).
Auf den Punkt der Komplexität soll hier noch mal etwas genauer eingegangen werden, denn die Komplexität einer Intervention ist insbesondere im Rahmen der Evaluation einer Intervention im Kontext einer kontrollierten Studie zur Erforschung der Frage nach Verbesserungen relevant. Hierbei sollten möglichst viele Einflussfaktoren, die die Ergebnisse beeinflussen könnten, kontrolliert werden. Ein erschwerender Faktor der Kontrolle von Komplexität bei der Einführung von DNT ist, dass Komplexität auch auf einer höheren Ebene eine Rolle spielt. Komplexität kann ebenso auf der Systemebene existieren. Ein komplexes System ist ein System, das sich an Veränderungen in seiner lokalen Umgebung anpassen kann, aus anderen komplexen Systemen zusammengesetzt ist und sich nicht linear verhält (die Veränderung des Ergebnisses ist nicht proportional zur Änderung des Inputs) (Shiell et al. 2008). Eine Pflegeeinrichtung als Setting ist beispielsweise ein komplexes System.
Wenn digitale Pflegetechnologien in einer Pflegeeinrichtung implementiert werden, bedeutet dies, dass sowohl im „kleinen Rahmen" dieser Intervention verschiedene Komponenten zusammenwirken als auch Komponenten des Kontextes der Pflegeeinrichtung für das Ergebnis und die Veränderungen im Rahmen der Intervention eine Rolle spielen.
Die Schwierigkeit bei der Evaluation und Bewertung von digitalen Pflegetechnologien besteht also darin, dass der Anspruch einer methodisch kontrollierten und verwertungsorientierten Informationssammlung (Kromrey 2012) und die damit einhergehende Einordnung der Ergebnisse anhand begründeter Kriterien auf die Subjektivität und Kontextabhängigkeit der Interpretation im Rahmen einer komplexen Intervention, eingebettet in ein komplexes System, trifft. Es könnte hier beispielsweise sein, dass eine positiv evaluierte und positiv bewertete DNT in einem bestimmten Kontext nicht von der potenziellen Anwendergruppe in einem anderen Setting akzeptiert wird.

Dies führt zu dem Problem der Übertragbarkeit bzw. Transferierbarkeit der Ergebnisse einer Evaluation und Bewertung auf einen anderen Kontext oder ein anderes Setting (Zerth et al. 2021). Zerth et al. (2021) teilen für ein besseres Verständnis der Transferierbarkeit in eine Adoptionsprädiktion ersten, zweiten und dritten Grades ein. Sie beschreiben, dass bei der Adoptionsprädiktion ersten Grades eine Aufgabe darin bestünde, mit unterschiedlichen Methoden und Instrumenten, unter Berücksichtigung verschiedener Perspektiven, zu betrachten, was sich in einem konkreten Setting beim Technologieeinsatz lernen lässt. Damit wären Übertragungen von Erfahrungen innerhalb eines Settings möglich (Zerth et al. 2021)

Bei der Adoptionsprädiktion zweiten Grades wäre eine Voraussetzung für die Übertragbarkeit der Erfahrungen die Inhalts-, Struktur- und/oder Prozessähnlichkeit eines anderen Pflegearrangements – die allerdings vorher zunächst einmal bestmöglich analysiert werden müssten, um ähnliche Pflegearrangements zu identifizieren (Zerth et al. 2021). Betrachtet man die Vielschichtigkeit von Komponenten und Zusammenhängen der Technologieeinführungen, die beispielsweise im CFIR-Framework aufgezeigt werden (Damschroder et al. 2009), so wird klar, welcher Aufwand notwendig wäre, um ein Verständnis für die Zusammenhänge von Veränderungen durch digitale Pflegetechnologien zu entwickeln.
Die Adoptionsprädiktion dritten Grades beschreibt das Diffusionspotenzial einer DNT im gesamten Pflegemarkt. Notwendig dafür wäre eine Abschätzung der Adoption der Technologie von ähnlichen Pflegearrangements auf weitaus unterschiedlichere und die Abschätzung des Potenzials für eine Marktdurchdringung (Zerth et al. 2021).

Als Hilfestellung für die Evaluation von digitalen Pflegetechnologien vor dem im Kapitel 1.2 beschriebenen Hintergrund ist noch einiges an Grundlagenforschung notwendig. Ein möglichst umfängliches Bild über eine einzelne DNT als Voraussetzung für die Adoptionsprädiktion erhält man nur, wenn man verschiedene Evaluationsbereiche mit unterschiedlichen Instrumenten, Methoden und Outcomes aus verschiedenen Perspektiven und im Zusammenhang mit dem Rahmen, der durch das betrachtete (komplexe) soziotechnische System, in dem die Technologie eingeführt wird, entsteht, erforscht. Um dies leisten zu können, wird zunächst einmal eine möglichst umfängliche Übersicht über verfügbare Evaluationsbereiche, Instrumente, Methoden, Outcomes und Perspektiven benötigt. Zu Beginn dieser Forschungsarbeit lag weder eine umfängliche Übersicht über Evaluationsbereiche, Instrumenten, Methoden, Outcomes und Perspektiven noch eine umfängliche Aufarbeitung vorhandener Evidenz zu verschiedenen digitalen Pflegetechnologien unter Berücksichtigung mehrerer Outcome-Bereiche vor.

1.3 Zentrale Fragestellung und Ziel der Arbeit

Aufbauend auf dem soeben beschriebenen Forschungshintergrund zu digitalen Pflegetechnologien wird als zentrale Fragestellung dieser Arbeit untersucht, wie eine umfassende Evaluation und Bewertung von digitalen Pflegetechnologien ermöglicht werden kann und anhand welcher Kategorien und Kriterien dies geschehen müsste.
Es soll an dieser Stelle nochmal betont werden, dass nicht einerseits in der wissenschaftlichen Literatur kritisiert werden kann, dass wir nicht wissen, ob digitale Pflegetechnologien tatsächlich dazu geeignet sind, vorhandene Probleme in der Pflege zu lösen, und andererseits nicht genug dafür unternommen wird, dies in Praxis und Empirie herauszufinden. Neue,

strukturierte Evaluationsansätze sind notwendig, um Klarheit über die Frage nach dem Nutzen von DNT zu geben und Aufschluss darüber zu liefern, warum bisher trotz intensiver Bemühungen so wenig in der Praxis angekommen ist und wie man dieses Problem lösen kann.
Diese Arbeit hat daher das Ziel, eine neue Forschungsperspektive zu eröffnen, indem der Referenzrahmen, in dem sich digitale Pflegetechnologien und deren Evaluation befinden, genauer kartografiert wird. Dieses Rahmenpapier löst nicht einzelne kleinteilige Forschungslücken auf, sondern hat das Ziel, neue, größere Forschungsbereiche und die darin enthaltenen Lücken aufzudecken. Aufkommende Fragen können dann in den neu geschaffenen Referenzrahmen eingeordnet werden und der Kontext für die Erforschung von digitalen Pflegetechnologien wird besser verständlich. Der eröffnete Referenzrahmen hilft anderen Forscher:innen dabei, kleinteiligere Forschungsfragen unter einer neuen Perspektive zu bearbeiten.
Um die zentrale Fragestellung zu beantworten, wird ein kumulativer Ansatz gewählt, indem drei aufeinander aufbauende Schritte zur Beantwortung der Forschungsfrage in drei unterschiedlichen Artikeln bearbeitet werden. Diese Teilschritte haben jeweils eigene Fragestellungen, die sich auf die zentrale Fragestellung beziehen.

(1) Zunächst wurde analysiert, welche digitalen Pflegetechnologien bisher evaluiert wurden und welche Erkenntnisse dazu verfügbar sind: Im Artikel *„Digital technology and nursing care: a scoping review on acceptance, effectiveness and efficiency studies of informal and formal care technologies“* (Kapitel zwei) wurde dazu aufgearbeitet, (i) welche Bereiche digitaler Technologien, die auf die Unterstützung informeller oder formeller Pflege abzielen, bereits evaluatorisch für die Bereiche Akzeptanz, Effektivität und Effizienz (AEE) untersucht wurden, (ii) welche Zielsettings, Unterstützungsfelder und Zielgruppen dieser Technologien damit einhergingen, und (iii) welche Studiendesigns zur Evaluation der Outcome-Dimensionen verwendet wurden.
(2) Der zweite Teilschritt beinhaltete die Strukturierung des Felds bezogen auf den Teilbereich der Wirksamkeit von DNT. Dazu wurden im Artikel *„Measuring the effectiveness of digital nursing technologies: development of a comprehensive digital nursing technology outcome framework based on a scoping review“* (Kapitel drei) (i) die Outcome-Bereiche zur Messung von Wirksamkeit digitaler Pflegetechnologien analysiert, (ii) die aktuelle Forschungsliteratur untersucht mit der Frage danach, welche Outcome-Bereiche bisher im Fokus der Forschung zur Effektivität digitaler Pflegetechnologien standen und welche weniger häufig oder gar nicht untersucht wurden, und (iii) dazu die Instrumente analysiert und strukturiert aufgearbeitet, mit denen die Technologien in bisherigen Studien auf ihre Wirksamkeit untersucht wurden. Das Ziel der Studie

war es, ein Outcome-Framework für digitale Pflegetechnologien zu entwickeln, welches potenzielle Outcome-Bereiche und unterschiedliche Evaluationsperspektiven aufzeigt.

(3) Im dritten Teilschritt wurden vorhandene Evaluationsframeworks für DNT identifiziert und deren Stärken und Schwächen analysiert. Der Artikel „*Evaluation Frameworks for Digital Nursing Technologies: Analysis, Assessment, and Guidance*" (Kapitel vier) sollte dazu herausfinden, (i) welche Evaluationsframeworks zur strukturierten Evaluation von digitalen Pflegetechnologien in der Literatur bereits verfügbar sind, (ii) welche Zwecke, Perspektiven und Definitionen von Erfolg (von DNT) in diesen Frameworks beschrieben werden, (iii) was die Stärken und Schwächen der enthaltenen Frameworks sind, und (iv) welche Evaluationsbereiche in den Frameworks vertreten sind und wo die meisten Überschneidungen und Unterschiede zwischen diesen Frameworks liegen.

Was diese Arbeit leisten kann und was nicht

Die Einzelarbeiten in dieser Arbeit leisten einen Beitrag dazu, ein besseres Verständnis für das Thema Evaluation von digitalen Pflegetechnologien zu erlangen und geben Aufschlüsse darüber, welche Kategorien und Kriterien zur Bewertung von DNT geeignet sind.

Die Gesamtarbeit beschreibt als Referenzrahmen übergeordnete Evaluationsbereiche und Methoden sowie Perspektiven für die Evaluation von DNT und arbeitet unterschiedliche Technologiebereiche von DNT auf. Spezifische Outcome-Bereiche und Instrumente zur Evaluation von DNT werden in dieser Arbeit für das Thema Wirksamkeit benannt, da dieser Bereich für die Problemlösungskapazität der DNT am wichtigsten angesehen wurde. Die Arbeit widmet sich nicht der Aufarbeitung einer Übersicht zu Instrumenten für andere Evaluationsbereiche, wie beispielsweise zur Akzeptanz oder Effizienz. Hier sind darüberhinausgehende Untersuchungen notwendig, für die diese Arbeit als Grundlagenforschung eine gute Basis bietet.

Als Herausforderung, die diese Arbeit nicht zu lösen vermag, kann die Tatsache benannt werden, dass der Untersuchungsgegenstand (DNT) noch nicht weit genug in der Praxis verbreitet ist und daher Aussagen über den Gegenstand aufgrund der häufig in Laborumgebung stattfindenden Testungen limitiert sind (Krick et al. 2019; Lutze et al. 2019). Im Diskussionsteil dieses Rahmenpapiers folgt daher eine zusätzliche Ausarbeitung von Herausforderungen, die mit dem Reifegrad von DNT im Zusammenhang stehend. Außerdem wird auf den Aspekt des Innovationspotenzials von DNT eingegangen und dieser diskutiert.

1.4 Methodische Herangehensweisen der Arbeit

Diese Arbeit beschäftigt sich mit großen Forschungsfragen, deren Beantwortung dabei hilft, einen Überblick über das Themenfeld der Evaluation von digitalen Pflegetechnologien zu erhalten. Solche Herangehensweisen sind insbesondere dann sinnvoll, wenn sich Forschung neuen Themenfeldern widmet, die bisher noch nicht in der Gänze „kartiert“ wurden. Alle eingeschlossenen Artikel in dieser Arbeit bearbeiten jeweils große Unterfragestellungen und dienen dazu, die Forschungsliteratur möglichst umfassend abzubilden und übersichtlich darzustellen. Zwei der Artikel (Kapitel zwei und drei) basieren daher auf der Methodik des „Scoping Reviews“. Dem Namen „Scoping“ ist bereits zu entnehmen, dass diese Art von Review darauf gerichtet ist, einen großen Themenbereich zu umfassen. Für die Aufarbeitung der Fragestellungen wurde die Guideline zu Scoping Reviews von Arksey & O'Malley (2005) genutzt. Außerdem wurden verschiedene methodischen Ergänzungen von Levac et al. (2010), wie im Artikel beschrieben, berücksichtigt.

Die Artikel in Kapitel zwei und drei basieren dabei beide auf demselben Scoping Review, für den insgesamt 19.510 Artikel gescreent und 750 Volltexte mit Studien zu den Bereichen Effektivität, Akzeptanz und Effizienz von DNT analysiert wurden. Für eine tiefere Beantwortung der Fragestellungen aus dem Bereich Wirksamkeitsmessung wurden für den Artikel in Kapitel drei 123 Effektivitätsstudien aus dem ursprünglichen Scoping Review anhand einer neuen Fragestellung analysiert und eine zusätzliche Methodik zur Erstellung eines Outcome-Frameworks angewandt. Dafür wurden ergänzend existierende Frameworks für die Outcome-Messung von DNT recherchiert, die in einem deduktiven Prozess gemeinsam mit den vorhandenen Studien zur Ableitung von Outcome-Bereichen genutzt wurden. Diese Outcome-Bereiche wurden in einem Vier-Augen-Prozess definiert und durch einen Expertenworkshop validiert. Die beschriebene Methodik umfasst mehr als die übliche Vorgehensweise eines Scoping Reviews, denn sie enthält Elemente eines Critical Reviews, der sich statt der vollständigen Kartierung eines Themenbereichs darauf fokussiert, konzeptionelle Beiträge von Studien herauszuarbeiten und daraus neue Theorien oder Modelle abzuleiten (Grant & Booth 2009). Durch die Kombination der beiden Vorgehensweisen wird eine sehr umfangreiche und systematische Analyse der Literatur ermöglicht, die als Ergebnis die Ableitung eines neuen Modells erzeugt. Das so entwickelte DNT-Outcome-Modell beschreibt durch die dargestellten Outcome-Bereiche den Möglichkeitsraum für die Outcome-Messung von digitalen Pflegetechnologien.

In Kapitel vier wurde für die Aufarbeitung der Literatur zu bestehenden Evaluationsframeworks für DNT ein Overview (Grant & Booth 2009) durchgeführt. Dafür wurden drei Suchmethoden kombiniert: (1) eine systematische Suche in Pubmed, (2) eine narrative Suche in

Google Scholar, ergänzt um Snowballing, und (3) eine Expertenbefragung zu vorhandenen Evaluationsframeworks. Der Begriff Overview ist ein generischer Oberbegriff, hinter dem sich laut Grant & Booth (2009) verschiedene Vorgehensweisen und Elemente von anderen Review-Arten wiederfinden. In der Folge werden daher reflektierend die wichtigsten Eigenschaften der verschiedenen Review-Typen – Scoping Review, Overview und Critical Review sowie und in Abgrenzung dazu der Systematic Review – beschrieben (Tabelle 1 und 2). Dabei werden die Stärken und Schwächen der einzelnen Methoden aufgezeigt, um eine Abgrenzung der Methodik durchzuführen und genauer deutlich zu machen, warum für bestimmte Fragestellungen dieser Arbeit eine bestimmte Methodik genutzt und eine bestimmte andere Methodik nicht genutzt wurde.

Tabelle 1: Beschreibung und Überblick über Stärken und Schwächen der Review-Arten

Review-Typ	Beschreibung	Stärken	Schwächen
Overview	Zusammenfassung der Literatur. Überblick über die Literatur und Beschreibung ihrer Merkmale.[2]	Breite und oft vollumfängliche Zusammenfassung eines Themenbereichs.[2] Festigt bereits bekanntes Wissen.[1] Hebt Forschungslücken in Studien für zukünftige Forschung hervor.[1]	Legt keinen Schwerpunkt darauf extrahierte Daten zu analysieren.[1] Kann, muss aber keine systematische Suche enthalten. [1] Generischer Begriff für verschiedene Reviewarten.[2]
Scoping Review	Bewertung des möglichen Umfangs der verfügbaren Literatur zu einem bestimmten Thema[2] Zielt darauf ab Art und Umfang der Forschung zu identifizieren Nachweise (normalerweise einschließlich laufender Forschung).[1]	Beinhaltet eine vollsystematische Suche[1,] Identifiziert Forschungslücken und zukünftige Forschungsbereiche.[1] Hilft Forschung, Politik und Entscheidungsträger:innen dabei einen Überblick über bereits geleistete Wissenschaftliche Arbeit zu erhalten.[1]	Qualitätsbias: da der Einschluss auf Existenz von Literatur basiert und nicht auf einer Qualitätsbewertung.[1] Die Ergebnisse können nicht verwendet werden, um abschließende Aussagen zu treffen[2], oder um für Politik oder Praxis konkrete Handlungsempfehlungen abzuleiten[1]
Critical Review	Soll zeigen, dass der Autor die Literatur umfassend recherchiert und ihre Qualität kritisch bewertet hat. Geht über eine bloße Beschreibung hinaus und umfasst ein gewisses Maß an Analyse und konzeptioneller Innovation. Führt in der Regel zu einer Hypothese oder einem Modell. [2]	Informationen werden bei der Extraktion kritisch bewertet.[1] Schnelle Übersicht und vergleichsweise ausführliche Übersicht über einen Themenbereich.[1] Beinhaltet und vergleicht oft verschiedene, konkurrierende Denkschulen.[1]	Keine systematische Literatursuche.[1] Hat nicht das Ziel alles an verfügbarer Literatur zu einem Themenfeld zu identifizieren.[2] Keine formale Qualitätsbewertung.[1] Interpretative Elemente sind subjektiv und das resultierende Ergebnis ist

	Kritische Bewertung der Wirksamkeit und Qualität der eingeschlossenen Studien.[1]		der Ausgangspunkt für die weitere Bewertung, kein Endpunkt in selbst.[2]
Systematic Review	Systematische suche nach Forschungsergebnissen. Auswertung und Synthese von Forschungsergebnissen unter Einhaltung von Leitlinien für die Durchführung des Reviews.[2] Ermittlung zuverlässiger und hochwertiger Daten als Grundlage für evidenzbasierte Entscheidungen.[1]	Versucht alle bekannten Kenntnisse zu einem Thema zusammenführen.[2] Sammelt und bewertet die Qualität aller wissenschaftlichen Daten zu einem bestimmten Thema.[1] Reduziert Bias Risiko aufgrund seiner systematischen Natur.[1]	Selektionsbias durch Subjektivität der Reviewer.[1] Limitierter Einblick auf die Wirksamkeit, ohne Antworten auf komplexere Fragen zu liefern, wie beispielsweise warum etwas wirksam ist oder nicht.[2]

Inhalte übernommen und übersetzt aus Samnani et al. (2017)[1] und Grant & Booth (2009)[2]

Tabelle 2: Überblick über Suche, Bewertung, Synthese und Analyse der Review-Arten

Review Typ	Suche	Bewertung	Synthese	Analyse
Overview	Kann, muss aber keine umfangreiche Suche beinhalten (abhängig davon, ob systematischer Overview oder nicht).[2]	Kann, muss aber keine Qualitätsbewertung beinhalten (abhängig davon, ob systematischer Overview oder nicht).[2]	Typischerweise narrativ, kann aber tabellarische Merkmale enthalten (abhängig davon, ob systematischer Overview oder nicht).[2]	Die Analyse kann chronologisch, konzeptuell oder thematisch erfolgen.[2]
Scoping Review	Vollständigkeit der Suche steht im Vordergrund. Bestimmt durch Zeit/Umfang/Beschränkungen.[1] Kann auch laufende Forschung enthalten.[1]	Keine formale Qualitätsbewertung.[1]	Typischerweise tabellarisch mit narrativen Elementen.[1]	Kennzeichnet Quantität und Qualität der Literatur, z. B. durch Studiendesign und andere Eigenschaften.[1] Versucht einen nutzbaren Überblick zu erschaffen.[1]
Critical Review	Versucht, die wichtigsten Studien auf dem Gebiet zu identifizieren.[2]	Keine formale Qualitätsbewertung.[2] Kritisches Hinterfragen der Studien nach ihrem inhaltlichen Beitrag.[2]	Narrativ, konzeptuell oder chronologisch.[2]	Zielt darauf ab, konzeptionellen Beitrag der Studien zu identifizieren.[2] Soll bestehende Theorien darstellen

				oder neue Theorien ableiten.[2]
Systematic Review	Zielt auf eine vollumfängliche Suche und Identifikation der vorhanden Literatur.[1]	Die Qualitätsbewertung bestimmt über Ein- oder Ausschluss.[1]	Typischerweise narrativ mit begleitenden Tabellen.[1]	Zeigt auf, was bekannt oder unbekannt bleibt.[1] Leitet Empfehlungen für die Praxis ab.[1] Beschreibt Unsicherheiten bezüglich der Ergebnisse.[1] Gibt Empfehlungen für die zukünftige Forschung.[1]

Inhalte übernommen aus Samnani et al. (2017)[1] und Grant & Booth (2009)[2].

Wie aus der Tabelle deutlich wird, zielen der Scoping Review und der Systematic Review auf eine möglichst vollumfängliche Literatursuche ab. Der Overview kann, muss aber keine umfangreiche Suche enthalten und der Critical Review versucht, nur die wichtigsten Studien auf einem Gebiet zu identifizieren und muss daher nicht systematisch sein. Stellt man Scoping und Systematic Review genauer gegenüber, so wird ein Scoping Review, da er Art und Umfang der Forschung in einem Themengebiet identifizieren soll, einen deutlich größeren Literaturkorpus als Ergebnis hervorbringen als der Systematic Review, welcher durch die Hürde der Qualitätsbewertung nur hochwertige Studien zu einem spezifischen Thema als Ergebnis hervorbringen soll. Die Hauptaufgabe des Scoping Reviews ist es demnach, einen möglichst umfangreichen Überblick zu verschaffen, wohingegen beim Systematic Review zu einer spezifischen Thematik nach einer formalen Qualitätsbewertung beispielsweise via PRISMA-Statement (Page et al. 2021) die Ergebnisse der eingeschlossenen Studien zu spezifischen, evidenzgesicherten Empfehlungen abgeleitet werden können. Als Steigerung in der Evidenz-Hierarchie ist noch die Meta-Analyse zu nennen, die als Suchbasis wie ein Systematic Review funktioniert, jedoch bei der Auswertung die Ergebnisse quantitativer Studien statistisch zusammenführt, um numerische Aussagen zu den Effekten einzelner (möglichst ähnlicher) Interventionen liefern zu können (Grant & Booth 2009). Der Overview ist je nach Ausführung ebenfalls grundsätzlich geeignet, einen große Fragestellungen zu bearbeiten, wohingegen der Critical Review durch seine eingeschränkte Vorgehensweise bei der Suche allein dazu nicht ausreicht.

Für die großen Fragestellungen dieser Arbeit kam daher in erster Linie die Methodik des Scoping Reviews in Frage, da ein möglichst umfängliches Bild der Forschung zu digitalen Pflegetechnologien und deren Evaluation aufgearbeitet werden sollte und es nicht das Ziel war, die Effekte einzelner Studien zu vergleichen oder statistisch zusammenzurechnen. Wie zuvor beschrieben, wurden auch Elemente des Critical Reviews im Rahmen dieser Arbeit genutzt. Dies zielte darauf ab, den konzeptionellen Beitrag der analysierten Studien zu identifizieren (Grant & Booth 2009) und wurde genutzt, um mit dem DNT-Outcome-Framework ein neues Modell zur Erfassung von Wirksamkeit von digitalen Pflegetechnologien zu erarbeiten. Allerdings wurde hier bei der Recherche eine systematische Suche aufbauend auf einem Scoping Review vorgeschaltet, um eine möglichst umfassende Grundlage für die Erarbeitung des Modells zu erhalten.

Der Begriff Overview, der für die Analyse der Evaluationsframeworks in Kapitel vier genutzt wurde, enthält wie der Scoping Review aus Kapitel zwei und drei durch die gewählte Herangehensweise eine umfangreiche Suche. Die Kombination von systematischer Suche, narrativer Suche und Expertenbefragungen wurde gewählt, um neben der Literaturrecherche ebenfalls das vorhandene Wissen von im „Cluster Zukunft der Pflege“ (Boll et al. 2018a, S. III) verfügbaren Expert:innen mit in die Identifikation von Frameworks einbeziehen zu können. Auch diese Studie enthält also viele Elemente eines Scoping Reviews. Es wurde allerdings auf die Handsuche in einschlägigen Magazinen und die Kontaktierung von Organisationen wie von Arksey & O'Malley (2005) beschrieben verzichtet. Es ließe sich sicher darüber diskutieren, ob der Artikel in Kapitel vier nun ebenso ein Scoping Review ist oder nicht. Wichtig ist jedoch eher, dass die Herangehensweise zur Beantwortung der Fragestellung am geeignetsten erschien und daher durchgeführt wurde.

1.5 Forschungskontext

Diese Dissertation wurde im Rahmen des vom Bundesministerium für Bildung und Forschung geförderten Projekts „Pflegeinnovationszentrum“ (Boll et al. 2018b, S. 1) erstellt.

2 Akzeptanz, Effektivität und Effizienz als Kernbausteine der Evaluation von digitalen Pflegetechnologien

Im ersten Artikel „*Digital technology and nursing care: a scoping review on acceptance, effectiveness and efficiency studies of informal and formal care technologies*“ (Krick et al. 2019) nähert sich diese Forschungsarbeit der Fragestellung, wie eine umfassende Evaluation und Bewertung von digitalen Pflegetechnologien ermöglicht werden kann, durch eine Analyse der bisher evaluierten digitalen Pflegetechnologien und den dazu verfügbaren Erkenntnissen in der Forschungsliteratur. Nach einer umfangreichen Literatursuche (Scoping Review) wurden 715 Studien in die Auswertung und Analyse einbezogen, um zunächst den Begriff „digitale Pflegetechnologie“ (in diesem Artikel „Digital Technologies in Nursing Care“) besser verstehen und einordnen zu können. Gesucht und analysiert wurden Studien, die sich mit der Akzeptanz, Effektivität oder Effizienz bestimmter digitaler Pflegetechnologien beschäftigen. Dafür wurde zunächst eine Definition für die Art von Technologien aufgestellt, die gesucht wurden. Diese Definition war zum Zeitpunkt des Artikels schon sehr nah an der Definition von DNT aus diesem Rahmenpapier.

2.1 Pflegetechnologiebereiche

Im Rahmen des Artikels konnten außerdem Definitionen für insgesamt 16 Bereiche digitaler Pflegetechnologien aufgestellt werden. Ziel der Studie war es, die Technologiebereiche zu identifizieren, die als vielversprechend für eine genauere Betrachtung eingeordnet werden können. Das Spektrum der identifizierten und beforschten Technologien war breit. Es existieren jedoch bisher kaum Einzeltechnologien, die so gründlich beforscht wurden, dass zu ihnen gesicherte Erkenntnisse vorliegen. So waren von insgesamt n = 427 Studien zur Effektivität von DNT nur n = 30 RCTs und unter allen n = 424 Studien zur Akzeptanz sogar nur n = 8 RCTs. Als Ergebnis konnte festgestellt werden, dass Wirksamkeitsstudien am häufigsten für Informations- und Kommunikationstechnologien (IKT) (n = 94), Sensortechnologien (n = 68) und Roboter (n = 57) durchgeführt wurden. Akzeptanzstudien befassten sich häufig mit IKT (n = 93), Robotern (n = 64) und Studien zu „Electronic Health Records“/„Electronic Medical Records“ (n = 48). Studien zur Effizienz waren im Allgemeinen selten (insgesamt n = 42 von den insgesamt n = 715 Studien).

Viele Studien wiesen ein niedriges Evidenzniveau auf. Experimentelle Designs mit kleinen Fallzahlen, ohne Kontrollgruppen und in Laborsettings gehörten zu den am häufigsten verwendeten Methoden zur Bewertung von Akzeptanz und Wirksamkeit. Studiendesigns mit hohem Evidenzgrad waren am häufigsten für IKT, Roboter und E-Learning-Technologien zu finden.

2.2 Zielsettings, Zielgruppen und Unterstützungsbereiche

Bei der Analyse der Zielsettings der digitalen Pflegetechnologien in allen einbezogenen Artikeln waren die Pflege im Krankenhaus (n = 169), die informelle Pflege zu Hause (n = 147) und die stationäre Langzeitpflege (n = 122) am häufigsten vertreten. Für viele Technologien wurde allerdings auch kein Zielsetting angegeben (n = 91). DNT für die professionelle Pflege zu Hause (n = 48), die Tagespflege (n = 6) oder die sektorübergreifenden Pflege (n = 6) kamen seltener vor. Bei den Zielgruppen zeigte sich ebenfalls ein interessantes Bild. Die meisten untersuchten digitalen Pflegetechnologien fokussierten sich auf die zu pflegende Person (n = 382) und auf professionell Pflegende (n = 326). DNT, die auf informell Pflegende (n = 57) zielten, wurden nur in wenigen Fällen untersucht.
Bei der Analyse der Unterstützungsbereiche, auf die die einzelnen DNT zielten, zeigte sich, dass am häufigsten organisatorischen Aufgaben (n= 169) (zum Beispiel Arbeits- und Selbstorganisation) und der Bereich der persönlichen Sicherheit (n = 99) (zum Beispiel Sturzprävention) im Fokus waren. Darüber hinaus gab es einen großen Teil von Technologien, die in mehreren Bereichen unterstützen (n = 162). Ein Beispiel dafür sind IKTs, die sowohl organisatorische als auch psychologische oder soziale Unterstützung kombinieren. Digitale Pflegetechnologien, die ausschließlich physische (n = 46), psychologische (n = 40), soziale (n = 40) oder wirtschaftliche (n = 2) Unterstützung boten, kamen deutlich seltener vor.

Als Schlussfolgerung aus den Gesamtergebnissen des Artikels wurde gezogen, dass es empfehlenswert wäre, qualitativ hochwertige Evaluationen bestehender digitaler Pflegetechnologien in den Bereichen AEE auf einem hohen Evidenzniveau in realen Anwendungssettings zu erstellen, anstatt noch mehr systematische Übersichtsarbeiten zu erstellen, die die vorhandenen Studien auf geringem Evidenzniveau zusammenfassen. Außerdem sollte ein Schwerpunkt auf die Erforschung von Effizienz gelegt werden. Zukünftige Forschung sollte sich zudem einer genaueren Untersuchung der Forschungsmethoden zur Analyse von AEE widmen. Außerdem sollten groß angelegte, langfristige Evaluationen von digitalen Pflegetechnologien in der Versorgungspraxis ermöglicht werden, um die bestehenden Forschungslücken bei bestimmten DNT, Zielsettings, Zielgruppen und Unterstützungsbereichen zu schließen, die in dieser Arbeit ermittelt wurden.

3 Wirksamkeitsmessung: Wissensstand, Methoden und die Entwicklung eines Outcome-Modells

Im zweiten Artikel „*Measuring the effectiveness of digital nursing technologies: development of a comprehensive digital nursing technology outcome framework based on a scoping review*" (Krick et al. 2020) erfolgt eine Annäherung an die Frage, wie eine umfassende Evaluation und Bewertung von digitalen Pflegetechnologien ermöglicht werden kann, durch eine Strukturierung des Felds bezogen auf den Teilbereich der Wirksamkeitsmessung.
In diesem Artikel wurde die Begriffsbestimmung für „Digital Technologies in Nursing Care" aus dem Artikel in Kapitel zwei aufgegriffen und zum feststehenden Begriff der **„Digital Nursing Technologies" (DNT)** weiterentwickelt. Die Definition von DNT in diesem Artikel überschneidet sich mit der Definition DNT in diesem Rahmenpapier. Lediglich eine genauere Beschreibung der Komponente „Digital" wurde im Rahmenpapier hinzugefügt.
Die Begriffe „Wirksamkeit" und „Effektivität" werden in der deutschen Übersetzung dieser Studie für dieses Rahmenpapier synonym verwendet. Es sei jedoch darauf hingewiesen, dass die im Englischen getroffene Unterscheidung zwischen „Effectiveness" und „Efficacy" (beides übersetzt mit Wirksamkeit) im Artikel ausführlich diskutiert wird.
Mithilfe der Ergebnisse dieses Artikels wurde eine Grundlage für die Analysen der Wirksamkeit von DNT geschaffen. Insgesamt wurden dafür 123 Effektivitätsstudien aus dem ursprünglichen Scoping Review (Krick et al. 2019) anhand einer neuen Fragestellung analysiert und ergänzend existierende Frameworks für die Outcome-Messung von DNT recherchiert, die in einem deduktiven Prozess gemeinsam mit den vorhandenen Studien zur Ableitung von Outcome-Bereichen genutzt wurden. Ein Outcome-Bereich gibt die Inhaltsebene an, auf der eine Wirkung auftritt (zum Beispiel das Wohlbefinden oder die funktionale Gesundheit). Diese Outcome-Bereiche wurden in einem Vier-Augen-Prozess definiert und durch einen Expertenworkshop validiert.

3.1 Outcome-Bereiche im Fokus der Forschung zur Wirksamkeit

Insgesamt konnten 47 Outcome-Bereiche zur Wirksamkeitsmessung identifiziert werden, die in einem DNT-Outcome-Framework zusammengefasst wurden (Abbildung 1). Das Framework enthält zudem verschiedene Zielgruppen, auf die eine digitale Pflegetechnologie wirken kann: (1) Zu pflegende Menschen, (2) formelle Pflegekräfte, (3) informell Pflegende und (4) die Pflegeeinrichtung. Das DNT-Outcome-Framework trägt damit zu einer übersichtlichen und besser vergleichbaren Erhebung von Wirksamkeit bei.

Zudem wurden die einbezogenen 123 Effektivitätsstudien darauf untersucht, welche Outcome-Bereiche bisher im Fokus der Forschung zur Wirksamkeit digitaler Pflegetechnologien standen und welche weniger häufig oder gar nicht untersucht wurden.
Die Wirksamkeit von DNT bei pflegebedürftigen Personen wurde mit Abstand am häufigsten untersucht (n = 77 von 123 Studien), insbesondere im Hinblick auf ihre psychische Gesundheit (n = 33). Deutlich weniger Studien existieren zu professionell (n = 20) oder informell Pflegenden (n =10), und es ist auffällig, dass die Wirksamkeit von digitalen Pflegetechnologien auf die Lebensqualität beider Gruppen nur selten untersucht wurde. Die Wirkung von DNT auf Pflegeorganisationen wurde häufiger analysiert (n = 45). Dabei war die Qualität der Pflegeprozesse der am häufigsten für Organisationen erforschte Outcome-Bereich (n = 21 von 45).
Für alle Outcome-Bereiche konnten spezifische Instrumente (Outcome-Tools) identifiziert werden, die für die Messung der Wirksamkeit in zukünftigen Studien genutzt werden könnten. Die meisten Instrumente wurden für den Bereich der mentalen Gesundheit identifiziert (n = 40). Für alle Bereiche zusammen konnten n = 95 verschiedene Outcome-Tools identifiziert werden. Die meisten Tools wurden zur Wirksamkeitsmessung bei zu pflegenden Personen genutzt (n = 68). Es kann davon ausgegangen werden, dass wahrscheinlich ein Mangel an standardisierten Instrumenten zur Messung von Wirksamkeit von DNT in den Bereichen der professionell und informell Pflegenden sowie der Pflegeorganisationen vorliegt, da in diesen Bereichen nur wenige standardisierte Instrumente identifiziert werden konnten.

Diese Übersichtsarbeit bietet einen breiten Überblick über Outcome-Bereiche und Outcome-Tools, die für die Evaluation von DNT genutzt werden können. Die Verwendung des neu geschaffenen DNT-Outcome-Frameworks (Abbildung 1) dient als systematische Grundlage für zukünftige Wirksamkeitsevaluationen von DNT. Forschende können das Framework zur Strukturierung ihrer Wirksamkeitsevaluationen nutzen und erkennen, ob wesentliche Outcome-Bereiche in ihren bisherigen Überlegungen zu Evaluation übersehen wurden. Die Gewichtung der Bedeutung der verschiedenen Outcome-Bereiche – insbesondere derjenigen, die bisher weniger erforscht wurden – sollte Gegenstand weiterer Untersuchungen sein.

3.2 Das DNT-Outcome-Framework

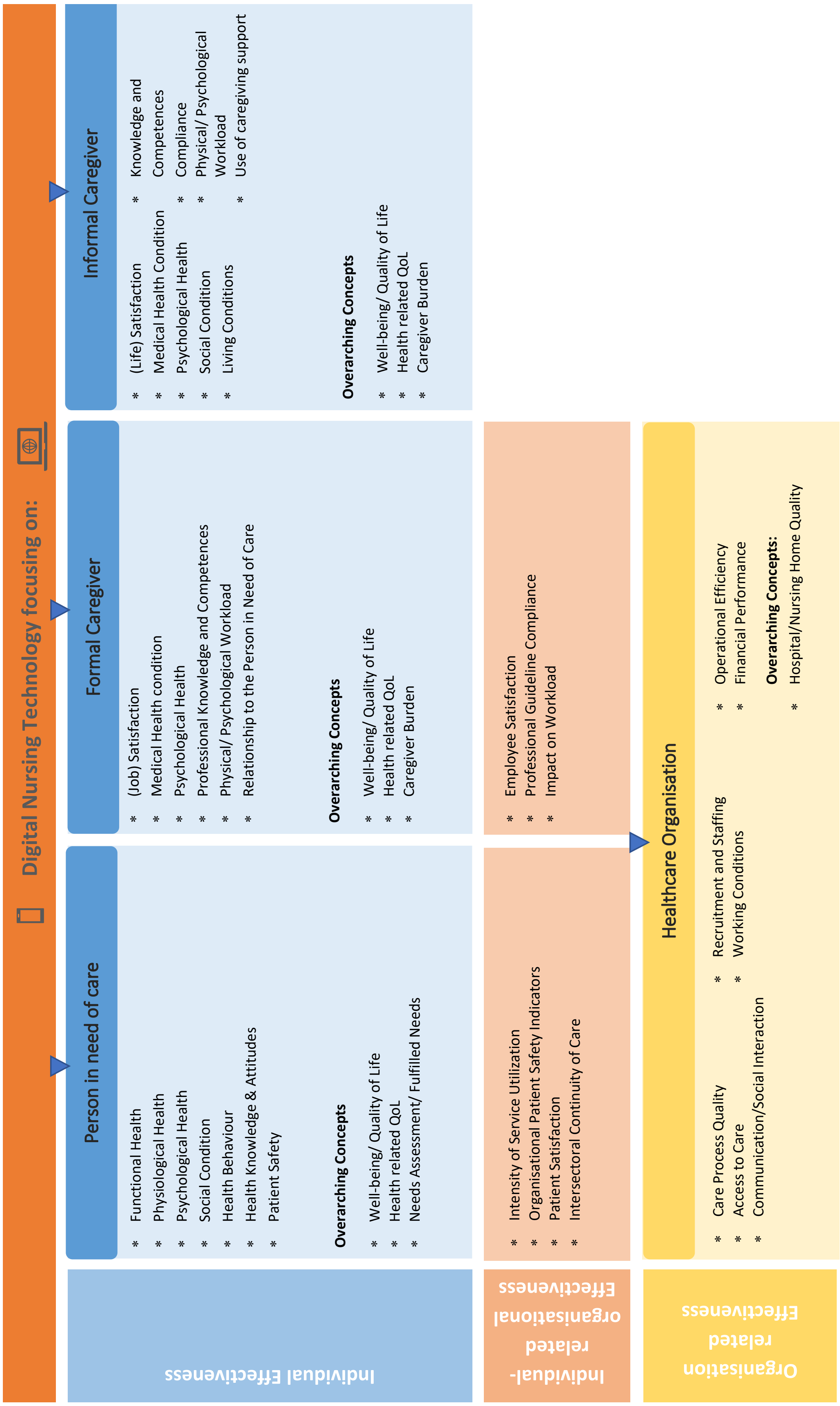

Abbildung 1: Das DNT Outcome Framework

Quelle: *Eigene Darstellung übernommen aus Krick et al. (2020).*

4 Evaluationsframeworks für digitale Pflegetechnologien – Übersicht aller Evaluationsbereiche und wesentlichen Merkmale

Im letzten Artikel „*Evaluation Frameworks for Digital Nursing Technologies: Analysis, Assessment, and Guidance*" (Krick 2021) nähert sich diese Forschungsarbeit der Fragestellung, wie eine umfassende Evaluation und Bewertung von digitalen Pflegetechnologien ermöglicht werden kann von der Seites des Evaluationsbegriffs, indem vorhandene Evaluationsframeworks für den Bereich der digitalen Pflegetechnologien untersucht werden und deren Stärken und Schwächen analysiert werden.

Evaluationsframeworks dienen dazu, den Evaluationsprozess von DNT zu strukturieren, indem sie Informationen und Definitionen zum Technologieerfolg sowie zu Evaluationsbereichen, Methoden und Instrumenten liefern. Auf diese Weise erleichtern sie einen systematischen Evaluationsansatz (Fynn et al. 2020) bei der DNT-Bewertung.

In die Auswertung wurden insgesamt 18 Evaluationsframeworks, die für digitale Pflegetechnologien anwendbar sind, einbezogen, um zu ermitteln,

(1) welche Zwecke, Perspektiven und Definitionen von Erfolg diese Frameworks beschreiben,
(2) welche Stärken und Schwächen diese spezifischen Frameworks haben, und
(3) welche Evaluationsbereiche in den Frameworks vertreten sind und wo die meisten Überschneidungen und Unterschiede existieren.

Insgesamt konnten neun übergreifende Evaluationsbereiche, sieben Kategorien von Zwecken, fünf Evaluationsperspektiven und drei Kategorien von Erfolgsdefinitionen identifiziert werden. Im Folgenden werden nur die Kernergebnisse zu den Inhalten der Frameworks wiedergegeben, weil die ausführliche Darstellung aller Details in diesem Rahmenpapier zu umfangreich wäre. Für einen höheren Detailgrad muss auf den Originalartikel zurückgegriffen werden.

4.1 Evaluationsbereiche aus den Frameworks

Die folgende Tabelle 3 zeigt alle neun Evaluationsbereiche, die in den analysierten 18 Frameworks identifiziert werden konnten. Für jeden Evaluationsbereich wurde eine Definition erstellt, die ebenfalls in der Tabelle dargestellt ist. Die Übersetzung der Inhalte zu den Kategorien aus dem Englischen ins Deutsche wurde vom Autor vorgenommen, um die ursprünglichen Inhalte wiederzugeben. Die Überschriften wurden im englischen Original belassen.

Tabelle 3: Die neun Evaluationsbereiche der betrachteten Frameworks

Focus	**Product/Technology**	**Objective Value/Effect**
Dieser Bereich umfasst die klare Definition der Ziele und des Zwecks der Technologie sowie die Probleme und Bedürfnisse, die sie für eine bestimmte Zielgruppe in einem bestimmten Umfeld lösen soll.	Dieser Bereich umfasst alle Aspekte der Technologie selbst. Das reicht vom optischen Erscheinungsbild über die Funktionalität bis hin zu bestimmten spezifischen technologischen Aspekten wie der Interoperabilität. (In dieser Kategorie gibt es eine Schnittstelle zur Kategorie „Individual", da hier bestimmte individuell wahrgenommene Aspekte wie Benutzerfreundlichkeit und Zugang abgedeckt werden.)	Diese Kategorie umfasst die relevanten Informationen über die Evidenz, die angestrebte Wertererzeugung (Wirkung) sowie die beabsichtigten und unbeabsichtigten Auswirkungen der Technologie.
Individual	**Organization**	**Societal**
Dieser Bereich umfasst Reaktionen und wahrgenommene Eindrücke sowie das Verhalten und die Beziehung des Einzelnen zur Technologie.	Dieser Bereich umfasst Aspekte, die für die Beziehung zwischen der Technologie und einer Organisation relevant sind.	Dieser Bereich umfasst relevante Aspekte der Technologie im gesellschaftlichen Kontext (z. B. politische, rechtliche, regulatorische oder soziokulturelle Aspekte – Überschneidungen mit dem Bereich „Ethics" sind möglich).
Ethics	**Economics**	**Strategic**
Dieser Bereich umfasst relevante ethische Standards und ethische Implikationen, die im Zusammenhang mit der Technologie zu berücksichtigen sind.	Dieser Bereich umfasst relevante ökonomische Aspekte für die Technologie (z. B. Geschäftsmodell, Preis, wirtschaftliche Bewertung).	Dieser Bereich umfasst strategische Aspekte, die für die Einführung und Verbreitung der Technologie von Bedeutung sein können.

4.2 Zwecke, Perspektiven und Definitionen von Erfolg für digitale Pflegetechnologien

In diesem Artikel wird der Zweck eines Frameworks als die Beschreibung dessen definiert, was mit dem Framework erreicht werden soll. In den untersuchten Frameworks werden folgende Zwecke benannt:

1. Unterstützung und Anleitung von Forscher:innen (im Entwicklungs- und Evaluationsprozess)

2. Ermittlung von Erfolgs- und Misserfolgsfaktoren (und Hilfestellung, um sie zu bewältigen)
3. Bewertung der Leistung/des Erfolgs einer Technologie (zum Beispiel Outcomes, Impacts, Errors)
4. Die Ergebnisse vergleichbar machen.
5. Einen Beitrag zur Qualität und Entwicklung der Technologie leisten.
6. Die Implementierung einer Technologie unterstützen.
7. Hilfestellung bei der Entscheidungsfindung

Perspektiven

Die Perspektive beschreibt den Standpunkt, von dem aus ein Framework entwickelt wurde. Dieser Standpunkt wurde entweder im Framework konkret benannt, wie die Perspektive der Pflegekraft beim „Adapted Nursing Care Performance Framework" von Rouleau et al. (2017), oder indirekt durch die Beschreibung des Umfangs und der Art des Frameworks deutlich, wie die universelle Perspektive beim NASSS-Framework von Greenhalgh et al. (2017). In dieser Arbeit wird diese Art von Perspektive auch als die Perspektive gedeutet, aus der die Ergebnisse einer Evaluation mithilfe des Frameworks interpretiert werden könnten. Die vorkommenden Perspektiven sind: (1) die universelle Perspektive (ist von der Grundausrichtung neutral und überlässt die Entscheidung zur Perspektivwahl der evaluierenden Person), (2) die Perspektive des Gesundheitssystems (des Gesamtsystems, das heißt über den Kostenträgeraspekt hinaus), (3) die Perspektive der Gesundheitsorganisation, (4) die Perspektive der Pflegekraft, und (5) die Investitionsperspektive. Es sind auch verschiedene weitere Perspektiven für Evaluationsframeworks denkbar, die nicht in den untersuchten Frameworks vorhanden waren, wie beispielsweise die Kostenträger, die Patient:innen/pflegebedürftigen Personen und die Perspektive der informellen Pflegepersonen.

Drei übergreifende Definitionen von erfolgreichen digitalen Pflegetechnologien

Insgesamt wurden drei übergreifende Definitionen von erfolgreichen digitalen Pflegetechnologien identifiziert. Die Analyse des Begriffs „Erfolg" konzentrierte sich auf die Definitionen oder Beschreibungen dessen, was die Artikel zu den Frameworks unter „Erfolg" oder „erfolgreicher Technologie" verstehen:

1. Erfolg ist, wenn die Technologie einen beabsichtigten (vorher definierten) Zweck erfüllt.
2. Erfolg bedeutet, dass die Implementierung, Verbreitung und/oder Nachhaltigkeit einer Technologie erreicht wird.
3. Eine erfolgreiche Technologie muss einen Nettonutzen erzeugen (Net Benefit).

4.3 Stärken und Schwächen der dargestellten Frameworks

Für die Bewertung der Stärken und Schwächen von Evaluationsframeworks für DNT wurden im Rahmen eines Expertenworkshops elf Qualitätskriterien entwickelt und die einbezogenen Frameworks anhand dieser Kriterien bewertet. Diese elf Qualitätskriterien lassen sich in fünf übergeordnete Bewertungsbereiche einteilen: (1) Schwerpunkte des Frameworks, (2) Illustration, (3) Terminologie, (4) Anleitung für die Verwendung, und (5) wissenschaftliche Qualität. Eine genauere Beschreibung aller Kriterien und die Analyse und Bewertung findet sich im zugrundeliegenden Artikel und wird aus Platzgründen an dieser Stelle nicht dargestellt. Die anhand dieser Kriterien am besten bewerteten Frameworks waren:

(1) Health Technology Adoption Framework (Poulin et al. 2013)

(2) Clinical Information Systems Success Model (CISSM) (Garcia-Smith & Effken 2013)

(3) Nonadoption, Abandonment, Scale-up, Spread, and Sustainability Framework (NASSS) (Greenhalgh et al. 2017)

Die Analyse und das Mapping der Informationen in diesem Artikel geben einen guten Überblick über die betrachteten Evaluationsframeworks, ihre Gemeinsamkeiten und Unterschiede, mögliche Bewertungsbereiche, Zwecke, Perspektiven, Erfolgsdefinitionen, Stärken und Schwächen. Diese Informationen können bei der Kommunikation zwischen Entscheidungsträger:innen und Forschenden helfen, um einen besseren Evaluationsprozess zu ermöglichen (Currie 2005), indem sie systematische Informationen und eine Struktur für die Evaluation von DNT bereitstellen. Forschende können außerdem die Qualitätskriterien aus diesem Artikel als Ausgangspunkt für die Auswahl oder Erstellung von Evaluationsframeworks für ihre Forschungsprojekte oder für die Bewertung der Qualität eines Evaluationsframeworks für DNT nutzen.

5 Diskussion und Beantwortung der übergeordneten Forschungsfrage

Die vorliegende Forschungsarbeit befasst sich mit der übergreifenden Frage danach, wie eine umfassende Evaluation und Bewertung von digitalen Pflegetechnologien ermöglicht werden kann und anhand welcher Kategorien und Kriterien dies geschehen müsste.

Die Beantwortung der Forschungsfrage, die diese Forschungsarbeit leistet, kann über die Artikelstruktur in drei Hauptkomponenten zusammengefasst werden. Eine umfassende Evaluation und Bewertung von digitalen Pflegetechnologien kann ermöglicht werden

(1) durch die qualitativ hochwertige Evaluation vielversprechender, spezifischer digitaler Pflegetechnologien in den Bereichen Akzeptanz, Effektivität und Effizienz auf einem hohen Evidenzniveau in realen Anwendungssettings (Kapitel zwei),

(2) durch die (Wirksamkeits-)Evaluation von digitalen Pflegetechnologien in verschiedenen, in dieser Arbeit herausgearbeiteten Outcome-Bereichen durch vorhandene oder neu zu entwickelnde Outcome-Tools auf verschiedenen Ebenen (individuelle Ebene, organisatorische Ebene, gesellschaftliche Ebene) zur Identifikation von wirksamen digitalen Pflegetechnologien (Kapitel drei), und

(3) durch die kritische Auswahl und Nutzung von strukturierten Evaluationsframeworks anhand der in dieser Arbeit erarbeiteten Kriterien und die Einordnung und Strukturierung des Evaluationsvorhabens anhand der in dieser Arbeit herausgearbeiteten Evaluationsbereiche als Grundlage für die Evaluationen von digitalen Pflegetechnologien aus verschiedenen, vorab festzulegenden Evaluations- und Bewertungsperspektiven (Kapitel vier).

Die Antworten und damit im Zusammenhang stehenden Problematiken sollen in den folgenden Abschnitten diskutiert werden.

5.1 Problematik des unklaren Potenzials von digitalen Pflegetechnologien

Eine **erste** wesentliche in dieser Arbeit beschriebene Problematik ist die Diskrepanz zwischen dem zugesprochenen Potenzial von digitalen Pflegetechnologien, zu einer Verbesserung in der Pflege beizutragen, und dem weiterhin existierenden Nicht-Wissen darüber, ob dies auch tatsächlich der Fall ist. Es stellt sich also weiterhin die Frage, ob das Potenzial zur Verbesserung von DNT in der Pflege, wie Hergesell (2019a) es beschrieben hat, nur diskursiv existiert oder auch empirisch durch entsprechende Evaluationen und Wirksamkeitsnachweise für einzelne DNT belegt werden kann.

Diese Arbeit hat mit ihren zwei Artikeln zum Thema Effektivität bzw. Wirksamkeit eine Grundlage für eine strukturierte Vorgehensweise solcher Evaluationen gelegt, jedoch noch nicht beantwortet, welche Erkenntnisse die Literatur zum Thema Wirksamkeit von digitalen Pflegetechnologien liefert. Um erste Anhaltspunkte zur Beantwortung dieser Frage zu geben, wurde in einem ergänzenden Artikel von Huter et al. (2020), an dem auch der Autor dieser Dissertation beteiligt war, eine genauere Analyse von insgesamt 123 Einzelstudien und 31 Reviews zur Effektivität von digitalen Pflegetechnologien, die im Rahmen des Scoping Reviews aus Kapitel zwei identifiziert wurden, durchgeführt. Das Ergebnis zeigte auf, dass es zwar viele Studien gibt, die positive Auswirkungen von digitalen Pflegetechnologien nachweisen, aber der Grad der Evidenz meist gering und die Studiengröße oft klein ist. Kaum eine Technologie ist intensiv genug erforscht worden, um schlüssige Ergebnisse zu liefern. Die heterogenen Ergebnisse in einigen Bereichen weisen außerdem darauf, dass die Auswirkungen der DNT stark von der Art und Weise und dem spezifischen Kontext abhängen könnten, in dem die Technologien eingeführt wurden (Huter et al. 2020). Diese Erkenntnis stützt die in diesem Rahmenpapier bereits diskutierte Problematik der Komplexität bei der Einführung und Evaluation von DNT und stärkt nachhaltig die Forderung danach, Studien zu DNT auf einem hohen Evidenzniveau in realen Anwendungssettings durchzuführen.

Die Evaluation von Akzeptanz, Effektivität und Effizienz

Die Analysen aus dieser Arbeit zeigten ebenso auf, dass neben der Evaluation der Wirksamkeit einer DNT zum besseren Verständnis des Potenzials von DNT auch die Erforschung der Bereiche Akzeptanz und der Effizienz eine wichtige Rolle spielen sollten. Analysiert wurde insbesondere die internationale Literatur. Im Vergleich dazu soll nun in aller Kürze die Forschung zu DNT in diesen Bereichen im deutschsprachigen Raum ins Verhältnis gesetzt werden.

Eine Ist-Stand-Analyse von n = 47 analysierten deutschsprachigen Projekten von Schley et al. (2021) zeigte auf, dass die Untersuchung der Akzeptanz von digitalen Pflegetechnologien am häufigsten als Ziel der betrachteten Projekte benannt wurde (n = 37). Dies bestätigt auch die relative Häufigkeit der Akzeptanzforschung in internationalen Studien aus dieser Arbeit (Krick et al. 2019). Außerdem wurden die Machbarkeit/Durchführbarkeit der Einführung (n = 31), Barrieren und förderliche Faktoren (n = 26), positive Erfahrungen der Nutzenden mit der Technologie (n = 26) und die technische Funktionsfähigkeit (n = 24) am häufigsten als Evaluationsziel benannt. Die Messung der Effektivität unter Alltagsbedingungen wurde in den deutschsprachigen Projekten etwas seltener als Evaluationsziel benannt (n = 22) als dies in der internationalen Forschung der Fall war (Krick et al. 2019).

Diese Untersuchungsziele geben bereits einen Hinweis darauf, dass die Erforschung der Einführung von digitalen Pflegetechnologien im deutschsprachigen Raum noch am Anfang steht und dies möglicherweise mit der Frühphasigkeit vieler digitaler Pflegetechnologien (Lutze et al. 2019) im Zusammenhang steht.

Als versorgungswissenschaftliche Zielgrößen wurden am häufigsten funktionelle Zielgrößen und Zielgrößen zur Nutzung in der Pflege untersucht. Dabei stand vor allem das emotionale Wohlbefinden (n = 23), die (globale) Lebensqualität (n = 21) und die kognitiven Funktionen (n = 15) von zu Pflegenden im Vordergrund. Außerdem wurden auch häufig technische Zielgrößen untersucht, wie die Funktionalität (n = 33), die Zuverlässigkeit (n = 30) und die technische Effizienz (n = 22). Die Mehrheit der untersuchten Projekte gab zudem an, dass ebenso ELSI-Aspekte untersucht werden sollten. Die Autoren der Ist-Stand-Analyse stellen jedoch in Frage, ob wirklich relevante Aspekte in den Projekten identifiziert und bewertet werden konnten (Schley et al. 2021). Gesundheitsökonomische Aspekte wurden in deutschen Projekten ebenso selten untersucht, wie dies auch in der international Literatur aufgezeigt werden konnte (Krick et al. 2019; Schley et al. 2021).

Deutlich wird durch diesen Vergleich, dass es keine deutschsprachigen Projekte gibt, die die als besonders relevant identifizierten Bereiche Akzeptanz, Effektivität und Effizienz (Krick 2021) gleichermaßen auf hohem Evidenzniveau in Alltagssettings evaluiert haben oder evaluieren werden. Jedoch finden sich die in dieser Arbeit als relevant identifizierten Bereiche Akzeptanz und Effektivität in vielen deutschsprachigen Projekten wieder, allerdings auf niedrigem Evidenzniveau genau wie in der internationalen Literatur. Effizienzstudien finden sich sowohl in der nationalen (Schley et al. 2021) als auch in der internationalen Forschung gleichermaßen seltener wieder (Krick et al. 2019). Von einem deutlich erweiterten Wissensstand über das Potenzial von DNT in den nächsten Jahren ist im Rahmen der untersuchten Projekte daher nicht auszugehen.

5.2 Problematik des Reifegrads von digitalen Pflegetechnologien

Eine **zweite** wesentliche in dieser Arbeit beschriebene Problematik ist die Tatsache, dass viele digitale Pflegetechnologien sich noch in frühen Entwicklungsphasen befinden und, dass dadurch eine Bewertung und Abschätzung langfristiger Implikationen aus unterschiedlichen Perspektiven erschwert wird. Insbesondere ist hervorzuheben, dass durch die frühen Entwicklungsphase der DNT bisher noch nicht viele dauerhaft in der Pflegepraxis angekommen sind (Lutze et al. 2019; Weber 2021). Die Frühphasigkeit vieler digitaler Pflegetechnologien erschwert eine aussagekräftige Evaluation zu den langfristigen Implikationen und Wirkungen und macht die als Antwort auf die Forschungsfrage geforderte Evaluationen von DNT in den

Bereichen Akzeptanz, Effektivität und Effizienz auf einem hohen Evidenzniveau in realen Anwendungssettings (damit ist insbesondere gemeint: im Regelbetrieb) meist gar nicht möglich.

Neben den genannten Beschreibungen zum niedrigen Reifegrad von DNT in der Literatur existiert allerdings keine strukturierte Analyse zum genauen Reifegrad der vorhandenen Technologien in der Pflegebranche. Eine genauere Analyse des Reifegrads digitaler Pflegetechnologien könnte man beispielsweise mit den so genannten Technology Readiness Levels (TRL) durchführen (EU 2014). Diese beschreiben die Technologieentwicklung von der Grundlagenforschung (TRL 1) und der Entwicklung eines Grundkonzepts einer Technologie (TRL 2) bis zu einer funktionierenden, regelhaft eingesetzten, wettbewerbsfähigen Technologie (TRL 9) (EU 2014). Erste Ansätze zu einer strukturierteren Verzahnung von Technologieentwicklung und pflegewissenschaftlicher Evaluation wurden in Zusammenarbeit mit dem Autor dieses Rahmenpapiers bereits im Rahmen eines Frameworks zur Unterstützung der Technikentwicklung und Evaluation für innovative Technologien in der Pflege initiiert. Hierbei erfolgt die Analyse einer DNT anhand verschiedener Analysebereiche bereits ab der Ideenfindung bis zur Langzeitnutzung (Huter et al. 2021).

An dieser Stelle soll noch mal betont werden, dass für eine umfassende Bewertung einer digitalen Pflegetechnologie die Durchführung einer Evaluation für **nur einen der Evaluationsbereiche** (zum Beispiel die Akzeptanz oder Effektivität) oder nur **für nur eine einzelne Zielgruppe** (zum Beispiel zu Pflegende) nicht ausreicht. Es sollten immer multiperspektivische, Multi-Endpunkt-Evaluationen auf verschiedenen Ebenen stattfinden.

Welche Endpunkte und welche Perspektiven relevant sind, hängt jedoch vom Einzelfall ab. Insbesondere die technologische „Reife“ der digitalen Pflegetechnologie im Entwicklungsprozess spielt dabei eine entscheidende Rolle. So könnten in frühen Phasen der Technologie-Entwicklung andere Evaluationsbereiche relevant sein als zu einem späteren Zeitpunkt (Huter et al. 2021). Bei frühphasigen digitalen Pflegetechnologien, also solchen, die noch keine Massentauglichkeit erreicht haben, sondern sich noch stark weiterentwickeln sollen, macht beispielsweise eine ausgiebige Wirksamkeitsanalyse im regelhaften Einsatz in der Pflegepraxis nur wenig Sinn, weil der Aufwand in keinem angemessenen Verhältnis zur Aussagekraft der Ergebnisse steht und die Technologie in der aktuellen Form ohnehin nicht für den regelhaften Einsatz konzipiert ist. Wenn man von der Annahme ausgeht, dass die meisten DNT in Deutschland sich im Moment in diesem Zustand befinden, wäre dies zumindest ein Erklärungsansatz, warum es noch nicht mehr Forschung auf höherem Evidenzniveau gibt.

Die Auswahl weiterer zur Evaluation genutzter Herangehensweisen (zum Beispiel Evaluationsbereiche oder Outcome-Tools) hängt ebenso vom Reifegrad der Technologie ab. Die in dieser Arbeit beschriebene Unterscheidung zwischen Einstellungs-, Handlungs- und Nutzungsakzeptanz nach Kollmann (1998) könnte beispielsweise in unterschiedlichen Phasen der technologischen Reife relevant sein. Die Einstellungsakzeptanz lässt sich bereits frühphasig erheben, wohingegen Nutzungsakzeptanz erst zu einem späteren Zeitpunkt sinnvoll erhoben werden kann.

Die vorangegangene Beschreibung des Zusammenhangs zwischen technologischem Reifegrad einer DNT und der für die Evaluation relevanten Kriterien zeigt auf, dass weiteren Hilfestellungen für eine strukturierte Auswahl von Evaluationsbereichen und Outcome-Bereichen notwendig sind, die auf den speziellen Faktor des Reifegrads der DNT eingehen. Eine solche Hilfestellung könnte auf den Erkenntnissen dieser Arbeit fußen.

5.3 Problematik der Komplexität

Eine **dritte** wesentliche in dieser Arbeit beschriebene Problematik ist die Herausforderung, dass es sich bei digitalen Pflegetechnologien um komplexe Interventionen handelt, die nicht monokausal als auslösender Faktor zu Veränderungen führen, sondern im Rahmen von Veränderungen in einem soziotechnischen System betrachtet werden müssen.

Da bereits im einleitenden Kapitel 1.2.2 auf das Thema der Komplexität eingegangen wurde, wird hier nur in aller Kürze zusammengefasst, welche Herausforderungen dies mit sich bringt und welche Konsequenzen daraus gezogen werden könnten.

Die Intervention mit einer DNT besteht im soziotechnischen Kontext aus einzelnen Komponenten und diese Komponenten können unabhängig voneinander oder interdependent wirken, was die Erklärung der Kausalität und die Definition der entsprechenden „Wirkstoffe“ der Intervention erschwert. Die entscheidende Frage ist, welche Komponenten oder Kombination von Komponenten zu einem Ergebnis führen (Shiell et al. 2008). Da sich digitale Pflegetechnologien dabei in einem komplexen soziotechnischen Raum bewegen (Zerth et al. 2021), steht das Ausmaß und die Ausprägung der Veränderungen unter anderem in Verbindung mit den Individuen, die die Technologie anwenden, dem vorhandenen Setting inklusive der Strukturen und Prozesse, dem Einführungsprozess und den Charakteristiken der Technologie selbst (Damschroder et al. 2009).

Eine umfassende Evaluation und Bewertung digitaler Pflegetechnologien muss daher im Sinne der in Kapitel 1.2.2 beschriebenen Transferierbarkeit der Ergebnisse zusätzliche Erhebungen zu relevanten Faktoren des Settings, der Anwendungsgruppe und weiteren in Kapitel vier beschriebenen Evaluationsbereichen beinhalten.

Höhmann & Bartholomeyczik (2013) beschreiben, dass für die Erfassung komplexer Wirkungszusammenhänge in der Pflege die Kombination verschiedener Methodenansätze bei der Evaluation von Implementierungsprozessen notwendig ist, um ein umfassendes Bild für die Bewertung von Interventionen zu erlangen. In dieser Arbeit wird insbesondere die Notwendigkeit zur Durchführung von Studien auf hohem Evidenzniveau (zum Beispiel RCT oder Systematic Review) eingefordert. Jedoch ist eine Kombination von Studien auf hohem Evidenzniveau mit beispielsweise qualitativen Studien (mit niedrigerem Evidenzniveau – und anderem Erkenntnisinteresse) für eine vollumfängliche Evaluation und Bewertung von digitalen Pflegetechnologien ebenso notwendig.

So reicht beispielsweise eine isolierte Wirksamkeitsevaluation nicht aus, um DNT umfangreich bewerten zu können, da damit zwar die Frage danach, „ob" eine digitale Pflegetechnologie wirkt, beantwortet werden kann, jedoch nicht geklärt werden kann, „wieso". Die Transferierbarkeit (Zerth et al. 2021) der Ergebnisse auf ein anderes Setting und die Reproduzierbarkeit der Wirkung ist also durch die Erkenntnis, dass eine DNT in einem Setting wirkt, noch nicht gesichert. Abhilfe schaffen könnten Prozessevaluationen bei der Durchführung der Intervention mit einer DNT in verschiedenen (strukturgleichen) Settings, die immer parallel zur Wirksamkeitserhebung durchgeführt werden (Craig et al. 2008; Craig & Petticrew 2013; McGill et al. 2021), um ein besseres Verständnis für die sich verändernden Prozesse zu erlangen.

Eine unterscheidende Betrachtung von Prozess- und Ergebnisevaluation (Fässler 2014) oder eine tiefgehende Diskussion zwischen qualitativen und quantitativen Forschungsmethoden wurde in dieser Arbeit bisher nicht fokussiert. Es soll an dieser Stelle allerdings auf diese Unterschiedlichkeit bei den Vorgehensweisen zur Evaluation von digitalen Pflegetechnologien hingewiesen werden. Eine umfangreiche Analyse von 47 Projekten zur Erforschung von DNT im deutschsprachigen Raum von Schley et al. (2021) hat ergeben, dass häufig qualitative Erhebungsmethoden zur Evaluation von digitalen Pflegetechnologien genutzt wurden (n = 32 von 47) und ausschließlich quantitative Erhebungen sehr selten stattfanden (n = 6 von 47). Zwar wurden qualitative und quantitative Methoden häufig im Sinne eines Mixed-Methods-Ansatzes kombiniert (n = 39 von 47), jedoch waren die quantitativen Erhebungen meist auf einem niedrigen Evidenzniveau. In allen Projekten wurden beispielsweise insgesamt nur n = 5 RCTs durchgeführt. Dies spiegelt auch den internationalen Stand zur Evaluation von DNT wieder, der in Kapitel zwei aufgezeigt wurde (Krick et al. 2019). Es soll an dieser Stelle keine vertiefende Methodendiskussion zwischen quantitativen und qualitativen Methoden in der Pflege aufgeworfen werden. Vielmehr sei darauf hingewiesen, dass zur Evaluation von digitalen Pflegetechnologien sowohl quantitative als auch qualitative Studientypen geeignet und notwendig sind, diese jedoch jeweils nicht ausschließlich eingesetzt werden sollten.

5.4 Was macht eine digitale Pflegetechnologie zu einer Innovation?

In diesem Abschnitt wird diskutiert, ob es einen Unterschied zwischen digitalen Pflegetechnologien und den im Titel der Arbeit angesprochenen digitalen technologischen Innovationen in der Pflege (DTIP) gibt, und in welchem Zusammenhang dies mit der Beantwortung der Forschungsfrage steht.

Im jüngsten Diskurs in der Forschungsliteratur werden die Begriffe (digitale) „Pflegetechnologien" und „Pflegeinnovationen" zum Teil synonym verwendet (Hergesell 2019b; Schneider et al. 2020; Zerth et al. 2021). Auch das BMBF-geförderte Projekt „Pflegeinnovationszentrum" beschäftigt sich vorrangig mit der Entwicklung und Evaluation von digitalen Pflegetechnologien (Boll et al. 2018b). In dem Standardwerk zur Diffusion von Innovationen beschreibt zudem Rogers (2003), dass die Begriffe „Innovation" und „Technologie" oft synonym verwendet werden. Vieles deutet also darauf hin, dass digitale Pflegetechnologien und der Innovationsbegriff in der Pflege bereits zusammengedacht werden. Jedoch bringt diese undifferenzierte Darstellung gegebenenfalls Probleme mit sich.
Laut dem deutschsprachigen Kompendium zur Innovationsforschung von Blättel-Mink & Menez (2015) spricht man grundsätzlich von einer Innovation bei einer Neuheit oder einer Erneuerung (zunächst unabhängig vom Bereich, auf den sich die Innovation bezieht).
Neuheiten und Erneuerungen werden dabei meist unterschieden in die übergeordneten Innovations-Kategorien: (1) radikale Innovation (auch Basisinnovationen) und (2) inkrementelle Innovation (auch Verbesserungsinnovationen) (Knape et al. 2020).
Radikale Innovationen treten in Form von „Transformationen" durch einen „relativen Quantensprung" oder in Form der „Disruption" durch den „Prozess der kreativen Zerstörung" auf (Knape et al. 2020, S. 17-18). Inkrementelle Innovationen treten in Form der „Migration", also einer marginale Leistungsverbesserung, oder in Form der „Substitution", einer schrittweisen oder schleichenden Veränderung durch eine Alternative, auf (Knape et al. 2020, S. 17-18).

Der entscheidende Unterschied zwischen DNT und DTIP, der an dieser Stelle postuliert werden soll, ist, dass nicht grundsätzlich davon ausgegangen werden kann, dass eine DNT in eine dieser Innovationskategorien fällt und damit eine DTIP ist. Die Begriffe DNT und DTIP sind ansonsten deckungsgleich. Sie unterscheiden sich lediglich beim Aspekt der Innovation. Wenn man eine ernsthafte Untersuchung von DNT daraufhin betreiben möchte, ob es sich dabei um eine DTIP handelt, muss im Einzelfall unterschieden werden, ob es sich bei einer DNT um eine radikale oder eine inkrementelle Innovation handelt.

Da eine radikale Innovation (Basisinnovation) dadurch gekennzeichnet ist, dass etwas zum ersten Mal in Erscheinung tritt, was vorher in dieser Form nicht existiert hat (Blättel-Mink &

Menez 2015), ist die radikale Innovation durch ihre Existenz eine Innovation. Eine radikale Innovation entspricht allerdings so grundsätzlicher Natur wie zum Beispiel der Erfindung des Autos, der Kernenergie oder des Smartphones, dass davon auszugehen ist, dass die meisten DNT nicht per se in diese Kategorie fallen, sondern eher abgeleitet bzw. übertragen werden aus anderen Bereichen. Jedoch ist wichtig zu beachten, dass es bei dieser Innovationsart eine Beschränkung der Reichweite gibt. Eine radikale Innovation muss innerhalb eines betrachteten Systems als neu gelten. Die radikale Innovation ist also nicht nur dann eine Innovation, wenn sie zum ersten Mal in Erscheinung tritt, sondern auch dann, wenn sie im jeweiligen System (zum Beispiel Bildungssystem oder Pflegesystem) zum ersten Mal in Erscheinung tritt, auch wenn sie vorher in einem anderen System bereits genutzt wurde (Blättel-Mink & Menez 2015). Eine DNT kann daher eine DTIP im Sinne einer radikalen Innovation sein, wenn eine bestimmte, in anderen Bereichen genutzte Technologie, zum ersten Mal im Pflegesystem eingesetzt wird oder die Technologie eine absolut erstmalig auftretende Neuerscheinung ist.

Etwas schwieriger gestaltet sich die Einordnung einer DNT als DTIP bei der inkrementellen Innovation. Die inkrementelle Innovation (Verbesserungsinnovation) stellt eine Verbesserung einer bereits vorhandenen Entität dar (zum Beispiel einer anderen DNT) (Blättel-Mink & Menez 2015). Insbesondere die Verbesserungsinnovation ist daher abhängig davon, dass ihr in Form einer Bewertung ein „Bessersein" zugesprochen wird. Die Bewertung dieses Besserseins kann unter anderem durch einen formalen Evaluationsprozess geschehen, bei dem eine bereits bestehende Praktik mit einer neuen Praktik unter Einsatz einer DNT verglichen wird. Ein zu betrachtender Evaluationsbereich für inkrementelle Innovationen kann der spezifische Nutzen für die adressierte Zielgruppe sein (Czypionka et al. 2021). Zur Bestimmung einer Verbesserung des Nutzens können die in dieser Arbeit herausgearbeiteten Kategorien und Vorgehensweisen zur Wirksamkeitsevaluation von DNT genutzt werden (Kapitel drei). Eine DNT, die einen verbesserten Nutzen im Verhältnis zu einer bestehenden Praktik aufweist, kann dann als DTIP eingeordnet werden.

Eine zweite Möglichkeit zur Einordnung einer DNT als DTIP im Sinne einer inkrementellen Innovation könnte der natürliche Prozess der Innovationsentscheidung von Individuen sein. Nach Rogers (2003) verläuft der Prozess, bei dem sich Individuen für oder gegen eine Innovation entscheiden (Innovationsentscheidungsprozess) in fünf zeitlich aufeinander folgenden Phasen ab:

(1) Dem Wissen über eine Innovation, (2) der Meinungsbildung über die Innovation (dabei bildet sich auch eine grundsätzliche Haltung des Individuums gegenüber der Innovation, die eine, laut Rogers, relativ dauerhafte Konsistenz aufweist), (3) der Entscheidungsphase, (4)

der Anwendungsphase und (5) der Bestätigungsphase (hier bestätigt sich die in Phase 3 getroffene Entscheidung zur Nutzung oder sie wird wieder verworfen).
Eine der Kernkomponenten, die laut Rogers (2003) eine entscheidende Rolle für die Innovationsentscheidung bildet, ist der relative Vorteil der Lösung (gegenüber einer vorherigen). Individuen führen also jeweils einzeln einen eigenen (unstrukturierten und individuellen) Innovationsevaluationsprozess durch. Setzt sich eine DNT in der Pflegepraxis durch und wird regelmäßig genutzt, so könnte man davon ausgehen, dass es sich dabei um eine DTIP handelt, da der Innovationsentscheidungsprozess bereits von vielen einzelnen Individuen durchgeführt worden ist.

Festgehalten werden kann an dieser Stelle, dass DNT, wenn es sich dabei um radikale Innovationen handelt, per Existenz DTIP sind. Jedoch handelt es sich bei den meisten DNT vermutlich eher um inkrementelle Innovationen, die anhand eines Evaluations- und Bewertungsprozesses (formal oder individuell) ihr Bessersein und ihre Einordnung als DTIP beweisen müssen. Die Unterscheidung in die Kategorien DNT und DTIP (und dabei insbesondere die Unterscheidung in radikale und inkrementelle Innovationen) ist daher eine weitere Möglichkeit, Technologien in der Pflege einzuordnen und zu bewerten.

6 Schlussfolgerungen und Ausblick

Diese Arbeit hatte das Ziel, eine neue Forschungsperspektive zu eröffnen, indem der Referenzrahmen, in dem sich digitale Pflegetechnologien und deren Evaluation befinden, genauer kartografiert wird. Die Einzelarbeiten in dieser Arbeit leisten einen Beitrag dazu, ein besseres Verständnis für das Thema Evaluation von digitalen Pflegetechnologien zu erlangen, und geben Aufschlüsse darüber, welche Kategorien und Kriterien zur Bewertung von DNT geeignet sind. Die Gesamtarbeit beschreibt als Referenzrahmen übergeordnete Evaluationsbereiche und Methoden, sowie Perspektiven für die Evaluation von DNT und arbeitet unterschiedliche Technologiebereiche digitaler Pflegetechnologien auf. Spezifische Outcome-Bereiche und Outcome-Tools zur Evaluation von DNT werden in dieser Arbeit für das Thema Wirksamkeit benannt, da dieser Bereich für die Problemlösungskapazität der digitalen Pflegetechnologien als am wichtigsten angesehen wird. Die Arbeit widmet sich nicht der Aufarbeitung einer Übersicht zu Instrumenten für andere Evaluationsbereiche, wie beispielsweise zur Akzeptanz oder Effizienz – hier sind darüberhinausgehende Untersuchungen notwendig, für die diese Arbeit als Grundlagenforschung eine gute Basis bietet.

Aufkommende zukünftige Forschungsfragen im Bereich DNT können durch diese Arbeit in den neu geschaffenen Referenzrahmen eingeordnet werden und der Kontext für die Erforschung von digitalen Pflegetechnologien wird besser verständlich. Der eröffnete Referenzrahmen hilft anderen Forscher:innen dabei, kleinteiligere Forschungsfragen unter einer neuen Perspektive zu bearbeiten.

Im Rahmen dieser Arbeit ist insbesondere klargeworden, dass es bei der Aufarbeitung zur Frage nach der idealen Evaluation und Bewertung von digitalen Pflegetechnologien ein begrenztes Standardisierungspotenzial gibt. Der geschaffene Referenzrahmen und die enthaltenen Evaluationsbereiche, Methoden und Vorgehensweisen müssen perspektivenspezifisch reflektiert und genutzt werden. Die Einordnung und Bewertung der Ergebnisse einer solchen Evaluation müssen ebenso perspektivenspezifisch erfolgen und sollten daher, um ein Gesamtbild zu erhalten, multiperspektivisch anhand verschiedener Endpunkte und Kriterien auf verschiedenen Ebenen stattfinden.

Forschende sollten zukünftig, wie in Kapitel zwei empfohlen, qualitativ hochwertige Evaluationen bestehender digitaler Pflegetechnologien in den Bereichen AEE auf einem hohen Evidenzniveau in realen Anwendungssettings durchführen. Die zukünftige Forschung sollte sich zudem einer genaueren Untersuchung der Forschungsmethoden zur Analyse von AEE widmen. Außerdem sollten groß angelegte, langfristige Evaluationen von digitalen Pflegetechnologien in der Versorgungspraxis ermöglicht werden, um die bestehenden Forschungslücken bei bestimmten DNT, spezifischen Zielsettings, Zielgruppen und Unterstützungsbereichen zu schließen, die in dieser Arbeit ermittelt wurden.

Das in Kapitel drei geschaffene DNT-Outcome-Framework kann von Forschenden als systematische Grundlage für zukünftige Wirksamkeitsevaluationen von DNT genutzt werden. Es kann insbesondere zur Strukturierung von Wirksamkeitsevaluationen herangezogen werden und dabei helfen zu erkennen, ob wesentliche Outcome-Bereiche bei den bisherigen Überlegungen übersehen wurden. Die enthaltenen Outcome-Bereiche können dabei mithilfe der identifizierten Outcome-Tools untersucht werden. Die Gewichtung der Bedeutung der verschiedenen Outcome-Bereiche – insbesondere derjenigen, die bisher weniger erforscht wurden – sollte Gegenstand weiterer Untersuchungen sein.

Zudem kann das Mapping der Informationen zu Evaluationsframeworks aus Kapitel vier als Überblick über Gemeinsamkeiten und Unterschiede vorhandener Frameworks genutzt werden, sowie dazu, mögliche Bewertungsbereiche, Zwecke, Perspektiven, Erfolgsdefinitionen, Stärken und Schwächen anhand der entwickelten Qualitätskriterien für Evaluationsframeworks besser einordnen zu können. Dies ermöglicht eine systematische und strukturierte Herangehensweise an wissenschaftliche Evaluationsvorhaben für DNT.

Insgesamt gibt diese Arbeit anhand der aufgearbeiteten Informationen einen umfangreichen Überblick darüber, wie eine umfassende Evaluation und Bewertung von digitalen Pflegetechnologien ermöglicht werden kann und anhand welcher Kategorien und Kriterien dies geschehen müsste.

Literatur

Aldehaim, A.Y., Alotaibi, F.F., Uphold, C.R. & Dang, S. (2016). The Impact of Technology-Based Interventions on Informal Caregivers of Stroke Survivors: A Systematic Review. Telemed J E Health, 22(3), 223-231.

Archibald, M.M. & Barnard, A. (2018). Futurism in nursing: Technology, robotics and the fundamentals of care. Journal of Clinical Nursing, 27(11-12), 2473-2480.

Arditi, C., Rège-Walther, M., Wyatt, J.C., Durieux, P. & Burnand, B. (2012). Computer-generated reminders delivered on paper to healthcare professionals; effects on professional practice and health care outcomes. Cochrane Database of Systematic Reviews,(12), N.PAG-N.PAG.

Arksey, H. & O'Malley, L. (2005). Scoping studies: towards a methodological framework. International Journal of Social Research Methodology, 8(1), 19-32.

Ayoubian, A., Nasiripour, A.A., Tabibi, S.J. & Bahadori, M. (2020). Evaluation of Facilitators and Barriers to Implementing Evidence-Based Practice in the Health Services: A Systematic Review. Galen Med J, 9, e1645.

Babel, W. (2021). Industrie 4.0, China 2025, IoT : der Hype um die Welt der Automatisierung. Wiesbaden: Springer Vieweg.

Baisch, S., Kolling, T., Rühl, S., Klein, B., Pantel, J., Oswald, F. & Knopf, M. (2018). Emotionale Roboter im Pflegekontext. Zeitschrift für Gerontologie und Geriatrie, 51(1), 16-24.

Barnard, A. (1997). A critical review of the belief that technology is a neutral object and nurses are its master. Journal of Advanced Nursing, 26(1), 126-131.

Barnard, A. & Sandelowski, M. (2001). Technology and humane nursing care: (ir)reconcilable or invented difference. Journal of Advanced Nursing, 34(3), 367-375.

Behrens, J., Fink, A., Kaap-Fröhlich, S., Krautz, B., Möhler, R., Reick, S., Langer, G., Bartoszek, G., Eberhardt, D., Köpke, S. & Meyer, G. (2016). Evidence-based nursing and caring : Methoden und Ethik der Pflegepraxis und Versorgungsforschung - vertrauensbildende Entzauberung der "Wissenschaft". Bern: Hogrefe.

Beikirch, E. (2015). Das Strukturmodell – Chancen einer schlanken Pflegedokumentation. Poster Präsentation: Konferenz zur Pflegedokumentation, Haus auf dem Wimberg.

Beiter, R., Doria, J., Gottschaller, S., Kaeber, F., Kegel, J., Leipold, C. & Zöllner, O. (2020). Fühlt sich das noch gut an? Ein quantitativ-qualitatives Forschungsprojekt zur Akzeptanz der Künstlichen Intelligenz im Alltag. Stuttgart: Hochschule der Medien Stuttgart.

Bemelmans, R., Gelderblom, G.J., Jonker, P. & de Witte, L. (2012). Socially Assistive Robots in Elderly Care: A Systematic Review into Effects and Effectiveness. Journal of the American Medical Directors Association, 13(2), 114-120.e111.

Blättel-Mink, B. & Menez, R. (2015). Kompendium der Innovationsforschung. Wiesbaden: Springer VS.

Blum, D., Raj, S.X., Oberholzer, R., Riphagen, I.I., Strasser, F. & Kaasa, S. (2015). Computer-Based Clinical Decision Support Systems and Patient-Reported Outcomes: A Systematic Review. Patient, 8(5), 397-409.

BMBF. Technik zum Mensch bringen - Forschungsprogramm zur Mensch-Technik-Interaktion. 2015, Issue Art. Nr.: Doi.

Bundesministerium für Bildung und Forschung (Hrsg.) (2020). Miteinander durch Innovation. Forschungsprogramm, Interaktive Technologien für Gesundheit und Lebensqualität. Bonn:

Boll, S., Hein, A., Heuten, W. & Wolf-Ostermann, K. (2018a). Grußwort der Organisatoren. In: S. Boll, A. Hein, W. Heuten & K. Wolf-Ostermann (Hrsg.), Zukunft der Pflege. Tagungsband der 1. Clusterkonferenz 2018 "Innovative Technologien für die Pflege" (S.). Oldenburg: OFFIS - Institut für Informatik.

Boll, S., Hein, A., Kadmon, M., Wolf-Ostermann, K., Heuten, W., Lindemann, G. & Wiedermann, F. (2018b). Pflegeinnovationszentrum: Technologien für eine bedarfsgerechte Zukunft der Pflege. In: S. Boll, A. Hein, W. Heuten & K. Wolf-Ostermann (Hrsg.), Zukunft der Pflege. Tagungsband der 1. Clusterkonferenz 2018 "Innovative Technologien für die Pflege" (S. iii-iv). Oldenburg: OFFIS - Institut für Informatik.

Bowes, A., Dawson, A. & Greasley-Adams (2013). Literature review: the cost effectiveness of assistive technology in supporting people with dementia. Report to the Demtia Services Development Trust: University of Stirling.

Brandt, Å., Alwin, J., Anttila, H., Samuelsson, K. & Salminen, A.-L. (2012). Quality of evidence of assistive technology interventions for people with disability: An overview of systematic reviews. Technology & Disability, 24(1), 9-48.

Bright, T.J., Wong, A., Dhurjati, R., Bristow, E., Bastian, L., Coeytaux, R.R., Samsa, G., Hasselblad, V., Williams, J.W., Musty, M.D., Wing, L., Kendrick, A.S., Sanders, G.D. & Lobach, D. (2012). Effect of clinical decision-support systems: A systematic review. Annals of Internal Medicine, 157(1), 29-43.

Craig, P., Dieppe, P., Macintyre, S., Mitchie, S., Nazareth, I. & Petticrew, M. (2008). Developing and evaluating complex interventions: The new Medical Research Council guidance. BMJ Clinical Research, 337(7676).

Craig, P. & Petticrew, M. (2013). Developing and evaluating complex interventions: reflections on the 2008 MRC guidance. International journal of nursing studies, 50(5), 585-587.

Currie, L.M. (2005). Evaluation frameworks for nursing informatics. Int J Med Inform, 74(11-12), 908-916.

Czypionka, T., Stacherl, B. & Hobodites, F. (2021). Wert von Innovation im Gesundheitswesen. Wien: Institut für Höhere Studien – Institute for Advanced Studies (IHS).

Damschroder, L.J., Aron, D.C., Keith, R.E., Kirsh, S.R., Alexander, J.A. & Lowery, J.C. (2009). Fostering implementation of health services research findings into practice: a consolidated framework for advancing implementation science. Implementation Science, 4(1), 50.

Ekeland, A.G., Bowes, A. & Flottorp, S. (2010). Effectiveness of telemedicine: a systematic review of reviews. Int J Med Inform, 79(11), 736-771.

Elsbernd, A., Lehmeyer, S., Schilling, U., Warendorf, K. & Wu, J. (2014). „Bedarfsgerechte technikgestützte Pflege in Baden-Württemberg - Technologien und Dienstleistungen für ein selbstbestimmtes Leben im Alter“. Esslingen.

EU. HORIZON 2020 – WORK PROGRAMME 2014-2015. General Annexes. G. Technology readiness levels (TRL). 2014, Issue Art. Nr.: Doi.

Fässler, S.O., M. (2014). Wirkungsevaluation von Interventionen: Leitfaden für den Bereich gesundes Körpergewicht. . Bern und Lausanne: Gesundheitsförderung Schweiz.

Fehling, P. (2019). Entwicklungsstand der gegenwärtigen und künftigen technischen Assistenzsysteme. Pflege&Gesellschaft, 24((3)), 197–205.

Feldman, M.S. & Pentland, B.T. (2003). Reconceptualizing Organizational Routines as a Source of Flexibility and Change. Administrative Science Quarterly, 48(1), 94-118.

Friesacher, H. (2010). Pflege und Technik – eine kritische Analyse. Pflege & Gesellschaft, 15(4), 293-313.

Fynn, J.F., Hardeman, W., Milton, K. & Jones, A.P. (2020). A scoping review of evaluation frameworks and their applicability to real-world physical activity and dietary change programme evaluation. BMC Public Health, 20(1), 1000-1000.

Garcia-Smith, D. & Effken, J.A. (2013). Development and initial evaluation of the Clinical Information Systems Success Model (CISSM). Int J Med Inform, 82(6), 539-552.

Gehrke, W., Winzker, M., Urbanski, K. & Woitowitz, R. (2016). Digitaltechnik. Berlin: Springer Vieweg.

Grant, M.J. & Booth, A. (2009). A typology of reviews: an analysis of 14 review types and associated methodologies. Health Info Libr J, 26(2), 91-108.

Greenhalgh, T. (2008). Role of routines in collaborative work in healthcare organisations. BMJ, 337, a2448.

Greenhalgh, T., Robert, G., Macfarlane, F., Bate, P. & Kyriakidou, O. (2004). Diffusion of innovations in service organizations: systematic review and recommendations. Milbank Q, 82(4), 581-629.

Greenhalgh, T., Wherton, J., Papoutsi, C., Lynch, J., Hughes, G., A'Court, C., Hinder, S., Fahy, N., Procter, R. & Shaw, S. (2017). Beyond Adoption: A New Framework for Theorizing and Evaluating

Nonadoption, Abandonment, and Challenges to the Scale-Up, Spread, and Sustainability of Health and Care Technologies. J Med Internet Res, 19(11), e367.

Helmig, M., Röhrig, A. & Wemken-Stephan, P. (2021). Die Zusatzqualifizierung Pflege 4.0. Konzept – Erfahrungen – Perspektive. Berlin: k.o.s GmbH.

Hergesell, J. (2019a). Technische Assistenzen in der Altenpflege. Weinheim,Basel: Beltz Juventa.

Hergesell, J. (2019b). Von der Armen- und Siechenfürsorge zur digitalisierten Altenpflege. Eine figurationssoziologische Perspektive auf Pflegeinnovationen. In: S. Ernst & G. Becke (Hrsg.), Transformationen der Arbeitsgesellschaft: Prozess- und figurationstheoretische Beiträge (S. 235-258). Wiesbaden: Springer Fachmedien Wiesbaden.

Höhmann, U. & Bartholomeyczik, S. (2013). Komplexe Wirkungszusammenhänge in der Pflege erforschen: Konzepte statt Rezepte. 18(4).

Holden, R.J., Asan, O., Wozniak, E.M., Flynn, K.E. & Scanlon, M.C. (2016). Nurses' perceptions, acceptance, and use of a novel in-room pediatric ICU technology: testing an expanded technology acceptance model. BMC Medical Informatics and Decision Making, 16(1), 1-10.

Honekamp, I., Sauer, L., Wache, T. & Honekamp, W. (2019). Akzeptanz von Pflegerobotern im Krankenhaus. TATuP Zeitschrift für Technikfolgenabschätzung in Theorie und Praxis, 28, 58-63.

Hülsken-Giesler, M. (2007). Pflege und Technik – Annäherung an ein spannungsreiches Verhältnis zum gegenwärtigen Stand der internationalen Diskussion. 1. Teil. Pflege, 20(2), 103-112.

Hülsken-Giesler, M., Dütthorn, N. & Kreutzer, S. (2022). Neue Technologien für die Pflege: Eine Einleitung in die Diskussion. In: M. Hülsken-Giesler, S. Kreutzer & N. Dütthorn (Hrsg.), Neue Technologien für die Pflege. Grundlegende Reflexionen und pragmatische Befunde (S.). Göttingen: V&R unipress, Universitätsverlag Osnabrück.

Huter, K., Krick, T., Domhoff, D., Seibert, K., Wolf-Ostermann, K. & Rothgang, H. (2020). Effectiveness of Digital Technologies to Support Nursing Care: Results of a Scoping Review. J Multidiscip Healthc., 13, 1905-1926.

Huter, K., Krick, T., Domhoff, D., Seibert, K., Wolf-Ostermann, K. & Rothgang, H. (2021). Entwicklung eines Frameworks zur Unterstützung der Technikentwicklung und Evaluation für innovative Technologien in der Pflege. In: J. Zerth, C. Forster, S. Müller, C. Bauer, P. Bradl, T. Loose, K. Robert & M. Klemm (Hrsg.), Konferenzband. Kann Digital Pflege? 3. Clusterkonferenz „Zukunft der Pflege“, Nürnberg (S. 67 - 71). Nürnberg: Pflege Professionell.

Jacobs, K., Kuhlmey, A., Suhr, R., Eggert, S., Nordheim, J. & Blüher, S. (2019). Akzeptanz von Technikeinsatz in der Pflege. Zwischenergebnisse einer Befragung unter professionell Pflegenden. In: K. Jacobs, A. Kuhlmey, S. GreßJürgen, J. Kauber & A. Schwinger (Hrsg.), Pflege-Report 2019 (S. 211-218). Berlin: Springer.

Kidhom, K., Bowes, A., Dyrehauge, S., Ekeland, A.G., Flottorp, S.A., Jensen, L.K., Pedersen, C.D. & Rasmussen, J. (2010). The MAST Manual. MAST - Model for ASsessment of Telemedicine: MethoTelemed team.

Klawunn, R., Walzer, S., Zerth, J., Anika, H.-S., Schepputat, A., Forster, C., Müller, S., Dierks, M.-L. & Krick, T. (2021). Auswahl und Einführung von Pflegetechnologien in Einrichtungen der Pflegepraxis - Erfahrungen aus den vier Pflegepraxiszentren und dem Pflegeinnovationszentrum des Clusters „Zukunft der Pflege. In: U. Bettig, M. Frommelt, H. Maucher, R. Schmidt & G. Thiele (Hrsg.), Digitalisierung in der Pflege. Auswahl und Einsatz innovativer Pflegetechnologien in der geriatrischen Praxis (S. S. 37 - 70). Heidelberg: Medhochzwei.

Knape, T., Hufnagl, P. & Rasche, C. (2020). Innovationsmanagement unter VUKA-Bedingungen: Gesundheit im Fokus von Digitalisierung, Datenanalytik, Diskontinuität und Disruption. In: M.A. Pfannstiel, K. Kassel & C. Rasche (Hrsg.), Innovationen und Innovationsmanagement im Gesundheitswesen : Technologien, Produkte und Dienstleistungen voranbringen (S. 1-24). Wiesbaden: Springer Fachmedien Wiesbaden.

Kollmann, T. (1998). Die Bedeutung der Akzeptanz für die Einführung multimedialer Nutzungsgüter und -systeme. In: T. Kollmann (Hrsg.), Akzeptanz innovativer Nutzungsgüter und -systeme: Konsequenzen für die Einführung von Telekommunikations- und Multimediasystemen (S. 1-36). Wiesbaden: Gabler Verlag.

Kothgassner, O.D., Felnhofer, A., Hauk, N., Kastenhofer, E., Gomm, J. & Kryspin-Exner, I. (2013). Technology Usage Inventory (TUI): Manual.

Krick, T. (2021). Evaluation frameworks for digital nursing technologies: analysis, assessment, and guidance. An overview of the literature. BMC Nursing, 20(1), 146.

Krick, T., Huter, K., Domhoff, D., Schmidt, A., Rothgang, H. & Wolf-Ostermann, K. (2019). Digital technology and nursing care: a scoping review on acceptance, effectiveness and efficiency studies of informal and formal care technologies. BMC Health Services Research, 19(400).

Krick, T., Huter, K., Seibert, K., Domhoff, D. & Wolf-Ostermann, K. (2020). Measuring the effectiveness of digital nursing technologies: development of a comprehensive digital nursing technology outcome framework based on a scoping review. BMC Health Services Research, 20(1), 243.

Kromrey, H. (2012). Evaluation - ein vielschichtiges Konzept: Begriff und Methodik von Evaluierung und Evaluationsforschung ; Empfehlungen für die Praxis.

Kruse, C.S., Mileski, M., Alaytsev, V., Carol, E. & Williams, A. (2015). Adoption factors associated with electronic health record among long-term care facilities: a systematic review. BMJ Open, 5(1), e006615.

Kuhlmey, A., Blüher, S., Nordheim, J. & Zöllick, J. (2019). Technik in der Pflege – Einstellungen von professionell Pflegenden zu Chancen und Risiken neuer Technologien und technischer Assistenzsysteme. Abschlussbericht für das Zentrum für Qualität in der Pflege (ZQP).

Levac, D., Colquhoun, H. & O'Brien, K.K. (2010). Scoping studies: advancing the methodology. Implementation Science, 5(1), 69.

Lindwedel, U., Röll, N., Lautenschläger, S., Gradel, C., König, P. & Kunze, C. (2016). Effekte und Nutzen altersgerechter Assistenzsysteme (ENAS). Leitfaden für die Planung und Durchführung von Studien zur Evaluation neuer technischer Assistenzsysteme in Forschungs- und Entwicklungsprojekten. Furtwangen.

Lutze, M., Glock, G., Stubbe, J. & Paulicke, D. (2019). Digitalisierung und Pflegebedürftigkeit – Nutzen und Potenziale von Assistenztechnologien. Berlin: GKV-Spitzenverband.

Lutze, M., Trauzettel, F., Busch-Heizmann, A. & Bovenschulte, M. (2021). Potenziale einer Pflege 4.0. Wie technologische Innovationen in der Langzeitpflege Entlastung schaffen und die Arbeitszufriedenheit verändern können. Gütersloh: Bertelsmann Stiftung.

Maier, I., Bechtel, P., Borchers, U., Brenninger, R., Calmer, B., Flemming, D., Hübner, U., Meißner, T., Sellemann, B. & Tackenberg, P. (2019). Positionspapier: Digitalisierung in der Pflege. Berlin: Deutscher Pflegerat e.V.

McGill, E., Er, V., Penney, T., Egan, M., White, M., Meier, P., Whitehead, M., Lock, K., de Cuevas, R.A. & Smith, R. (2021). Evaluation of public health interventions from a complex systems perspective: a research methods review. Social Science & Medicine, 113697.

Mehta, D. & Senn-Kalb, L. (2021). In-depth Report: Industrie 4.0 2021. Statista Digital Market Outlook.

Merda, M., Schmidt, K. & Kähler, B. (2017). Pflege 4.0 – Einsatz moderner Technologien aus der Sicht professionell Pflegender. Forschungsbericht. Hamburg: Berufsgenossenschaft für Gesundheitsdienst und Wohlfahrtspflege (BGW).

Obser, G. & Schroll-Würdig, J. (Hrsg.) (2020). Innovationen für die Pflegepraxis – VIARRO Projektbericht. Nürnberg: NürnbergStift.

Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., McGuinness, L.A., Stewart, L.A., Thomas, J., Tricco, A.C., Welch, V.A., Whiting, P. & Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ, 372, n71.

Poulin, P., Austen, L., Scott, C.M., Waddell, C.D., Dixon, E., Poulin, M. & Lafreniere, R. (2013). Multi-criteria development and incorporation into decision tools for health technology adoption. J Health Organ Manag, 27(2), 246-265.

Rammert, W. (2016). Technik - Handeln - Wissen. Zu einer pragmatischen Technik- und Sozialtheorie. Wiesbaden: Springer VS.

Remmers, H. (2015). Natürlichkeit und Künstlichkeit: Zur Analyse und Bewertung von Technik in der Pflege des Menschen. TATuP - Zeitschrift für Technikfolgenabschätzung in Theorie und Praxis, 24(2), 11-20.

Roes, M., deJong, A. & Wulff, I. (2013). Implementierungs- und Disseminationsforschung – ein notwendiger Diskurs (Implementation and Dissemination Research - a necessary discourse). Pflege und Gesellschaft, 18.

Rogers, E.M. (2003). Diffusion of Innovations. New York: The Free Press.

Rosenbrock, R. & Gerlinger, T. (2014). Gesundheitspolitik : Eine systematische Einführung. [s.l.]: Verlag Hans Huber.

Rösler, U., Merda, M. & Melzer, M. (2018). Digitalisierung in der Pflege. Wie intelligente Technologien die Arbeit professionell Pflegender verändern. Berlin: Bundesanstalt für Arbeitsschutz und Arbeitsmedizin.

Rouleau, G., Gagnon, M.P., Côté, J., Payne-Gagnon, J., Hudson, E. & Dubois, C.A. (2017). Impact of information and communication technologies on nursing care: Results of an overview of systematic reviews. Journal of Medical Internet Research, 19(4).

Sahota, O., Drummond, A., Kendrick, D., Grainge, M.J., Vass, C., Sach, T., Gladman, J. & Avis, M. (2014). REFINE (REducing Falls in In-patieNt Elderly) using bed and bedside chair pressure sensors linked to radio-pagers in acute hospital care: a randomised controlled trial. Age Ageing, 43(2), 247-253.

Samnani, S.S., Vaska, M., Ahmed, S. & Turin, T.C. (2017). Review Typology: The Basic Types of Reviews for Synthesizing Evidence for the Purpose of Knowledge Translation. J Coll Physicians Surg Pak, 27(10), 635-641.

Sandelowski, M. (1997). (Ir) Reconcilable Differences? The Debate Concerning Nursing and Technology. Image: the Journal of Nursing Scholarship, 29(2), 169-174.

Schley, A., Hirt, J., Horstmannshoff, C., Schüssler, S., Lutze, M., Jagoda, F., Häussl, A., Mueller, M. & Balzer, K. (2021). Evaluation von digitalen Assistenzsystemen für die Pflege in öffentlich geförderten Forschungsprojekten in Deutschland, Österreich und der deutschsprachigen Schweiz (EvaDigiAssSys): ein Survey. 26, 131-155.

Schneider, M., Besser, J. & Geithner, S. (2020). Technologische Innovationen in der Pflege: von der routinebasierten zur anlassinduzierten Pflege. In: M.A. Pfannstiel, K. Kassel & C. Rasche (Hrsg.), Innovationen und Innovationsmanagement im Gesundheitswesen: Technologien, Produkte und Dienstleistungen voranbringen (S. 615-632). Wiesbaden: Springer Fachmedien Wiesbaden.

Sebastião, M., Hechtel, N. & Krückeberg, J. (2020). „In den Müll?!" – Ursachenforschung zur Nicht-Nutzung technischer Innovationen in der stationären Pflege. Gesundheitswesen,(EFirst).

Seeling, C. & Blotenberg, D. (2017). Möglichkeiten und Grenzen der Mensch-Technik-Interaktion - Neue zentrale Erkenntnisse zur Techniknutzung und -affinität älterer Menschen im ländlichen Raum. Pflege & Gesellschaft, 22(3), 248-271.

Seibert, K., Domhoff, D., Huter, K., Krick, T., Rothgang, H. & Wolf-Ostermann, K. (2020). Application of digital technologies in nursing practice: Results of a mixed methods study on nurses' experiences, needs and perspectives. Z Evid Fortbild Qual Gesundhwes.

Shiell, A., Hawe, P. & Gold, L. (2008). Complex interventions or complex systems? Implications for health economic evaluation. BMJ, 336(7656), 1281-1283.

Stockmann, R. (2002). Was ist eine gute Evaluation. . Saarbrücken: Centrum für Evaluation.

Stylianides, A., Mantas, J., Roupa, Z. & Yamasaki, E.N. (2018). Development of an Evaluation Framework for Health Information Systems (DIPSA). Acta Inform Med, 26(4), 230-234.

Theobald, H. (2022). Zur Situation der Pflegekräfte in Deutschland – Herausforderungen und Lösungsansätze. In: F. Waldenberger, G. Naegele, H. Kudo & T. Matsuda (Hrsg.), Alterung und Pflege als kommunale Aufgabe : Deutsche und japanische Ansätze und Erfahrungen (S. 163-178). Wiesbaden: Springer Fachmedien Wiesbaden.

van Achterberg, T., Schoonhoven, L. & Grol, R. (2008). Nursing Implementation Science: How Evidence-Based Nursing Requires Evidence-Based Implementation. Journal of Nursing Scholarship, 40(4), 302-310.

Weber, K. (2021). Technik in der Pflege: Bestandsaufnahme, Entwicklungsmöglichkeiten und normative Bewertung. (Hrsg.), Neue Technologien für die Pflege (S. 153-174). V&R unipress.

Windeler, J., Antes, G., Behrens, J., Donner-Banzhoff, N. & Lelgemann, M. (2008). Randomised Controlled Trials (RCTs). Z Evid Fortbild Qual Gesundhwes, 102(5), 321-325.

Zerth, J., Jaensch, P. & Müller, S. (2021). Technik, Pflegeinnovation und Implementierungbedingungen. In: K. Jacobs, K. A., S. Greß, J. Klauber & A. Schwinger (Hrsg.), Pflege-Report 2021 (S. 157-172). Berlin: Springer.

Zettl, A. & Trübswetter, A. (2018). Digitale Transformation in der Pflege – Neue Ansätze für die nutzerzentrierte Implementierung. In: S. Hess & H. Fischer (Hrsg.), Mensch und Computer 2018 – Usability Professionals (S. 323-336). Bonn: Gesellschaft für Informatik e.V. Und German UPA e.V.

Zöllick, J.C., Kuhlmey, A., Suhr, R., Eggert, S., Nordheim, J. & Blüher, S. (2020). Akzeptanz von Technikeinsatz in der Pflege. In: K. Jacobs, A. Kuhlmey, S. Greß, J. Klauber & A. Schwinger (Hrsg.), Pflege-Report 2019: Mehr Personal in der Langzeitpflege - aber woher? (S. 211-218). Berlin, Heidelberg: Springer Berlin Heidelberg.

Anhang A: Erklärung zum Eigenanteil an gemeinsam verfassten Artikeln

Artikel 1: Digital technology and nursing care: a scoping review on acceptance, effectiveness and efficiency studies of informal and formal care technologies (Krick et al. 2019)	
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Artikel 2: Measuring the effectiveness of digital nursing technologies: development of a comprehensive digital nursing technology outcome framework based on a scoping review (Krick et al. 2020)	
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Anhang B: Versicherung zur Erstellung der Arbeit

Hiermit versichere ich, dass ich diese Arbeit ohne unerlaubte fremde Hilfe verfasst und keine anderen als die von mir angegebenen Quellen und Hilfsmittel benutzt habe. Die den benutzten Werken wörtlich oder inhaltlich entnommen Stellen habe ich als solche gekennzeichnet und die zu Prüfungszwecken beigelegte elektronische Version der Dissertation ist identisch mit der abgegebenen gedruckten Version. Eine Überprüfung der Dissertation mit einer qualifizierten Software im Rahmen der Untersuchung von Plagiatsvorwürfen wird von mir gestattet.

Buchholz, 08.02.2023

Tobias Krick

Anhang C: Einzelarbeiten (inklusive Anhang)

Artikel 1: Krick, T., Huter, K., Domhoff, D., Schmidt, A., Rothgang, H. & Wolf-Ostermann, K. (2019). Digital technology and nursing care: a scoping review on acceptance, effectiveness and efficiency studies of informal and formal care technologies. BMC Health Services Research, 19(400).

Zugriff zum Volltext:
https://bmchealthservres.biomedcentral.com/articles/10.1186/s12913-019-4238-3

Artikel 2: Krick, T., Huter, K., Seibert, K., Domhoff, D. & Wolf-Ostermann, K. (2020). Measuring the effectiveness of digital nursing technologies: development of a comprehensive digital nursing technology outcome framework based on a scoping review. BMC Health Services Research, 20(1), 243

Zugriff zum Volltext:
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Artikel 3: Krick, T. (2021). Evaluation frameworks for digital nursing technologies: analysis, assessment, and guidance. An overview of the literature. BMC Nursing, 20(1), 146.

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BMC Health Services Research

RESEARCH ARTICLE Open Access

Digital technology and nursing care: a scoping review on acceptance, effectiveness and efficiency studies of informal and formal care technologies

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Abstract

Background: The existence, usage and benefits of digital technologies in nursing care are relevant topics in the light of the current discussion on technologies as possible solutions to problems such as the shortage of skilled workers and the increasing demand for long-term care. A lack of good empirical overviews of existing technologies in the present literature prompted us to conduct this review. Its purpose was to map the field of digital technologies for informal and formal care that have already been explored in terms of acceptance, effectiveness and efficiency (AEE), and to show the scope of the used methods, target settings, target groups and fields of support.

Methods: A systematic literature search was conducted using Medline, Scopus, CINAHL, Cochrane Library, ACM Digital Library, IEEE Xplore, the Collection of Computer Science Bibliographies, GeroLit and CareLit. In addition, project websites were manually screened for relevant publications.

Results: Seven hundred fifteen papers were included in the review. Effectiveness studies have been most frequently performed for ICT, robots and sensors. Acceptance studies often focussed on ICT, robots and EHR/EMR. Efficiency studies were generally rare. Many studies were found to have a low level of evidence. Experimental designs with small numbers and without control groups were the most common methods used to evaluate acceptance and effectiveness. Study designs with high evidence levels were most commonly found for ICT, robots and e-learning. Technologies evaluated for informal caregivers and children or indicated for formal care at home or in cross-sectoral care were rare.

Conclusion: We recommend producing high-quality evaluations on existing digital technologies for AEE in real-life settings rather than systematic reviews with low-quality studies. More focus should be placed on research into efficiency. Future research should be devoted to a closer examination of the applied AEE evaluation methods. Policymakers should provide funding to enable large-scale, long-term evaluations of technologies in the practice of care, filling the research gaps for technologies, target settings and target groups identified in this review.

Keywords: Technology, Care, Nursing, Scoping Review, Efficiency, Effectiveness, Acceptance, Evaluation, Effect, Digital

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Background

Digital technologies promise great opportunities to overcome existing problems and challenges in the care sector. Many health care systems face challenges such as a shortage of skilled workers and, simultaneously, an increasing demand for long-term care owing to demographic change [1]. Research activities on digital technologies and care are flourishing, nurtured by the expectation that information technologies can help people in need of care to maintain their independence and improve their quality of life and health [2], and also support formal and informal caregivers. Initial studies emphasize positive effects of electronic systems on, for example, patient safety and improvements in the care process [3], which could help to make the best possible use of the available resources.

The German cooperative research project "Pflegeinnovationszentrum" (Nursing Care Innovation Centre), funded by the Federal Ministry of Education and Research (BMBF), aims at establishing a competence centre for innovations in nursing care. Its intention is to collate and produce evidence on the acceptance, effectiveness, and efficiency (AEE) of digital technologies in nursing care and translate these findings into practice. This includes the translation of competencies on these technologies into nursing education A first, essential step of the project is to assess the broad range of technologies developed to support nursing care and nursing education and to provide an overview on existing evidence relating to the AEE of these technologies by conducting this review. We are interested in these outcome dimensions because they can indicate whether a technology has a realistic chance to be transferred into nursing practice. The scope of the existing literature on technology in nursing care and nursing education is very broad. In the present scoping review, we aim to provide insight into the full scope of studies containing information on AEE for informal and formal care.

There is a large number of small-scale studies that explore individual technologies for informal and formal care in the present literature. For example, electronic point-of-care wound documentation for residential long-term care [4], noise-sensor light alarms for the intensive care unit [5], companion robots for elderly care [6] or multi-municipal support networks for informal carers [7]. Virtual reality technology is tested in nursing education [8] and nursing homes use electronic medical records to organize their patient data and thereby optimize their performance [9]. Existing overview articles usually focus on individual technologies [10–14] or on specific target groups like stroke survivors [15], often in combination with single outcome dimensions, such as effectiveness [11], acceptance [16] or efficiency [17]. Still, many systematic reviews in the field of technology and nursing care resume that solid evidence with respect to effectiveness and efficiency of the investigated technologies is still missing or scarce [11, 18–23]. To the best of our knowledge, there is no review article that outlines the broad range of technologies developed to support formal and informal care, and no research findings are available that outline the existing evidence with respect to AEE for this broad field of technologies. This study thus makes a significant contribution to the overview of the entire study scope on the subject of digital technology and nursing care covering all areas of informal and formal care, including nursing education. The study contributes to reveal for which areas of technology there may be evidence that qualifies to be justifiably analysed in detail and for which areas solid research on AEE needs to be intensified.

Objective and research question

The ultimate objective of this scoping review is to identify technology areas that are promising for further research, to identify current research gaps and to examine how research is conducted [24]. We therefore aim to map the field of digital technologies for informal and formal care that have already been explored in terms of AEE and to show the scope of the used methods, target settings, fields of support and target groups of these technologies. This scoping review should enable researchers to identify the areas of technologies for which it is necessary to systematically analyse the existing evidence and for which areas of technologies further research is necessary. Since our aim is therefore not only to summarize well-researched technologies, but also to identify less-researched technologies that have so far been studied at a low level of evidence, a scoping review is the appropriate method.

This review is thus guided by the following main research questions:

(i) Which areas of digital technologies aiming to support informal or formal care are most frequently researched with respect to all outcome dimensions (AEE)? (ii) Which target settings, fields of support and target groups are addressed in these studies? (iii) Which study designs have been used to analyse the outcome dimensions?

Methods

Methodological basis

Our scoping review was conducted on the basis of Arksey and O'Malley's scoping review framework [25]. Additional processual advice by Levac, Colquhoun et al. [26] was taken into consideration to enhance the scientific process. The processual advices were particularly used for the identification of relevant studies by balancing comprehensiveness with the feasibility of resources and the iterativity of the team process to select, extract and chart the data.

Data sources

The database search included the following nine electronic databases: Medline, Scopus, CINAHL, Cochrane Library, ACM Digital Library, IEEE Xplore, the Collection of Computer Science Bibliographies, GeroLit and CareLit. An additional hand-search of relevant projects from German-speaking countries was carried out to supplement the results. The literature search was carried out in March 2018. Due to the large number of studies found, the reference lists of the included studies were not scrutinized.

Eligibility criteria

We included scientific papers that were published between 2011 and 2018, contained empirical studies (abstract available) in German or English language. All Databases have been searched in March 2018, which limits the included time period from January 2011 to March 2018. The considered time period was limited to 7 years, to make the scope manageable and to focus on the most innovative developments.

Included papers had to report study results relating to acceptance, effectiveness (including efficacy) or efficiency (including cost analysis) of digital technologies in nursing care and nursing education. Such technologies were required to i) either support the immediate action of a caregiver or ii) contribute to the self-reliance of the person in need of care in such a way that direct on-site care assistance can be waived, or iii) substitute the nursing support by using technology or iv) support the training or education of nurses. The assistance of the technology may relate to the person in need of care, formal caregivers, informal caregivers or organizational processes. It potentially involves a wide range of technical innovations. Target settings that have been included are residential long-term care, formal and informal care at home, hospital care, cross-sectoral care, palliative inpatient care, intensive care unit (ICU) care, day-care centre care.

We excluded studies i) without human participation; ii) situated in an emergency department, rehabilitation or surgery context; iii) comprising the following technologies: solely mechanical devices and aids, electrical devices that are not networked or that do not rely on sensors to detect the activity of the person in need of care or caregiver or their immediate vicinity, biotechnology, nanotechnology, medical devices (unless very closely related to nursing activities), imaging diagnostics, tissue engineering, devices with functional diagnostic focus, invasive technologies, mobile visits, telemedicine services, purely pleasure-oriented games, textile technology and technical evaluations of algorithms. Excluded settings and technologies were chosen in alignment with the underlying project.

Search Terms

The search terms selected were based on an initial literature review and the available knowledge of experts involved in this project. Each term has been adapted to the respective format of each database. German equivalents have been used for the two German databases (GeroLit and CarelLit). All search queries can be provided upon request.

English search strategy

(Care OR Caring OR Nursing) AND (Technol* OR Robot* OR Intelligent OR Smart OR Assistive OR Decision Support System OR Ambient Assisted Living OR Sensor OR Wearable OR Virtual Reality OR Mixed Reality OR Tagging OR Tracking OR Remote Health Monitoring OR Fall Detection OR Human Computer Interaction OR Human Machine Interaction OR Gerontotechnology OR Gerontechnology OR Head Mounted Display OR Exoskeleton OR Augmented Reality OR Biomedical Monitoring) AND (Effectiveness OR Efficacy OR Effect OR Efficiency OR Acceptance OR Adoption OR Acceptability HTA OR Health Technology Assessment OR Evaluation OR Evaluations OR Cost-Benefit Analysis OR Cost Benefit OR Cost Effectiveness OR Cost Utility OR Cost Analysis OR Cost Analyses OR Cost Consequence OR Economic Evaluation OR Economic Evaluations OR Economic Analysis OR Economic Analyses OR Costs and Benefits OR Benefits and Costs OR Costs and Outcomes OR Marginal Analysis)

German search strategy

(Pflege) UND (Techn* ODER Technik ODER Robot* ODER Computer ODER Maschine ODER Smart ODER Intelligent ODER Assistive ODER Ambient assisted living ODER Sensor ODER Wearable ODER Virtual reality ODER Mixed reality ODER Ortung ODER Sturzerkennung ODER Mensch-Maschine-Interaktion ODER Gerontechnologie ODER Head mounted display ODER Exoskelett ODER Augmented reality ODER Biomedizinisches Monitoring) UND (Effektivität ODER Effektivität ODER Effizienz ODER Evaluation ODER Akzeptanz ODER Adoption ODER Technikakzeptanz ODER HTA ODER Health technology assessment ODER Kosten ODER Nutzen ODER Kosten-Nutzen-Analyse ODER Wirksamkeit ODER Gesundheitsökonomische Analyse ODER Marginalanalyse)

Identifying relevant studies

We imported all search results into EndNote X8 and reimported all titles and abstracts into the Excel screening workbook by VonVille [27]. Two researchers independently screened 100 titles and Cohen's kappa was calculated to verify agreement between the reviewers on the inclusion and exclusion criteria. The eligibility criteria were refined until a good agreement of 0.716 was reached. Two pairs of two reviewers each independently screened half of the titles and abstracts. A third person was consulted in case of disagreement on whether an article should be included. The eligibility criteria were then refined again before screening the full texts to reach a maximum consensus on criteria. Considering the large number of full texts to be screened in relation to the existing resources, we created a control scheme whereby each author screened a part of the full texts and, in case of exclusion, a further author checked whether the exclusion criteria matched.

Data extraction

A data extraction form was collectively drawn up in Excel and piloted to record authors, year, title, abstract, country, study design, number of study participants, technology category, outcome dimension, target setting, field of support of the technology and the addressed target groups. Patterns were filtered out from a digital, automated data analysis [28], as well as from previous interviews with experts and an initial literature search, to develop an optimal technology category system. We iteratively added categories if technologies were found that did not fit into any previously known pattern. Sixteen technology categories were drawn up to classify the technologies discussed in each article. Most of the categories still comprise a wide range of technologies. In a final step, the extraction form was optimized and adapted for all categories in an iterative team process. Four authors screened the full texts and extracted information. Each full text was reviewed once if it was clearly classified with the extraction form. If a text was excluded, a second author checked the reason and re-included if necessary.

Methodological quality appraisal

In line with guidelines for conducting a scoping review, no formal assessment of methodological quality of the included articles was performed [25, 26, 29].

Charting the data

During the analysis phase, we iteratively reviewed the results to find an adequate means of presenting the descriptive numerical data. Despite this process we observed that a non-overlapping categorization of individual technologies was not possible due to the complexity of the technologies and their interconnectedness. Since we were aware of this issue from the beginning, we refined the categories in many revision processes to guarantee the best possible classification system. Technologies were assigned to the most fitting category; for instance, although a robot presented in the study has multiple sensors, it is classified as a robot, not a sensor. The importance of all results for both the practical implementation and the study situation were then discussed in a team process [26].

Results

Search results

A total of 27.339 articles were retrieved for this review, including 27.278 from the databases and 61 from handsearch. After removing duplicates, 19.510 remained for screening the titles. 1.949 articles were chosen from screening the abstracts, yielding 1.044 full-texts eligible for full-text screening. 715 full texts were included for the data analysis (see PRISMA flow diagram in Fig. 1). The studies included came from 69 different countries. A complete list of all contained studies can be found in Additional file 1.

Technology categories

We analysed the number of included studies on each technology area to identify which technology areas were most frequently explored in terms of all outcome dimensions (AEE), and which were least frequently researched. An overview of the distribution of included studies in terms of technology categories is presented in Table 1. The table is sorted by frequencies. A lack of universal definitions for different technology categories, was clearly noticeable during the analysis of the studies. The definitions we developed to differentiate the technologies in this review are included in Table 1. The most widely researched technology category is Information and Communication Technologies (ICT) (n = 147). ICT comprises a wide range of technologies. In general, ICT are technologies that provide or document relevant information with a primary focus on improve interpersonal communication. Included technologies can be found in Table 1. Electronic Health Records (EHR)/ Electronic Medical Records (EMR), Hospital/Care Institution Information Systems (HIS) or monitoring technologies could also be included in the category ICT. Since these areas represent large fields of research, we have decided to present them separately. The second most frequently researched category is robots (n = 102). We found that the robots under scrutiny here differ greatly in their focus. They provide support on numerous different levels, e.g. physical, psychological, social, organisational, security or educational and therapeutic. All types of robots that were called “robot” in the article are grouped in this category.

The third most frequently researched technology category is sensors (n = 83). These sensors can either aim

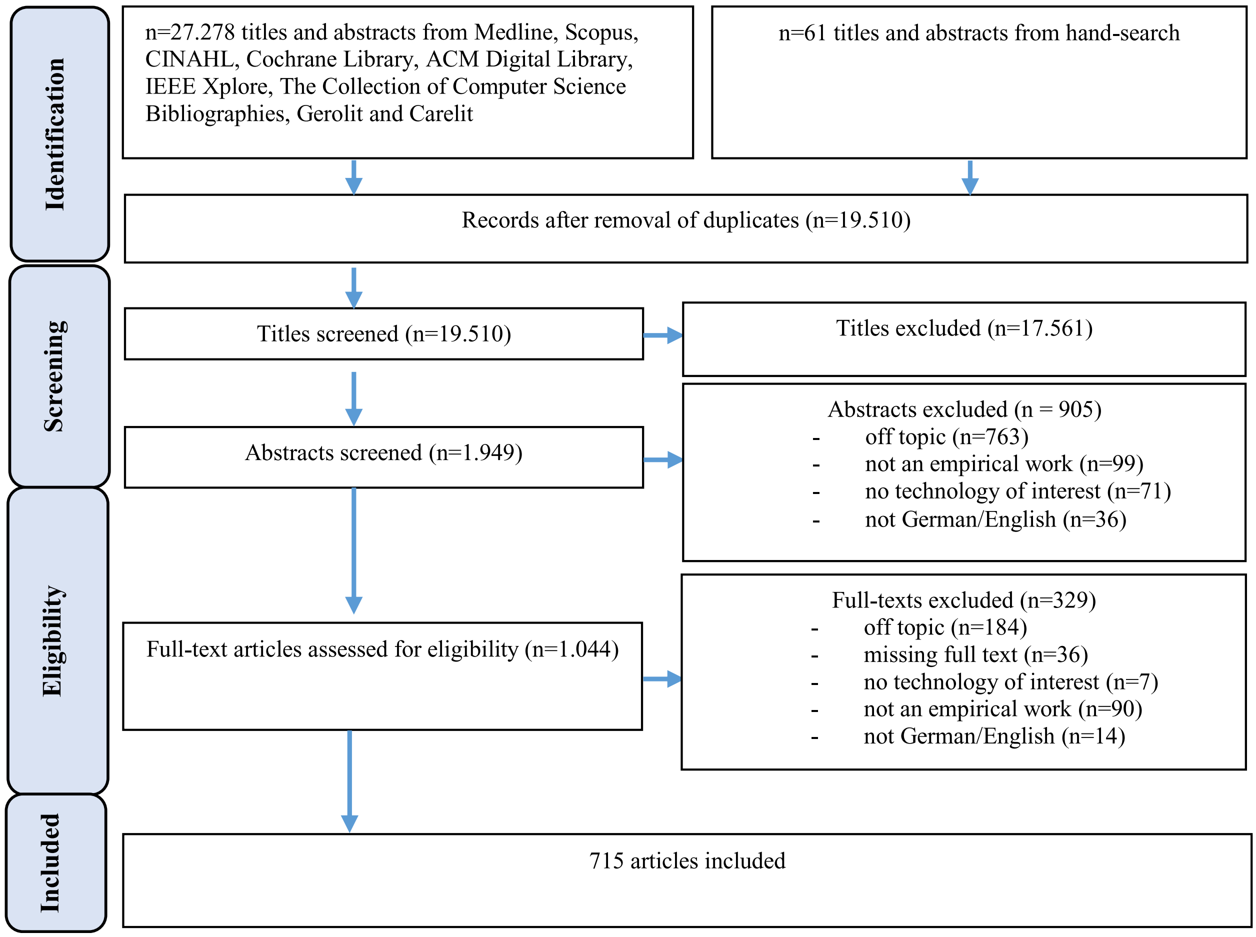

Fig. 1 Search results and publication selection process

at measuring behaviour, movement, falls and other parameters or to measure in combination with controlling other devices like pumps or alarm systems. Many studies cover multiple technologies (n = 80) rather than one technology only. Most of them are reviews that focus on specific target groups or nursing problems. A large share of these studies are acceptance studies that comprise a range of different technologies. Only few studies actually provide research on the effectiveness or efficiency of technological systems comprising different types of technologies. Less researched technologies are virtual reality (VR) technologies (n = 11) that create a virtual world, tracking technologies (n = 9) intended to locate either people or objects, and serious games, which are used for learning purposes or to improve personal independence. We found only one study on personal medical records (PMR), which – in contrast to EMR – allows patients access to all their data. Still, depending on the classification system, PMR could also be subordinated to studies on EMR. This study should therefore not be given a special status. In summary, ICT, robot and sensor technologies can be stated as the most frequently explored areas of technology in terms of all outcome dimensions (AEE). VR, tracking technologies and serious games are the least researched technologies.

Outcome dimensions and technologies

The inclusion criteria of this study comprise a broad understanding of the outcome dimensions "acceptance", "effectiveness" and "efficiency". This is reflected in the broad scope of conceptualizations of these outcome dimensions in the studies included and widely differing measurement concepts. Acceptance studies include the quantitative measurement of acceptance in accordance with a wide range of theoretical acceptance models as well as qualitatively described acceptance results. Effectiveness comprises results on the technical effectiveness or accuracy of technologies as well as personal health or care-related outcomes, organisational or learning outcomes. As there are only very few studies focussing on costs of technologies at all, studies categorized as efficiency-studies include simple cost analyses next to very few full economic evaluations.

Table 1 Technology categories with included studies

Category	Definitions	Number of included studies
ICT	ICT are technologies, that either provide or document relevant information, support data management and transfer and focus mostly on improvement of interpersonal communication. The category comprises for example Telecare, Tele-ICU or software applications for process planning.	147
Robot	Robots are machines that interact with their physical environment by sensors, actuators and information technology. This includes social assistive robots, physical assistive robots and complex robotic systems.	102
Sensor	Sensors measure physical or chemical properties and are used to assess, e.g. behaviour, movements or odours. They are often used to control/trigger other devices like pumps or alarm systems.	83
Multiple Technologies	Interventions/studies that include technologies from different technology categories.	80
EHR/EMR	Electronic health records (EHR) and electronic medical records (EMR) are digital records of patient related health information. EMR refers to patient data that is stored and exchanged inside an institution, mostly a hospital. The main focus of the EHR is the capability to exchange information between two systems.	57
Monitoring	Monitoring technologies are complex and analytical technologies to monitor patient, caregiver or organisational relevant data over a period. They often integrate sensors but are more complex than single sensor solutions.	51
Assistive Device	Assistive Devices assist or support a caregiver or a person in need of care in performing a particular task and are enhanced with digital technology, i.e. are digitally connected or equipped with sensor technology.	39
E-Learning	E-Learning includes forms of learning that use electronic or digital media to present or distribute learning resources, or to support communication in learning settings. [30]	38
HIS	Hospital/Care Institution Information Systems (HIS) collect, store, manage and transmit data in hospitals or other care institutions. They can comprise operational management systems, EMR and/or other organisational systems.	30
Educational Technology	Educational Technologies assist learning in nursing education by simulating real life care scenarios and/or incorporate feedback systems. Examples are high fidelity simulations and nurse self-training systems.	23
AAL	AAL technologies are integrated multifunctional, often modular systems that support a person in his/her living environment. AAL generally comprises a set of different technologies, often sensors and communication technologies, that intend to support the well-being, security and independent living of an elderly person. [31]	18
Decision Support	Decision support systems are software solutions that link individual patient data (input) with treatment guidelines and a recommendation (output) to be delivered to a person in charge of care. [12]	18
Virtual Reality	Virtual Reality refers to non-immersive as well as fully immersive, 360-degree artificial environment, which is experienced through a head mounted display (HMD). [32]	11
Tracking	Tracking technologies locate people or objects.	9
Serious Games	Serious Games aim to develop, improve or help maintaining certain skills or competencies, or to evoke behaviour changes.	8
PMR	Personal medical records (PMR) are digital records of patient related health information, that are accessible for patients.	1
Total		715

With respect to the specific outcome dimensions (AEE), 60 % of all included studies (n = 427) analyse aspects of the effectiveness of care technologies, 59 % (n = 424) analyse acceptance and only 5,8 % (n = 42) analyse efficiency or at least included a cost analysis. Multiple counts of studies are possible, because some studies consider multiple outcome dimensions, which is why the percentage shares add up to more than 100 %. A detailed analysis by outcome dimension (Table 2) shows that acceptance studies are most frequently performed for ICT (n = 93), followed by robots (n = 64) and EMR/EHR (n = 48). Studies on effectiveness have been most frequently carried out for ICT (n = 94). Sensor technologies represent the second largest group (n = 68) and

Table 2 Number of studies by technology category and study outcome dimensions

Technology	Outcome Dimensions			
	Acceptance	Effectiveness	Efficiency	Total number of studies
ICT	93	94	9	147
Robot	64	57	1	102
Sensor	47	68	5	83
Multiple Technologies	25	48	7	80
EHR/EMR	48	17	5	57
Monitoring	26	32	4	51
Assistive Device	25	24	3	39
E-Learning	18	26	0	38
HIS	25	11	3	30
Educational Technology	12	15	0	23
AAL	15	7	2	18
Decision Support	6	13	3	18
Virtual Reality	7	6	0	11
Tracking	6	5	0	9
Serious Games	6	4	0	8
PMR	1	0	0	1
Total	424	427	42	715

robotic technologies make up the third (n = 57). Efficiency has been studied very rarely for all technologies. ICT (n = 9) can be highlighted for this category. Still, compared to the considerably high total number of ICT studies, only 6% of them cover efficiency or cost analyses. In summary, we have found a large number of effectiveness studies with a focus on ICT, robots and sensors, and a large number of acceptance studies focusing on ICT, robots, and EHR/EMR. Efficiency studies are very rare.

Target settings and technologies

The most frequently researched technologies and their target settings are depicted in Table 3. Most of the included studies aim at hospital care (n = 169), which accounts for almost a quarter of all included studies (about 24%). Studies on technologies for informal care at home represent 21% (n = 147) and studies on technologies for residential long-term care make up 17% of the studies included (n = 122). Ninety-one articles left the setting undefined (13 %). These are more or less explorative studies researching general aspects of the technology in question without considering specific applications. It is noticeable that technologies for formal care (n = 48) at home are much less intensively researched than technologies for informal care at home. Studies on technologies for formal care at home account for only 6.7% of all included studies. Hardly any studies focus on cross-sectoral care (<1%).

Regarding the most common technologies by setting, ICT (n = 42), EHR/EMR (n = 33) and HIS (n = 22) are most frequently researched in hospital care. The use of medication administration systems [33–35], a multilingual translation aid [36] and the use of a smartphone nurse call system [37] are typical applications for ICT ins this domain. In the informal home-care setting ICT (n = 28), sensors (n = 26) and monitoring technologies (n = 23) are the most commonly used. Sensors, for example, often check activities of everyday life or abnormal behaviours such as falls [38]. In the field of residential long-term care, robots are by far the most researched technology category, followed by sensors (n = 16) and ICT (n = 10). Social robots [39], therapeutic robots [40] and also robotic auxiliary systems such as robotic transport assistants [41] can be highlighted as common applications. Studies situated in formal care at home mostly focus on ICT n = 22). One purpose of ICTs in this setting is communication between nurses and other health professionals, such as general practitioners, in order to obtain sufficient patient-relevant information [42].

We found very few studies on virtual reality (VR) technologies in the literature. Studies on VR were performed only in hospitals (n = 4), residential long-term care (n = 2) and in the field of education (n = 5). Distraction therapy for pain patients in hospital can be cited as an example for the use of this technology [43]. In education, VR is used primarily in terms of VR learning simulations [44–46]. In summary, most of the included technologies are for hospital care, informal care at home and residential long-term

Table 3 Number of studies by technology category and specific target setting

Technology	Target Setting										
	Hospital care	Informal care at home	Residential long-term care	Formal care at home	ICU care	Cross sectoral care	Day-care centre care	Education	Palliative inpatient care	N.A.	Undefined
ICT	42	28	10	22	16	3	3	9	0	3	15
Robot	5	22	46	2	1	0	3	2	0	2	23
Sensor	12	26	16	2	6	0	0	0	1	0	21
Multiple Technologies	15	19	12	7	1	0	0	6	0	9	15
EHR/EMR	33	2	10	1	4	3	0	3	0	0	1
Monitoring	12	23	6	2	3	0	0	0	1	0	5
Assistive Device	12	8	3	6	1	0	0	0	0	0	9
E-Learning	0	0	0	0	0	0	0	38	0	0	0
HIS	22	0	6	1	4	0	0	0	0	0	0
Educational Technology	0	0	0	0	0	0	0	23	0	0	0
AAL	0	11	4	4	0	0	0	0	0	0	0
Decision Support	9	3	3	0	1	0	0	0	0	1	0
Virtual Reality	4	0	2	0	0	0	0	5	0	0	0
Tracking	3	4	1	1	0	0	0	0	0	0	1
Serious Games	0	0	3	0	0	0	0	4	0	0	1
PMR	0	1	0	0	0	0	0	0	0	0	0
Total	169	147	122	48	37	6	6	90	2	15	91

care. There is also a large number of studies in which the setting remains undefined. Only a few studies focus on formal care at home, and hardly any on cross-sectoral care.

Field of support and technologies

We also analysed the fields of support that the technologies are promoting (Table 4). Most technology applications included in this review aim at providing organisational support (*n* = 169). This corresponds to a share of 24% of all included studies. Work organization, self-management and organisational support in everyday life are included in this category. Organisational support is most commonly pursued by ICT (*n* = 49) and EHR/EMR (*n* = 48). Many technologies aim not just at one field, but at multiple areas. Technologies supporting several areas account for 21% of all included studies (*n* = 162). Security-related technologies make up around 14% of all included studies, thus forming another important support area (*n* = 99). Sensors are the most commonly explored security support technology (*n* = 45). Physical (*n* = 46), social (*n* = 40) or psychological support systems are relatively less explored. In the included studies, robotic systems are most frequently employed to provide support in one of these three categories. Technologies that focus mainly on economic support (*n* = 2) are rather uncommon. The total results in 713 studies, because two studies could not be assigned to a field of support. In summary, most of the included studies on technologies aim to provide support at the organisational level (work- and self-organisation) and in the field of security. Furthermore, there is a large number of technologies that aim at multiple support areas. Technologies that provide physical, psychological, social or economic support were explored less often.

Target groups and technologies

The data analysis of the target groups presented in Table 5 shows which target groups are most frequently addressed by the different technologies. In general, the research on most of the technologies included in this review addresses people in need of care (*n* = 382). Formal caregivers (*n* = 326) represent the second largest target group. Technologies for informal caregivers are relatively rarely explored. Only 8% of all included studies focus on informal caregivers (*n* = 57). Also, technologies that address the institutional level are less explored (6% of all studies). Children in need of care are rarely found as a specific target group in the included studies (*n* = 7). The described trends differ for some of the technology categories. EHR/EMR systems usually address formal caregivers (*n* = 40) and AAL systems mostly target at people in need of care (*n* = 17). Sensors (*n* = 70) and monitoring technologies (*n* = 35) are also primarily used to record the parameters of people in

Table 4 Number of studies by technology category and specific field of support

Technology	Field of support									
	Organisational	Security	Educational	Monitoring	Physical	Psychological	Social	Economic	Multiple	Total
ICT	49	15	12	4	3	8	9	0	45	145
Robot	9	2	3	0	21	13	27	0	27	102
Sensor	2	45	0	21	4	3	1	0	7	83
Multiple Technologies	12	8	6	2	3	3	2	1	43	80
EHR/EMR	48	2	3	0	0	1	0	0	3	57
Monitoring	3	10	0	33	0	0	0	0	5	51
Assistive Device	5	7	0	1	12	4	0	0	10	39
E-Learning	0	0	38	0	0	0	0	0	0	37
HIS	23	3	0	0	0	0	0	0	4	30
Educational Technology	0	0	23	0	0	0	0	0	0	23
AAL	4	1	0	0	1	0	0	0	12	18
Decision Support	9	1	0	0	0	3	1	1	3	18
Virtual Reality	0	0	5	0	2	3	0	0	1	11
Tracking	4	5	0	0	0	0	0	0	0	9
Serious Games	0	0	4	0	0	2	0	0	2	8
PMR	1	0	0	0	0	0	0	0	0	1
Total	169	99	94	61	46	40	40	2	162	713

need of care. Whereas educational technologies are exclusively intended for the education of formal caregivers (n = 23), educational technologies for informal caregivers or people in need of care themselves are not explored so far in terms of AEE. Most studies on technologies for informal caregivers describe ICT systems that provide better information about the caring process or help in ways of communication with professionals or the people in need of care. In summary, most of the included technologies focus on people in need of care and formal caregivers. Technologies with a focus on children and informal caregivers are much less commonly researched.

Table 5 Number of studies by technology category and specific target group

Technology	Formal Caregivers	Informal Caregivers	People in Need of Care		Institution	Undefined
			Total	Children		
ICT	81	25	74	4	4	0
Robot	16	5	97	0	1	0
Sensor	17	1	70	0	0	0
Multiple Technologies	30	14	42	0	11	2
EHR/EMR	40	0	1	0	16	0
Monitoring	17	3	35	2	0	1
Assistive Device	14	2	30	1	0	0
E-Learning	37	0	1	0	0	0
HIS	23	0	1	0	8	0
Educational Technology	23	0	0	0	0	0
AAL	5	4	17	0	0	0
Decision Support	12	1	3	0	2	1
Virtual Reality	5	0	6	0	0	0
Tracking	2	2	8	0	2	0
Serious Games	4	0	4	0	0	0
PMR	0	0	1	0	0	0
Total	326	57	382	7	44	4

Study design and outcome dimensions

The quality and scope of evidence that is generated in the studies on acceptance, effectiveness and efficiency largely depends on the studies' designs. We refer to common evidence-based nursing and evidence-based medicine guidelines [47, 48] to assess the evidence level of the different study designs. Based on these guidelines, we categorise meta-analysis, systematic reviews (Ia), RCTs (Ib) and quasi-experiments (II) as the highest levels of evidence, evidence from well-designed cohort studies or case-control studies as a medium level of evidence (III) and evidence from single descriptive, qualitative (IVa) or uncontrolled interventional studies (IVb) as a low level of evidence. Table 6 presents the outcome dimensions, differentiated by study design. About 22% of the studies on acceptance (n = 96) and 32% of the studies on effectiveness (n = 138) included in this review fall into a study design category that we call "experimental no control (n.c.)". This study design thus makes up most of the studies on both outcome dimensions. In this category studies are included that tested technical performance and accuracy (with respect to effectiveness), analysed acceptance under laboratory conditions or first effects with no control groups (mostly under laboratory conditions as well). The term "experiment" is used here in a technical understanding that differs from the methodological understanding of "experimental studies" in the social sciences. The experimental testing of technologies with user studies to understand acceptance, usability, feasibility, and technical effects in engineering is often done with small groups of people who "test" the technology in controlled environments to get accurate measurements and / or to answer questions about the technology [49–53]. The term "experimental (n.c.)" used in our study describes these user studies and connects them with other studies widely used in the social sciences. This situation occurs because nursing technologies are located in an intermediate region between the social and technical sciences. This study design is also classified as having a low level of evidence (IVb) according to the referred guidelines [47, 48].

Table 6 Number of studies by study design and outcome dimension

Design	Outcome Dimension		
	Acceptance	Effectiveness	Efficiency
Experimental n.c.	96	138	3
Mixed Methods	83	55	5
Qualitative	68	13	0
Case Study	53	36	5
Cross-sectional	51	18	3
Systematic Review	24	45	5
Other Types of Review	19	25	5
Quasi-experiment	14	46	5
RCT	8	30	4
Cohort Study	6	8	1
Modelling Study	1	4	5
Meta-analysis	1	8	1
Case-control	0	1	0
Total	424	427	42

Besides these studies, 20% of the research on acceptance is carried out using mixed methods designs (n = 83). Qualitative approaches (16%), case study designs (12%) and cross-sectional analyses (12%) also make up a considerable share. Larger, cross-sectional studies have often been performed on technologies already in use such as EMR/EHR. This analysis shows that a majority of the included studies on acceptance were performed at a relatively weak level of evidence design. We have found only a few quasi-experiments (n = 14) and RCTs (n = 8) that analysed acceptance, but relatively many systematic reviews (n = 24). These reviews tended to include all types of study designs (qualitative and quantitative) [54–57], which are medium level of evidence designs.

The research approaches to measuring effectiveness found in this review are different. In addition to the experimental n.c. designs already mentioned, mixed methods designs (n = 56) and quasi-experiments (n = 47) were frequently used to measure effects. Mixed methods designs thus account for 13% and quasi-experiments for 12% of all studies on effectiveness in this review. It is notable that 45 systematic reviews and 8 meta-analysis were found, but only 30 RCTs. Consequently, for each single technology the number of available RCTs is very small. This is consistent with the fact that a lot of systematic reviews conclude that the study situation is not sufficient to report meaningful results on effectiveness [11, 18–23], because there are very few high-quality studies.

Efficiency studies are generally rare. Therefore, a common type of study cannot be named. We found efficiency analyses in modelling studies, quasi-experiments, case studies, mixed methods studies, systematic reviews and other types of reviews (each n = 5). Most of the studies categorized as efficiency studies contained only cost analyses (n = 21). Cost-effectiveness analyses were performed in 13 studies. Studies providing cost-benefit (n = 3) or cost-utility analyses (n = 1) were even less common. In summary, most of the included studies on acceptance and effectiveness have an experimental n.c. design. In addition, next to mixed method approaches, acceptance was frequently measured qualitatively and effectiveness with quasi-experiments. Efficiency studies have very rarely been carried out and often focus on cost analysis only.

Study design and technology

It remains to be clarified for which technology categories included in this review studies with a high level of evidence can be found and for which areas such studies can hardly be found. Table 7 lists common study designs of the included articles in relation to the technology categories for which they were applied. We defined meta-analysis, systematic reviews (Ia), RCTs (Ib) and quasi-experiments (II) as having the highest levels of evidence. Nevertheless, it should be kept in mind that the systematic reviews and meta-analyses included in this review not only consist of data from RCTs, and that they often conclude that the quality of included studies was not sufficient. Other study designs may contribute to a greater insight, depending on the outcome dimensions and the research question. We only consider the formal levels of evidence here. Most high level of evidence studies of the described three levels (Ia,Ib,II) can be found for the category ICT (n = 33), followed by robots (n = 18), e-learning (n = 16), sensors (n = 10) and assistive devices (n = 10).

Few studies with a high level of evidence were found for VR (1 RCT), tracking (1 quasi-experiment) and there were no high-evidence studies for PMR. Despite the wide range of technology categories included, only a few of them have been explored comprehensively using methods with a high level of evidence. Since the technology categories include very different individual technologies, a differentiated analysis would be required here to identify particularly good and less well-researched individual technologies. The robot “Paro” can be highlighted as an example for an individual technology, for which we found a total of seven RCT studies [58–64].

To summarize, studies with a higher level of evidence design (meta-analysis, systematic reviews, RCTs, quasi-experiments) were most commonly found for ICT, robots and e-learning. Only a few studies with a high level of evidence have been found for most of the other areas of technology, like for example VR and tracking.

Discussion

The aim of this study was to map the field of digital technologies for informal and formal care that have already been explored in terms of AEE and to give a structured overview of the used methods, target settings, fields of support and target groups of these technologies. To our knowledge this is the first study trying to provide a quantitative overview over the entire study scope on the subject of digital technology and nursing care, covering all areas of informal and formal care, including nursing education.

ICT, robot and sensor technologies can be stated to be the most frequently explored areas of technology in terms of all outcome dimensions (AEE). Virtual reality

Table 7 Number of studies by technology category and selected study design

Technology	Design								
	Experimental n.c.	Case Study	Qualitative	Cross-sectional	Mixed Methods	Quasi-experiment	RCT	Systematic Review	Meta-analysis
ICT	26	21	18	10	24	15	6	12	0
Robot	43	9	9	1	20	6	9	3	0
Sensor	59	5	2	1	4	5	4	1	0
Multiple Technologies	7	5	9	9	8	0	3	21	0
EHR/EMR	4	9	11	13	10	0	0	2	1
Monitoring	28	5	4	5	4	0	1	1	1
Assistive Device	12	5	5	4	2	2	4	2	2
E-Learning	5	3	3	3	5	9	2	4	1
HIS	2	7	5	4	6	1	1	4	0
Educational Technology	4	3	2	4	3	3	0	1	1
AAL	4	2	0	3	4	1	1	3	0
Decision Support	1	3	1	0	3	2	1	3	2
Virtual Reality	5	1	1	0	0	3	1	0	0
Tracking	4	0	0	2	2	1	0	0	0
Serious Games	3	1	1	0	0	2	1	0	0
PMR	0	0	0	1	0	0	0	0	0
Total	207	79	71	60	95	50	34	56	8

technologies, tracking technologies and serious games are technology categories that are comparatively less researched so far. It can be assumed that the most frequently researched technologies have been the most important areas for researchers and research funders in recent years. Without knowing more about the results of the studies, it is reasonable to conclude that this research interest has either been motivated by high expectations for these technologies in terms of supporting nursing care from the perspective of care research and nursing science – or that nursing contexts are application areas of high interest from the perspective of technical sciences developing these technologies. The rarely researched technologies may be promising fields of research for the future.

Taking a closer look at the outcome dimensions, it has been shown that there is a large number of effectiveness studies with a focus on ICT, robots and sensors, and a large number of acceptance studies focusing on ICT, robots and EHR/EMR. However, a large proportion of these studies has a low level of evidence, as will be elaborated below. Efficiency studies are very rare in general. This points to the low consideration of the relationship between benefits and costs of a technology, so far. There could be several reasons for this. One possible reason is that there are not enough high-quality studies that allow a comparison of the effects of a technology with costs in the form of a health economic evaluation. Many technologies are still under development or have never reached the implementation phase. Subsequently, they may not have reached the stage for high-quality studies in real-life settings, which makes it difficult to accurately estimate future costs. Another reason could be that the future costs of a technology are difficult to predict if the technology is currently still in the development phase, since it can be assumed that the future price of a technology will be significantly lower than the current one.

When analysing the target settings of all included articles, we found that most technologies aim at hospital care, informal care at home or residential long-term care. There is also a large proportion of technologies for which the setting remains undefined. We do not consider it expedient to leave the target setting undefined during the development phase of a technology, because it hinders a purposeful development of the technology. Research gaps related to target settings were found for formal care at home and cross-sectoral care. If this is reflected in relation to the target groups for which the technologies were developed, the analysis shows that most of the included technologies focus on people in need of care and formal caregivers. This means that technologies relating to informal care at home are primarily intended for people in need of care and not for informal caregivers. We assume that this is mainly due to the fact that these technologies are often developed to strengthen the independence of people in need of care and hence to prevent the intervention of informal caregivers. Still, this review identifies informal caregivers as an under-represented group in the exploration of digital technologies. Research on technologies for assisting children in need of care has also very seldom been carried out.

We also analysed the fields of support the included technologies are intended for. Most of the technologies included provide support at the organisational level (work and self-organisation) and the field of security. Furthermore, there is a large part of technologies that provide support in multiple areas. This category often refers to research settings, where multiple technologies are combined, such as AAL, or to systematic reviews that focus on a specific target group or setting and thus include several aspects of support. Another large part are ICTs, which combine organizational as well as psychological or social support. Technologies that exclusively support physical, psychological, social or economic areas were relatively rare.

Our analysis also includes a valuation of the study designs used to evaluate AEE. Although there are many studies on different technologies overall, there are only a few studies with a high level of evidence, considering all outcome dimensions. There are significantly more RCTs, quasi-experiments and systematic reviews for effectiveness than for acceptance. Efficiency studies have been carried out very rarely and often focus on cost-analysis only. Given the low number of studies with a high level of evidence, there are only a few studies that can deliver high-evidence results.

Most of the included studies on acceptance and effectiveness were carried out in an experimental n.c. design. This type of study is essential during the development of a technology in order to establish its effectiveness from a technical–scientific point of view. From the perspective of health and nursing science, however, the evidence level is low with respect to the measurement of health or nursing related effects when applied in actual nursing practice. In addition, next to mixed method approaches, acceptance was frequently measured qualitatively and effectiveness using quasi-experiments.

Studies with a higher level of evidence design (meta-analysis, systematic reviews, RCTs, quasi-experiments) were most commonly found for ICT, robots and e-learning. It is important to distinguish between systematic reviews and meta-analyses on the one hand and RCTs and quasi-experiments on the other. A systematic review has a high level of evidence if it is based on studies with high evidence levels. If a systematic review is based on low-quality studies with a low level of evidence, it adds only a little insight into the effectiveness or acceptance of a technology. Therefore, a closer analysis of the systematic reviews and meta-analyses included here in terms of quality and results is needed to finally judge their quality. This applies especially to the area of multiple technologies. However, for ICT, robot and e-learning there are relatively many RCTs and quasi-experiments, so it can be expected that systematic reviews on a high level of evidence are possible in these research areas. Still, a first look at the systematic reviews included in this article reveals that many of them actually conclude that there are not enough high-evidence studies, and more high-quality studies are needed. This also seems to apply to sub-areas of ICT [10], robots [11] e-learning [65], AAL [23] and assistive technologies[19, 20].

Overall, the methods used in all studies appear to be very diverse, and the measured outcome parameters diverge broadly for the different technology categories, which also could be a problem for the subsequent comparability of results of the studies in terms of AEE.

Limitations

Although our scoping review was conducted in line with the standards of the methodology [25, 26], we still need to acknowledge some limitations. We have ventured into a field with a huge scope. Given the broad field and large number of potentially relevant technologies, producing a concise capture, systematization and summary of all information was indeed a challenging. To make the scope manageable, the considered time period was limited to 7 years. This must be named as a limitation, because no longer period could be displayed. A systematization of all technological innovations without any overlaps was not possible due to the complexity of the technologies. The highest possible quality standards for classification were developed in an iterative team process, but possible overlaps should be taken into account when interpreting the presented results.

Looking at all 715 studies included in this review it was noticeable that a lot of studies describe their methods and results poorly. This made it difficult to evaluate and describe relevant information. The quality of the description of the study tended to increase with the quality of the study design. Still the impression arose that not uncommonly, study authors tended to enhance their study design by labelling it a study design of a higher evidence level than was actually used.

We also had to make methodical compromises due to the available resources, as recommended by Levac et al. [26], but we were still able to maintain the quality by applying the four-eyes principle in all steps of exclusion using a special sequencing method we developed for this review. The publication bias must be mentioned as a further limitation of this review. We considered published scientific studies only, and no grey literature. This review therefore tends to contain fewer publications with negative or neutral findings [66]. Consequently, it can be assumed that there may be a bias towards promising technologies.

There may also be an over-representation of some technology areas, as we have included both systematic reviews and primary studies. Some primary studies are included in the systematic reviews. However, we have accepted this limitation in order to get an overview of the different levels of evidence used to explore individual technology areas.

We did not scrutinize the reference lists of all studies found in the databases, moreover, due to the huge amount of potential publications found at this stage. We are therefore unable to consider technologies in early stages of development and without any published studies involving actual users. Nevertheless, a comprehensive overview of the scope of relevant literature has been provided by our thorough search through nine databases, covering the key areas of health and nursing science as well as the field of computer science.

Conclusion

The results of this scoping review can be used as a basis for further research in the field of digital technology and nursing care. We mapped the field of technologies for informal and formal care that has already been explored in terms of AEE, and presented a structured overview of the methods used, target settings, fields of support and target groups of these technologies and provide data-based indications which technologies appear to be promising for further research. Given the broad field and large number of potentially relevant technologies, producing a concise capture, systematization and summary of all information was indeed a challenging research.

We recommend that for the time being the scientific community should not focus on conducting systematic reviews on digital technologies in nursing care, because there appears to be a lack of high-quality studies. Rather, we recommend producing high-quality evaluations on existing technologies in terms of acceptance, effectiveness and efficiency in real-life settings. A special focus should be placed on research into efficiency, as – at the time of writing – the proportion of efficiency studies is particularly low. Future research should also be devoted to taking a closer look at the applied evaluation methods for AEE and deciding whether they are appropriate or whether new methods are needed to perform an ideal measurement of AEE. When analysing the target settings and target groups, we found that formal care at home and cross-sectoral care technologies are underexplored in terms of AEE. There are also numerous technologies where the setting remains undefined. We recommend defining an application setting when developing technologies for care. Technologies for informal caregivers and children in need of care have seldom been explored. Policymakers should provide funding to enable large-scale, long-term evaluations of digital technologies in the practice of care, filling research gaps for technologies, target settings and target groups we identified.

Additional file

Additional file 1: Overview of all included studies. (PDF 572 kb)

Abbreviations

AAL: Ambient Assisted Living; ACM: Association for Computing Machinery; AEE: Acceptance, Effectiveness and Efficiency; EHR: Electronic Health Records; EMR: Electronic Medical Records; HIS: Hospital/Care Institution Information Systems; HMD: Head Mounted Display; ICT: Information and Communication Technology; ICU: Intensive Care Unit; IEEE: Institute of Electrical and Electronics Engineers Living; PMR: Personal Medical Records

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Authors' contributions

All authors conceptualized the study. TK handled a large part of the screening in all stages, interpreted the results and wrote the first draft of the manuscript. KH, DD and AS shared work in all stages of the screening process. HR and KWO obtained funding for the study. TK, KH and DD conceptualised the data abstraction form. TK, KH, DD, HR and KWO read and provided substantial edits on the manuscript. All authors authorized the final version of the manuscript that was submitted. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Not applicable.

Consent for publication

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Competing interests

The authors declare that they have no competing interests.

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References

1. Isfort M, Rottländer R, Weidner F, Tucman D, Gehlen D, Hylla J. Pflege-Thermometer 2016. In: Eine bundesweite Befragung von Leitungskräften zur Situation der Pflege und Patientenversorgung in der ambulanten Pflege. Köln: Deutsches Institut für angewandte Pflegeforschung e.V. (dip); 2016.
2. Billings J, Carretero S, Kagialaris G, Mastroyiannakis T, Meriläinen-Porras S: The Role of Information Technology in Long-Term Care for Older People. In: Long-Term Care in Europe. edn. Edited by Leichsenring Kea: Palgrave Macmillan; 2013.
3. Buntin MB, Burke MF, Hoaglin MC, Blumenthal D. The Benefits Of Health Information Technology: A Review Of The Recent Literature Shows Predominantly Positive Results. Health Affairs. 2011;30(3):464–71.
4. Florczak B, Scheurich A, Croghan J, Sheridan P Jr, Kurtz D, McGill W, McClain B. An observational study to assess an electronic point-of-care wound documentation and reporting system regarding user satisfaction and potential for improved care. Ostomy Wound Manage. 2012;58(3):46–51.
5. Jousselme C, Vialet R, Jouve E, Lagier P, Martin C, Michel F. Efficacy and mode of action of a noise-sensor light alarm to decrease noise in the pediatric intensive care unit: a prospective, randomized study. Pediatr Crit Care Med. 2011;12:e69–72.
6. Robinson H, MacDonald B, Broadbent E. Physiological effects of a companion robot on blood pressure of older people in residential care facility: a pilot study. Australas J ageing. 2015;34:27–32.
7. Torp S, Bing-Jonsson PC, Hanson E. Experiences with using information and communication technology to build a multi-municipal support network for informal carers. Inform Health Soc Care. 2013;38(3):265–79.
8. Fagan M, Kilmon C, Pandey V. Exploring the adoption of a virtual reality simulation: The role of perceived ease of use, perceived usefulness and personal innovativeness. Campus-Wide Information Systems. 2012;29(2):117–27.
9. Hitt LM, Tambe P. Health care information technology, work organization, and nursing home performance. Ind Labor Relat Rev. 2016;69(4):834–59.
10. Arditi C, Rège-Walther M, Wyatt JC, Durieux P, Burnand B. Computer-generated reminders delivered on paper to healthcare professionals; effects on professional practice and health care outcomes. Cochrane Database of Systematic Reviews 2012(12):N.PAG-N.PAG.
11. Bemelmans R, Gelderblom GJ, Jonker P, de Witte L. Socially Assistive Robots in Elderly Care: A Systematic Review into Effects and Effectiveness. J Am Med Dir Assoc. 2012;13(2):114–20 e111.
12. Blum D, Raj SX, Oberholzer R, Riphagen II, Strasser F, Kaasa S. Computer-Based Clinical Decision Support Systems and Patient-Reported Outcomes: A Systematic Review. Patient. 2015;8(5):397–409.
13. Brandt Å, Alwin J, Anttila H, Samuelsson K, Salminen A-L. Quality of evidence of assistive technology interventions for people with disability: An overview of systematic reviews. Technol Disabil. 2012;24(1):9–48.
14. Bright TJ, Wong A, Dhurjati R, Bristow E, Bastian L, Coeytaux RR, Samsa G, Hasselblad V, Williams JW, Musty MD, et al. Effect of clinical decision-support systems: A systematic review. Ann Intern Med. 2012;157(1):29–43.
15. Aldehaim AY, Alotaibi FF, Uphold CR, Dang S. The Impact of Technology-Based Interventions on Informal Caregivers of Stroke Survivors: A Systematic Review. Telemed J E Health. 2016;22(3):223–31.
16. Kruse CS, Mileski M, Alaytsev V, Carol E, Williams A. Adoption factors associated with electronic health record among long-term care facilities: a systematic review. BMJ Open. 2015;5(1):e006615.
17. Bowes A, Dawson A, Greasley-Adams: Literature review: the cost effectiveness of assistive technology in supporting people with dementia. Report to the Demtia Services Development Trust. In.: University of Stirling; 2013.
18. Capurro D, Ganzinger M, Perez-Lu J, Knaup P. Effectiveness of eHealth interventions and information needs in palliative care: a systematic literature review. J Med Internet Res. 2014;16(3):e72.
19. Fleming R, Sum S. Empirical studies on the effectiveness of assistive technology in the care of people with dementia: A systematic review. J Assist Technol. 2014;8(1):14–34.
20. Van der Roest HG, Wenborn J, Pastink C, Droes RM, Orrell M. Assistive technology for memory support in dementia. The Cochrane database of systematic reviews. 2017;6:Cd009627.
21. Khosravi P, Ghapanchi AH. Investigating the effectiveness of technologies applied to assist seniors: A systematic literature review. Int J Med Inform. 2016;85(1):17–26.
22. Peretz D, Arnaert A, Ponzoni NN. Determining the cost of implementing and operating a remote patient monitoring programme for the elderly with chronic conditions: A systematic review of economic evaluations. J Telemed Telecare. 2018;24(1):13–21.
23. Calvaresi D, Cesarini D, Sernani P, Marinoni M, Dragoni AF, Sturm A. Exploring the ambient assisted living domain: a systematic review. J Ambient Intell Humaniz Comput. 2017;8(2):239–57.
24. Munn Z, Peters MD, Stern C, Tufanaru C, M A. Aromataris ESrosrGfawcbasosra: Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. BMC Med Res Methodol. 2018;18(1):143.
25. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. s. 2005;8(1):19–32.
26. Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. Implementation Science. 2010;5(1):69.
27. Vonville H: Screening titles/abstracts, reviewing full text, and reporting results. In: 142nd APHA Annual Meeting and Exposition 2014. New Orleans; 2014.

28. Domhoff D, El Ali A, Huter K, Krick T, Stratmann TC, Wolf-Ostermann K, Rothgang H. Digitale, automatisierte Analyse von Literaturdatenbanken in Public Health und Pflegewissenschaft - Quantitative Textanalyse großer Ergebnismengen mittels Topc Modelinhg. Eine Darstellung am Beispiel neuer Technologien in der Pflege. In: Boll S, Hein A, Heuten W, Wolf-Ostermann K, editors. Zukunft der Pflege Tagungsband der 1 Clusterkonferenz 2018 "Innovative Technologien für die Pflege". Oldenburg: OFFIS - Institut für Informatik; 2018. p. 190–5.
29. Peters MD, Godfrey CM, Khalil H, McInerney P, Parker D, Soares CB. Guidance for conducting systematic scoping reviews. Int J Evid Based Healthc. 2015;13(3):141–6.
30. Kerres M. Mediendidaktik - Konzeption und Entwicklung digitaler Lernangebote, vol. 5., erweiterte Auflage. Berlin: De Gruyter; 2018.
31. Nazário DC, Campos PJ, Inacio EC, Dantas MAR: Quality of Context Evaluating Approach in AAL Environment Using IoT Technology. In: 2017 IEEE 30th International Symposium on Computer-Based Medical Systems (CBMS): 22-24 June 2017 2017; 2017: 558-563.
32. Weiss S, Bongartz H, Heuten W, Boll S. Applications Of Immersive VR in Nursing Education –A Review. In: Boll S, Hein A, Heuten W, Wolf-Ostermann K, editors. Zukunft der Pflege Tagungsband der 1 Clusterkonferenz 2018 "Innovative Technologien für die Pflege". Oldenburg: OFFIS - Institut für Informatik; 2018.
33. Seibert HH, Maddox RR, Flynn EA, Williams CK. Effect of barcode technology with electronic medication administration record on medication accuracy rates. Am J Health Syst Pharm. 2014;71(3):209–18.
34. Ching JM, Williams BL, Idemoto LM, Blackmore CC. Using Lean 'Automation with a Human Touch' to Improve Medication Safety: A Step Closer to the 'Perfect Dose. Joint Commission Journal on Quality & Patient Safety. 2014; 40(8):341–50.
35. Novak LL, Anders S, Gadd CS, Lorenzi NM, Novak LL, Anders S, Gadd CS, Lorenzi NM. Mediation of adoption and use: a key strategy for mitigating unintended consequences of health IT implementation. J Am Med Inform Assoc. 2012;19(6):1043–9.
36. Albrecht UV, Behrends M, Matthies HK, Von Jan U. Usage of multilingual mobile translation applications in clinical settings. J Med Internet Res. 2013; (4):15.
37. Chuang ST, Liu YF, Fu ZX, Liu KC, Chien SH, Lin CL, Lin PY. Application of a smartphone nurse call system for nursing care. Telemed J E-Health. 2015; 21(2):105–9.
38. Cohen C, Kampel T, Verloo H. Acceptability of an intelligent wireless sensor system for the rapid detection of health issues: findings among home-dwelling older adults and their informal caregivers. In: Patient preference and adherence, vol. 10; 2016. p. 1687–95.
39. Chu M-T, Khosla R, Khaksar SMS, Nguyen K. Service innovation through social robot engagement to improve dementia care quality. Assistive Technol. 2017;29(1):8–18.
40. Birks M, Bodak M, Barlas J, Harwood J, Pether M. Robotic Seals as Therapeutic Tools in an Aged Care Facility: A Qualitative Study. Journal of Aging Research. 2016;2016.
41. Jacobs T, Graf B: Practical evaluation of service robots for support and routine tasks in an elderly care facility. In: 2012 IEEE Workshop on Advanced Robotics and its Social Impacts (ARSO): 21-23 May 2012 2012; 2012: 46-49.
42. Lyngstad M, Hofoss D, Grimsmo A, Hellesø R. Predictors for assessing electronic messaging between nurses and general practitioners as a useful tool for communication in home health care services: A cross-sectional study. J Med Internet Res. 2015;17(2).
43. Mazzacano SD, McSherry T, Atterbury M, Helmold E, Gartner S, Schulman C. Effect of virtual reality distraction therapy on pain and anxiety in adult patients undergoing complex dressing changes: a randomized controlled trial. J Burn Care Res. 37, 2016:S157.
44. Verkuyl M, Atack L, Mastrilli P, Romaniuk D. Virtual gaming to develop students' pediatric nursing skills: A usability test. Nurse Education Today. 2016;46:81–5.
45. Dubovi I, Levy ST, Dagan E. Now I know how! The learning process of medication administration among nursing students with non-immersive desktop virtual reality simulation. Comput Educ. 2017;113:16–27.
46. Yamamoto M, Takabayashi N, Ono K, Watanabe T, Ishii Y. Development of a nursing communication education support system using nurse-patient embodied avatars with a smile and eyeball movement model. In: 2014 IEEE/ SICE International Symposium on System Integration: 13-15 Dec. 2014, vol. 2014; 2014. p. 175–80.
47. Ackley BJ, Swan BA, Ladwig G, Tucker S. Evidence-based nursing care guidelines: Medical-surgical interventions. St. Louis, MO: Mosby Elsevier; 2008.
48. Concato J. Observational Versus Experimental Studies: What's the Evidence for a Hierarchy? NeuroRx. 2004;1(3):341–7.
49. Febretti A, Lopez KD, Stifter J, Johnson AE, Keenan G, Wilkie D. Evaluating a Clinical Decision Support Interface for End-of-life Nurse Care. In: CHI ?14 Extended Abstracts on Human Factors in Computing Systems, vol. 2014. New York, NY, USA: ACM; 2014. p. 1633–8.
50. Ferrari M, Harrison B, Rawashdeh O, Hammond R, Avery Y, Rawashdeh M, Sa'deh W, Maddens M. Clinical Feasibility Trial of a Motion Detection System for Fall Prevention in Hospitalized Older Adult Patients. Geriatric Nursing. 2012;33(3):177–83.
51. Garrido JE, Penichet VMR, Lozano MD, Valls JAF. Automatic detection of falls and fainting. J Univ Comput Sci. 2013;19(8):1105–22.
52. Grice PM, Killpack MD, Jain A, Vaish S, Hawke J, Kemp CC: Whole-arm tactile sensing for beneficial and acceptable contact during robotic assistance. In: IEEE International Conference on Rehabilitation Robotics: 2013; 2013.
53. Gross HM, Schroeter C, Mueller S, Volkhardt M, Einhorn E, Bley A, Langner T, Merten M, Huijnen C, Heuvel Hvd et al: Further progress towards a home robot companion for people with mild cognitive impairment. 2012 IEEE International Conference on Systems, Man, and Cybernetics (SMC): 14-17 Oct. 2012 2012; 2012: 637-644.
54. Hawley-Hague H, Boulton E, Hall A, Pfeiffer K, Todd C. Older adults' perceptions of technologies aimed at falls prevention, detection or monitoring: A systematic review. Int J Med Inf. 2014;83(6):416–26.
55. Peek STM, Wouters EJM, van Hoof J, Luijkx KG, Boeije HR, Vrijhoef HJM. Factors influencing acceptance of technology for aging in place: A systematic review. Int J Med Inf. 2014;83(4):235–48.
56. Radhakrishnan K, Xie B, Berkley A, Kim M. Barriers and Facilitators for Sustainability of Tele-Homecare Programs: A Systematic Review. Health Serv Res. 2016;51(1):48–75.
57. Young LB, Chan PS, Cram P, Young LB, Chan PS, Cram P. Staff acceptance of tele-ICU coverage: a systematic review. Chest. 2011;139(2):279–88.
58. Jøranson N, Pedersen I, Rokstad AMM, Ihlebæk C. Effects on Symptoms of Agitation and Depression in Persons With Dementia Participating in Robot-Assisted Activity: A Cluster-Randomized Controlled Trial. J Am Med Dir Assoc. 2015;16(10):867–73.
59. Jøranson N, Pedersen I, Rokstad AMM, Ihlebæk C. Change in quality of life in older people with dementia participating in Paro-activity: a cluster-randomized controlled trial. J Adv Nurs. 2016;72(12):3020–33.
60. Liang A, Piroth I, Robinson H, MacDonald B, Fisher M, Nater UM, Skoluda N, Broadbent E. A Pilot Randomized Trial of a Companion Robot for People With Dementia Living in the Community. J Am Med Dir Assoc. 2017;18(10): 871–8.
61. Moyle W, Cooke M, Beattie E, Jones C, Klein B, Cook G, Gray C. Exploring the effect of companion robots on emotional expression in older adults with dementia: a pilot randomized controlled trial. J Gerontol Nurs. 2013;39:46–53.
62. Petersen S, Houston S, Qin H, Tague C, Studley J. The Utilization of Robotic Pets in Dementia Care. In: J Alzheimer's Dis, vol. 55; 2017. p. 569–74.
63. Robinson H, MacDonald B, Kerse N, Broadbent E. The Psychosocial Effects of a Companion Robot: A Randomized Controlled Trial. J Am Med Dir Assoc. 2013;14(9):661–7.
64. Valenti SM, Aguera-Ortiz L, Olazaran RJ, Mendoza RC, Perez MA, Rodriguez PI, Osa RE, Barrios SA, Herrero CV, Carrasco CL, et al. Social robots in advanced dementia. Front Aging Neurosci. 2015;7.
65. Sinclair PM, Kable A, Levett-Jones T, Booth D. The effectiveness of Internet-based e-learning on clinician behaviour and patient outcomes: A systematic review. Int J Nurs Stud. 2016;57:70–81.
66. Hopewell S, Loudon K, Clarke M, Oxman A, Dickersin K. Publication bias in clinical trials due to statistical significance or direction of trial results. Cochrane Database Syst Rev. 2009;21(1).

Publisher's Note

Additional file 1: Overview of all included studies

Nr.	Authors	Year	Title
1	M. Aanesen, A. T. Lotherington and F. Olsen	2011	Smarter elder care? A cost-effectiveness analysis of implementing technology in elder care
2	K. S. Abate	2013	The Effect of Podcast Lectures on Nursing Students' Knowledge Retention and Application
3	B. Abdelbari, D. Lieve, M. Eric, a. Frank Van Fraeyenhove and S. Dirk	2012	Falls prevention in a palliative care unit: evaluation of an infrared sensor device
4	A. P. Achilleos, C. Mettouris, G. A. Papadopoulos, K. Neureiter, C. Rappold, C. Moser, M. Tscheligi, L. Vajda, A. Tóth, P. Hanák, O. Jimenez and R. Smit	2013	The connected vitality system: Enhancing social presence for older adults
5	J. Adler-Milstein and A. K. Jha	2017	HITECH Act Drove Large Gains In Hospital Electronic Health Record Adoption
6	S. Ahmadzada, M. A. Zayyad and M. Toycan	2016	Readiness assessment for the use of cloud computing in eHealth systems: A field study of hospitals in the capital of Azerbaijan
7	H. S. Ahn, M. H. Lee, E. Broadbent and B. A. MacDonald	2017	Gathering Healthcare Service Robot Requirements from Young People’s Perceptions of an Older Care Robot
8	C. Aileen Wai-Kiu, C. Sek-Ying, J. Wing-Hung Sit, E. Mi-Ling Wong, D. Tze-Fun Lee and O. Wai-Man Fung	2016	Case-Based Web Learning Versus Face-to-Face Learning: A Mixed-Method Study on University Nursing Students
9	M. Akiyama and Y. Sasaki	2013	Efficacy of the drug administration support system for improving drug compliance in home-care
10	N. Al Saleem and A. Al Harthy	2015	Innovative information systems in the intensive care unit, king saud medical city in Saudi Arabia
11	A. Alaiad and L. Zhou	2015	Patients' Behavioral Intentions toward Using WSN Based Smart Home Healthcare Systems: An Empirical Investigation
12	A. Alaiad and L. Zhou	2017	Patients' Adoption of WSN-Based Smart Home Healthcare Systems: An Integrated Model of Facilitators and Barriers
13	I. Alakärppä, S. Larsson, J. Riekki and E. Jaakkola	2011	Sound aided interface of a pervasive pain monitoring system
14	M. B. Alazzam, A. S. H. Basari, A. S. Sibghatullah, M. R. Ramli, M. M. Jaber and M. H. Naim	2016	Pilot study of EHRs acceptance in Jordan hospitals by UTAUT2
15	U. V. Albrecht, M. Behrends, H. K. Matthies and U. Von Jan	2013	Usage of multilingual mobile translation applications in clinical settings
16	J. Alcalá, O. Parson and A. Rogers	2015	Detecting anomalies in activities of daily living of elderly residents via energy disaggregation and Cox processes
17	A. Y. Aldehaim, F. F. Alotaibi, C. R. Uphold and S. Dang	2016	The Impact of Technology-Based Interventions on Informal Caregivers of Stroke Survivors: A Systematic Review
18	G. L. Alexander, R. W. Madsen, E. L. Miller, M. K. Schaumberg, A. E. Holm, R. L. Alexander, K. K. Wise, M. L. Dougherty and B. Gugerty	2017	A national report of nursing home information technology: year 1 results
19	G. L. Alexander, R. W. Madsen, E. L. Miller, D. S. Wakefield, K. K. Wise and R. L. Alexander	2017	The State of Nursing Home Information Technology Sophistication in Rural and Nonrural US Markets
20	G. L. Alexander, K. S. Pasupathy, L. M. Steege, E. B. Strecker and K. M. Carley	2014	Multi-disciplinary communication networks for skin risk assessment in nursing homes with high IT sophistication
21	G. L. Alexander, L. M. Steege, K. S. Pasupathy and K. Wise	2015	Case studies of IT sophistication in nursing homes: A mixed method approach to examine communication strategies about pressure ulcer prevention practices
22	A. Almutairi and R. M. Crindle	2015	A pilot study in Jeddah City of nurses perceptions of Electronic Medical Records
23	H. Aloulou, M. Mokhtari, T. Tiberghien, J. Biswas, C. Phua, J. H. Kenneth Lin and P. Yap	2013	Deployment of assistive living technology in a nursing home environment: Methods and lessons learned
24	M. H. Alsulami and A. S. Atkins	2016	Factors Influencing Ageing Population for Adopting Ambient Assisted Living Technologies in the Kingdom of Saudi Arabia
25	M. M. Altuwaijri	2011	Achieving excellence in Electronic Health Record deployment in Middle East hospitals

26	A. G. Alvarez and G. T. M. Dal Sasso	2011	Virtual Learning Object for the Simulated Evaluation of Acute Pain in Nursing Students
27	J. Alwin, J. Persson and B. Krevers	2013	Perception and significance of an assistive technology intervention - the perspectives of relatives of persons with dementia*
28	A. Aman	2013	Clinical information systems in private hospitals
29	M. Amiribesheli and A. Bouchachia	2016	Towards Dementia-Friendly Smart Homes
30	T. Ando, M. Takeda, T. Maruyama, Y. Susuki, T. Hirose, S. Fujioka, O. Mizuno, K. Yamada, Y. Ohno and H. Yukio	2013	Biosignal-based relaxation evaluation of head-care robot
31	S. Andreadis, T. G. Stavropoulos, G. Meditskos and I. Kompatsiaris	2016	Dem@home: Ambient intelligence for clinical support of people living with dementia
32	C. M. Angst, S. Devaraj and J. D'Arcy	2012	Dual role of IT-assisted communication in patient care: A validated structure-process-outcome framework
33	A. Appari, E. K. Carian, M. E. Johnson and D. L. Anthony	2012	Medication administration quality and health information technology: a national study of US hospitals
34	A. Appari, E. M. Johnson and D. L. Anthony	2014	Information technology and hospital patient safety: a cross-sectional study of US acute care hospitals
35	C. Arditi, M. Rège-Walther, J. C. Wyatt, P. Durieux and B. Burnand	2012	Computer-generated reminders delivered on paper to healthcare professionals; effects on professional practice and health care outcomes
36	L. E. Arenas, P. J. Bedoya, L. Correa, J. G. Barreneche and A. M. Hernández	2017	Usability evaluation for a vital signs monitor prototype
37	N. Armstrong	2012	Design, development and evaluation of assistive technologies to assist people with Alzheimers disease by supporting their caregivers
38	I. Asghar, S. Cang and H. Yu	2018	Usability evaluation of assistive technologies through qualitative research focusing on people with mild dementia
39	C. C. V. Avelino, F. R. Borges, C. M. Inagaki, M. De Abreu Nery and S. L. T. Goyatá	2016	Development of a course in the virtual learning environment on the ICNP
40	M. Azarm-Daigle, C. Kuziemsky and L. Peyton	2015	A review of cross organizational healthcare data sharing
41	O. Aziz and S. N. Robinovitch	2011	An Analysis of the Accuracy of Wearable Sensors for Classifying the Causes of Falls in Humans
42	D. ÃztÃ¼rk and L. DinÃ§	2014	Effect of web-based education on nursing students' urinary catheterization knowledge and skills
43	M. M. Baig and H. GholamHosseini	2013	Wireless remote patient monitoring in older adults
44	M. M. Baig, H. GholamHosseini, M. J. Connolly and G. Kashfi	2014	A wireless patient monitoring system for hospitalized older adults: Acceptability, reliability and accuracy evaluation
45	S. Baisch, T. Kolling, S. Rühl, B. Klein, J. Pantel, F. Oswald and M. Knopf	2018	Emotional robots in a nursing context: Empirical analysis of the present use and the effects of Paro and Pleo
46	H. U. Balaguera, D. Wise, C. Y. Ng, H. W. Tso, W. L. Chiang, A. M. Hutchinson, T. Galvin, L. Hilborne, C. Hoffman, C. C. Huang and C. J. Wang	2017	Using a Medical Intranet of Things System to Prevent Bed Falls in an Acute Care Hospital: A Pilot Study
47	W. Bani-issa, N. Al Yateem, I. K. Al Makhzoomy and A. Ibrahim	2016	Satisfaction of health-care providers with electronic health records and perceived barriers to its implementation in the United Arab Emirates
48	A. Bankole, M. Anderson, A. Knight, K. Oh, T. Smith-Jackson, M. A. Hanson, A. T. Barth and J. Lach	2011	Continuous, Non-invasive Assessment of Agitation in Dementia Using Inertial Body Sensors
49	A. Barriga, J. M. Conejero, J. Hernández, E. Jurado, E. Moguel and F. Sánchez-Figueroa	2016	A vision-based approach for building telecare and telerehabilitation services
50	M. Baslyman, R. Rezaee, D. Amyot, A. Mouttham, R. Chreyh, G. Geiger, A. Stewart and S. Sader	2015	Real-time and Location-based Hand Hygiene Monitoring and Notification: Proof-of-concept System and Experimentation
51	L. Battista and G. Summa	2016	Preliminary evaluation of a wireless remote monitoring system for home mechanical ventilation
52	U. Bayen, A. Dogangün, T. Grundgeiger, A. Haese, G. Stockmanns and J. Ziegler	2013	Evaluating the effectiveness of a memory aid system

53	E. A. Beccaluva, A. Bonarini, R. Cerabolini, F. Clasadonte, F. Garzotto, M. Gelsomini, V. A. Iannelli, F. Monaco and L. Viola	2017	Exploring engagement with robots among persons with neurodevelopmental disorders
54	K. Beedholm, K. Frederiksen and K. Lomborg	2016	What Was (Also) at Stake When a Robot Bathtub Was Implemented in a Danish Elder Center: A Constructivist Secondary Qualitative Analysis
55	A. N. Belbachir, M. Litzenberger, S. Schraml, M. Hofstätter, D. Bauer, P. Schön, M. Humenberger, C. Sulzbachner, T. Lunden and M. Merne	2012	CARE: A dynamic stereo vision sensor system for fall detection
56	M. Belshaw, B. Taati, J. Snoek and A. Mihailidis	2012	Towards a Single Sensor Passive Solution for Automated Fall Detection?Falling in the home is one of the major challenges to independent living among older adults. The associated costs, coupled with a rapidly growing elderly population, are placing a burden on healthcare systems worldwide that will swiftly become unbearable. To facilitate expeditious emergency care, we have developed an artificially intelligent camera-based system that automatically detects if a person within the field-of-view has fallen. The system addresses concerns raised in earlier work and the requirements of a widely deployable in-home solution. The presented prototype utilizes a consumer-grade camera modified with a wide-angle lens. Machine learning techniques applied to carefully engineered features allow the system to classify falls at high accuracy while maintaining invariance to lighting, environment and the presence of multiple moving objects. This paper describes the system, outlines the algorithms used and presents empirical validation of its effectiveness. I.
57	J. A. G. Beltran, M. C. Leon, A. I. G. Martınez and J. I. N. Hipolito	2014	Health emergency event notification system, towards to the seamless service mobility
58	R. Bemelmans, G. J. Gelderblom, P. Jonker and L. de Witte	2012	Socially Assistive Robots in Elderly Care: A Systematic Review into Effects and Effectiveness
59	R. Bemelmans, G. J. Gelderblom, P. Jonker and L. de Witte	2015	Effectiveness of Robot Paro in Intramural Psychogeriatric Care: A Multicenter Quasi-Experimental Study
60	C. C. Bennett, S. Sabanovic, J. A. Piatt, S. Nagata, L. Eldridge and N. Randall	2017	A Robot a Day Keeps the Blues Away
61	K. Bennett, F. Grasso, V. Lowers, A. McKay and C. Milligan	2015	Evaluation of an App to Support Older Adults with Wounds
62	R. Berenbaum, Y. Lange and L. Abramowitz	2011	Augmentative Alternative Communication for Alzheimer?s Patients and Families? Using SAVION
63	S. D. Bersch, C. M. J. Chislett, D. Azzi, R. Kusainov and J. S. Briggs	2011	Activity detection using frequency analysis and off-the-shelf devices: Fall detection from accelerometer data
64	M. Bettinelli, Y. Lei, M. Beane, C. Mackey and T. Liesching	2015	Does Robotic Telerounding Enhance Nurse-Physician Collaboration Satisfaction About Care Decisions?
65	L. M. Beuscher, F. Jing, N. Sarkar, M. S. Dietrich, P. A. Newhouse, K. F. Miller and L. C. Mion	2017	Socially Assistive Robots: Measuring Older Adults' Perceptions
66	K. C. Bezboruah, D. Paulson and J. Smith	2014	Management attitudes and technology adoption in long-term care facilities
67	P. Bhattarai and J. Phillips	2017	The role of digital health technologies in management of pain in older people: an integrative review
68	A. A. Bindakheel, A. Bulgiba and R. Omar	2014	Adoption of information communication technology at a hospital: A case study of the King Fahad Medical City
69	M. Birks, M. Bodak, J. Barlas, J. Harwood and M. Pether	2016	Robotic Seals as Therapeutic Tools in an Aged Care Facility: A Qualitative Study
70	M. Birks, P. Hartin, C. Woods, E. Emmanuel and M. Hitchins	2016	Students' perceptions of the use of eportfolios in nursing and midwifery education
71	J. D. Blakey, D. Guy, C. Simpson, A. Fearn, S. Cannaby, P. Wilson and D. Shaw	2012	Multimodal observational assessment of quality and productivity benefits from the implementation of wireless technology for out of hours working
72	D. Blum, S. X. Raj, R. Oberholzer, I. I. Riphagen, F. Strasser and S. Kaasa	2015	Computer-Based Clinical Decision Support Systems and Patient-Reported Outcomes: A Systematic Review
73	M. E. Bobillier Chaumon, S. Bekkadja, F. Cros and B. Cuvillier	2014	The user-centered design of an ambient technology for preventing falls at home

74	W. Boonchieng, E. Boonchieng, W. Tuanrat, C. Khuntichot and K. Duangchaemkarn	2017	Integrative system of virtual electronic health record with online community-based health determinant data for home care service: MHealth development and usability test
75	R. G. Booth, B. Sinclair, G. Strudwick, L. Brennan, J. Tong, H. Relouw, M. Hancock and W. Vlasic	2017	Identifying Error Types Made by Nursing Students Using eMAR Technology
76	E. Børøsund, C. M. Ruland, S. Moore and M. Ekstedt	2014	Nurses' experiences of using an interactive tailored patient assessment tool one year past implementation
77	S. Bouakaz, M. Vacher, M. E. Bobillier Chaumon, F. Aman, S. Bekkadja, F. Portet, E. Guillou, S. Rossato, E. Desserée, P. Traineau, J. P. Vimont and T. Chevalier	2014	CIRDO: Smart companion for helping elderly to live at home for longer
78	D. J. Bouvier, J. G. Hinz and C. A. Schmidt	2016	Pilot Study: User Acceptance of a Virtual Coach in a Mirror by Elderly Persons with Dementia
79	A. Bowes, A. Dawson and Greasley-Adams	2013	Literature review: the cost effectiveness of assistive technology in supporting people with dementia. Report to the Demtia Services Development Trust
80	K. H. Bowles, A. L. Hanlon, H. A. Glick, M. D. Naylor, M. O'Connor, B. Riegel, N. W. Shih and M. G. Weiner	2011	Clinical effectiveness, access to, and satisfaction with care using a telehomecare substitution intervention: a randomized controlled trial
81	L. Bowtell, A. A. Kist, D. Osbourne and V. Parker	2013	Improving clinical practice outcomes for nurses with an interactive emulator
82	L. Bowtell, C. Moloney, A. A. Kist, V. Parker, A. Maxwell and N. Reedy	2012	Using Remote Access Laboratories in nursing education
83	A. Boyd, J. Synnott, C. Nugent, D. Elliott and J. Kelly	2017	Community-based trials of mobile solutions for the detection and management of cognitive decline
84	S. L. Bradley	2011	A phenomenological exploration of nurses' perceptions of the effect of electronic documentation on healing relationships
85	D. Bragg, N. Huynh and R. E. Ladner	2016	A Personalizable Mobile Sound Detector App Design for Deaf and Hard-of-Hearing Users
86	Å. Brandt, J. Alwin, H. Anttila, K. Samuelsson and A.-L. Salminen	2012	Quality of evidence of assistive technology interventions for people with disability: An overview of systematic reviews
87	F. Braun, A. Lemkaddem, V. Moser, S. Dasen, O. Grossenbacher and M. Bertschi	2017	Contactless respiration monitoring in real-time via a video camera
88	C. Bräutigam, P. Enste, M. Evans, J. Hilbert, J. Merkel and F. Öz	2017	Digitalisierung im Krankenhaus. Mehr Technik - bessere Arbeit?
89	T. J. Bright, A. Wong, R. Dhurjati, E. Bristow, L. Bastian, R. R. Coeytaux, G. Samsa, V. Hasselblad, J. W. Williams, M. D. Musty, L. Wing, A. S. Kendrick, G. D. Sanders and D. Lobach	2012	Effect of clinical decision-support systems: A systematic review
90	E. Broadbent, N. Kerse, K. Peri, H. Robinson, C. Jayawardena, T. Kuo, C. Datta, R. Stafford, H. Butler, P. Jawalkar, M. Amor, B. Robins and B. MacDonald	2016	Benefits and problems of health-care robots in aged care settings: A comparison trial
91	E. Broadbent, J. R. Orejana, H. S. Ahn, J. Xie, P. Rouse and B. A. MacDonald	2015	The cost-effectiveness of a robot measuring vital signs in a rural medical practice
92	M. Browning, S. Cooper, R. Cant, L. Sparkes, F. Bogossian, B. Williams, P. O'Meara, L. Ross, G. Munro and B. Black	2016	The use and limits of eye-tracking in high-fidelity clinical scenarios: A pilot study
93	J. R. Bruun-Pedersen, S. Serafin and L. B. Kofoed	2016	Going Outside While Staying Inside — Exercise Motivation with Immersive vs. Non–immersive Recreational Virtual Environment Augmentation for Older Adult Nursing Home Residents
94	B. B. Bundschuh, R. W. Majeed, T. Bürkle, K. Kuhn, U. Sax, C. Seggewies, C. Vosseler and R. Röhrig	2011	Quality of human-computer interaction - Results of a national usability survey of hospital-IT in Germany
95	M. B. Buntin, M. F. Burke, M. C. Hoaglin and D. Blumenthal	2011	The Benefits Of Health Information Technology: A Review Of The Recent Literature Shows Predominantly Positive Results
96	A. Bygholm and A. M. Kanstrup	2014	Learning from an Ambient Assisted Living Lab: The case of the Intelligent Bed

97	R. G. Cady	2012	Measuring the Impact of Technology on Nurse Workflow: A Mixed Methods Approach
98	R. G. Cady and S. M. Finkelstein	2014	Task-technology fit of video telehealth for nurses in an outpatient clinic setting
99	H. Cai, E. Toft, O. Hejlesen, J. Hansen, C. Oestergaard and B. Dinesen	2015	Health professionals' user experience of the intelligent bed in patients' homes
100	D. Calvaresi, D. Cesarini, P. Sernani, M. Marinoni, A. F. Dragoni and A. Sturm	2017	Exploring the ambient assisted living domain: a systematic review
101	W. Cao, X. Liu and F. Li	2017	Robust device-free fall detection using fine-grained Wi-Fi signatures
102	D. Capurro, M. Ganzinger, J. Perez-Lu and P. Knaup	2014	Effectiveness of eHealth interventions and information needs in palliative care: a systematic literature review
103	P. Carayon, R. Cartmill, M. A. Blosky, R. Brown, M. Hackenberg, P. Hoonakker, A. S. Hundt, E. Norfolk, T. B. Wetterneck, J. M. Walker, P. Carayon, R. Cartmill, M. A. Blosky, R. Brown, M. Hackenberg, P. Hoonakker, A. S. Hundt, E. Norfolk, T. B. Wetterneck and J. M. Walker	2011	ICU nurses' acceptance of electronic health records
104	K. J. Carlson and D. J. Gagnon	2016	Augmented Reality Integrated Simulation Education in Health Care
105	S. H. Carpenter	2016	What deters nurses from participating in web-based graduate nursing programs?: A cross-sectional survey research study
106	S. Carretero, J. Stewart and C. Centeno	2015	Information and communication technologies for informal carers and paid assistants: benefits from micro-, meso-, and macro-levels
107	V. Castilho, A. F. C. Lima, F. M. T. Fugulin, H. H. C. Peres and R. R. Gaidzinski	2014	Total staff costs to implement a decision support system in nursing
108	L. Cattelani, F. Chesani, P. Palumbo, L. Palmerini, S. Bandinelli, C. Becker and L. Chiari	2014	FRAT-Up, a Rule-Based System Evaluating Fall Risk in the Elderly
109	F. Cavallo, M. Aquilano, M. Bonaccorsi, R. Limosani, A. Manzi, M. C. Carrozza and P. Dario	2013	On the design, development and experimentation of the ASTRO assistive robot integrated in smart environments
110	J. G. Cegarra-Navarro, A. K. P. Wensley and M. T. SÃ¡nchez-Polo	2011	Improving quality of service of home healthcare units with health information technologies
111	M. Chang, T. Yu, J. Luo, K. Duan, P. Tu, Y. Zhao, N. Nagraj, V. Rajiv, M. Priebe and M. Stachura	2017	Multi-Modal Sensor System for Pressure Ulcer Wound Assessment and Care
112	Y. J. Chang, C. H. Chen, L. F. Lin, R. P. Han, W. T. Huang and G. C. Lee	2012	Wireless sensor networks for vital signs monitoring: Application in a nursing home
113	S. Changping	2011	Application of SimMan universal patient simulator in the teaching of medical nursing
114	P. Chanyagorn, B. Kungwannarongkun and W. Chanyagorn	2016	Design of electronic nursing Kardex system for medication error prevention in IPD patients
115	Y. Charlon, E. Campo and D. Brulin	2018	Design and evaluation of a smart insole: Application for continuous monitoring of frail people at home
116	Y. Charlon, N. Fourty, W. Bourennane and E. Campo	2013	Design and evaluation of a device worn for fall detection and localization: Application for the continuous monitoring of risks incurred by dependents in an Alzheimer's care unit
117	N. Charness	2014	Utilizing Technology to Improve Older Adult Health
118	P. Chaurasia, S. I. McClean, C. D. Nugent, I. Cleland, S. Zhang, M. P. Donnelly, B. W. Scotney, C. Sanders, K. Smith, M. C. Norton and J. Tschanz	2016	Modelling assistive technology adoption for people with dementia
119	C. Chen, D. Zhang, L. Sun, M. Hariz and B. Jean-Bart	2013	AQUEDUC: improving quality and efficiency of care for elders in real homes
120	S. T. Chen, Y. G. L. Huang and I. T. Chiang	2012	Using Somatosensory Video Games to Promote Quality of Life for the Elderly with Disabilities
121	A. Cheng, W. Eppich, V. Grant, J. Sherbino, B. Zendejas and D. A. Cook	2014	Debriefing for technology-enhanced simulation: a systematic review and meta-analysis
122	Y. M. Cheng	2013	Exploring the roles of interaction and flow in explaining nurses' e-learning acceptance

123	J. Cherian, V. Rajanna, D. Goldberg and T. Hammond	2017	Did You Remember to Brush?: A Noninvasive Wearable Approach to Recognizing Brushing Teeth for Elderly Care
124	N. Chi and G. Demiris	2015	A systematic review of telehealth tools and interventions to support family caregivers
125	K. F. Chiang and H. H. Wang	2016	Nurses' experiences of using a smart mobile device application to assist home care for patients with chronic disease: A qualitative study
126	J. M. Ching, B. L. Williams, L. M. Idemoto and C. C. Blackmore	2014	Using Lean 'Automation with a Human Touch' to Improve Medication Safety: A Step Closer to the 'Perfect Dose'
127	C. Chi-Ping, L. Ting-Ting, L. Chia-Hui and M. E. Mills	2016	Nurses' Experiences of an Initial and Reimplemented Electronic Health Record Use
128	J. Chipps, P. Brysiewicz and M. Mars	2012	A Systematic Review of the Effectiveness of Videoconference-Based Tele-Education for Medical and Nursing Education
129	Y.-S. Choi, E. Lawler, C. A. Boenecke, E. R. Ponatoski and C. M. Zimring	2011	Developing a multi-systemic fall prevention model, incorporating the physical environment, the care process and technology: a systematic review
130	S. K. Y. Chow, W.-Y. Chin, H.-Y. Lee, H.-C. Leung and F.-H. Tang	2012	Nurses' perceptions and attitudes towards computerisation in a private hospital
131	S. Christiansen and A. Rethmeier	2015	Preparing Student Nurses for the Future of Wound Management: Telemedicine in a Simulated Learning Environment
132	M.-T. Chu, R. Khosla, S. M. S. Khaksar and K. Nguyen	2017	Service innovation through social robot engagement to improve dementia care quality
133	S. T. Chuang, Y. F. Liu, Z. X. Fu, K. C. Liu, S. H. Chien, C. L. Lin and P. Y. Lin	2015	Application of a smartphone nurse call system for nursing care
134	J. Chung and I. Cho	2017	The need for academic electronic health record systems in nurse education
135	J. Chung, G. Demiris, H. J. Thompson, K.-Y. Chen, R. Burr, S. Patel and J. Fogarty	2017	Feasibility testing of a home-based sensor system to monitor mobility and daily activities in Korean American older adults
136	J. Chung, H. J. Thompson, J. Joe, A. Hall and G. Demiris	2017	Examining Korean and Korean American older adults' perceived acceptability of home-based monitoring technologies in the context of culture
137	N. J. Cibulka and L. Crane-Wider	2011	Introducing Personal Digital Assistants to Enhance Nursing Education in Undergraduate and Graduate Nursing Programs
138	V. Claes, E. Devriendt, J. Tournoy and K. Milisen	2015	Attitudes and perceptions of adults of 60 years and older towards in-home monitoring of the activities of daily living with contactless sensors: An explorative study
139	J. Clark and M. McGee-Lennon	2011	A stakeholder-centred exploration of the current barriers to the uptake of home care technology in the UK
140	C. N. Clarke, S. H. Patel, R. W. Day, S. George, C. Sweeney, G. A. Monetes De Oca, M. A. Aiss, E. G. Grubbs, B. K. Bednarski, J. E. Lee, D. C. Bodurka, J. M. Skibber and T. A. Aloia	2017	Implementation of a standardized electronic tool improves compliance, accuracy, and efficiency of trainee-to-trainee patient care handoffs after complex general surgical oncology procedures
141	C. Cohen, T. Kampel and H. Verloo	2016	Acceptability of an intelligent wireless sensor system for the rapid detection of health issues: findings among home-dwelling older adults and their informal caregivers
142	M. Colombo, E. Marelli, R. Vaccaro, E. Valle, S. Colombani, E. Polesel, S. Garolfi, S. Fossi and A. Guaita	2012	Virtual reality for persons with dementia: An exergaming experience
143	E. J. Cook, G. Randhawa, A. Guppy, C. Sharp, G. Barton, A. Bateman and J. Crawford-White	2017	Exploring factors that impact the decision to use assistive telecare: perspectives of family care-givers of older people in the United Kingdom
144	F. Corno, L. D. Russis and A. M. Roffarello	2016	A Healthcare Support System for Assisted Living Facilities: An IoT Solution
145	H. Courtney-Pratt, E. Cummings, P. Turner, H. Cameron-Tucker, R. Wood-Baker, E. Walters and A. Robinson	2012	Entering a world of uncertainty: community nurses' engagement with information and communication technology
146	K. Cresswell, A. Majeed, D. W. Bates and A. Sheikh	2012	Computerised decision support systems for healthcare professionals: an interpretative review
147	Y. Dahl and K. Holbø	2012	Value Biases of Sensor-based Assistive Technology: Case Study of a GPS Tracking System Used in Dementia Care

148	F. DallaLibera, Y. Tsusaka, Y. Okazaki, R. Futakuchi, M. Yamamoto, N. Shikata and M. Terashima	2016	Analysis of velocity's influence on forces and muscular activity in the context of sit-to-stand motion assisted by an elderly care robot
149	J. Damant, M. Knapp, P. Freddolino and D. Lombard	2017	Effects of digital engagement on the quality of life of older people
150	A. Davies, L. Rixon and S. Newman	2013	Systematic review of the effects of telecare provided for a person with social care needs on outcomes for their informal carers
151	S. R. W. de Almeida, G. T. M. Dal Sasso and D. C. C. Barra	2016	Computerized nursing process in the Intensive Care Unit: Ergonomics and usability
152	J. C. De Gagne	2011	The impact of clickers in nursing education: A review of literature
153	F. S. N. de Góes, L. M. M. Fonseca, R. A. A. de Camargo, G. F. de Oliveira and H. R. Felipe	2015	Educational technology "Anatomy and Vital Signs": Evaluation study of content, appearance and usability
154	E. Delbreil and G. Zvobgo	2013	Wireless sensor technology in dementia care : Caregiver perceptions, technology take-up and business model innovation
155	C. M. DesRoches, P. Miralles, P. Buerhaus, R. Hess and K. Donelan	2011	Health information technology in the workplace: Findings from a 2010 national survey of registered nurses
156	A. Di Nuovo, F. Broz, N. Wang, T. Belpaeme, A. Cangelosi, R. Jones, R. Esposito, F. Cavallo and P. Dario	2017	The multi-modal interface of Robot-Era multi-robot services tailored for the elderly
157	A. Di Nuovo, N. Wang, F. Broz, T. Belpaeme, R. Jones and A. Cangelosi	2016	Experimental evaluation of a multi-modal user interface for a robotic service
158	N. Dimitrioglou, D. Kardaras and S. Barbounaki	2017	Multicriteria Evaluation of the Internet of Things Potential in Health Care: The Case of Dementia Care
159	M. Ding, R. Ikeura, Y. Mori, T. Mukai and S. Hosoe	2013	Measurement of human body stiffness for lifting-up motion generation using nursing-care assistant robot — RIBA
160	M. Ding, R. Ikeura, Y. Mori, T. Mukai and S. Hosoe	2014	Lift-up motion generation of nursing-care assistant robot based on human muscle force and body softness estimation
161	M. Ding, R. Ikeura, T. Mukai, H. Nagashima, S. Hirano, K. Matsuo, M. Sun, C. Jiang and S. Hosoe	2012	Comfort estimation during lift-up using nursing-care robot — RIBA
162	G. D'Onofrio, O. James, D. Sancarlo, F. Ricciardi, K. Murphy, F. Giuliani, D. Casey and A. Greco	2016	Managing active and healthy aging with use of caring service robots (MARIO)
163	G. D'Onofrio, O. James, D. Sancarlo, F. Ricciardi, K. Murphy, F. Giuliani, D. Casey and A. Greco	2016	Evaluation of the acceptability of a caring service robot (MARIO)
164	G. D'Onofrio, D. Sancarlo, F. Ricciardi, F. Panza, D. Seripa, F. Cavallo, F. Giuliani and A. Greco	2017	Information and Communication Technologies for the Activities of Daily Living in Older Patients with Dementia: A Systematic Review
165	C. N. Doukas and I. Maglogiannis	2011	Emergency Fall Incidents Detection in Assisted Living Environments Utilizing Motion, Sound, and Visual Perceptual Components
166	F. Drews and A. Doig	2014	Evaluation of a configural vital signs display for intensive care unit nurses
167	I. Dubovi, S. T. Levy and E. Dagan	2017	Now I know how! The learning process of medication administration among nursing students with non-immersive desktop virtual reality simulation
168	J. J. Duvall	2012	Motivation and technological readiness in the use of high-fidelity simulation: A descriptive comparative study of nurse educators
169	J. A. dx.Nielsen and L. Mathiassen	2013	Interpretive flexibility in mobile health: Lessons from a government-sponsored home care program
170	P. C. Dykes, E. H. I-Ching, J. R. Soukup, F. Chang and S. Lipsitz	2012	A case control study to improve accuracy of an electronic fall prevention toolkit
171	A. D. Edgcomb	2014	Automated Video-Based Fall Detection
172	M. Eldib, F. Deboeverie, D. V. Haerenborgh, W. Philips and H. Aghajan	2015	Detection of Visitors in Elderly Care Using a Low-resolution Visual Sensor Network
173	M. Eldib, F. Deboeverie, W. Philips and H. Aghajan	2016	Behavior analysis for elderly care using a network of low-resolution visual sensors
174	A. Ennis, J. Rafferty, J. Synnott, I. Cleland, C. Nugent, A. Selby, S. McIlroy, A. Berthelot and G. Masci	2017	A smart cabinet and voice assistant to support independence in older adults

175	B. Erol, M. G. Amin and B. Boashash	2017	Range-Doppler radar sensor fusion for fall detection
176	M. Z. Eslami, A. Zarghami, M. v. Sinderen and R. Wieringa	2013	Care-giver tailoring of IT-based healthcare services for elderly at home: A field test and its results
177	A. M. M. C. Espingardeiro	2014	A roboethics framework for the development and introduction of social assistive robots in elderly care
178	I. Eyers, B. Carey-Smith, N. Evans and R. Orpwood	2013	Safe and sound? Night-time checking in care homes
179	U. Fachinger, B. Schöpke and S. Helten	2015	Zur ökonomischen Relevanz von Lösungen zur Sturzerkennung
180	M. Fagan, C. Kilmon and V. Pandey	2012	Exploring the adoption of a virtual reality simulation: The role of perceived ease of use, perceived usefulness and personal innovativeness
181	C. Fagerström, H. Tuvesson, L. Axelsson and L. Nilsson	2017	The role of ICT in nursing practice: an integrative literature review of the Swedish context
182	J. Fan, D. Bian, Z. Zheng, L. Beuscher, P. A. Newhouse, L. C. Mion and N. Sarkar	2017	A Robotic Coach Architecture for Elder Care (ROCARE) Based on Multi-User Engagement Models
183	K. Fan, P. Wang and S. Zhuang	2018	Human fall detection using slow feature analysis
184	B. A. Farshchian and Y. Dahl	2015	The Role of ICT in Addressing the Challenges of Age-related Falls: A Research Agenda Based on a Systematic Mapping of the Literature
185	A. Febretti, K. D. Lopez, J. Stifter, A. E. Johnson, G. Keenan and D. Wilkie	2014	Evaluating a Clinical Decision Support Interface for End-of-life Nurse Care
186	M. Ferrari, B. Harrison, O. Rawashdeh, R. Hammond, Y. Avery, M. Rawashdeh, W. Sa'deh and M. Maddens	2012	Clinical Feasibility Trial of a Motion Detection System for Fall Prevention in Hospitalized Older Adult Patients
187	R. Fiedler, J. Giddens and S. North	2014	Faculty Experience of a Technological Innovation in Nursing Education
188	S. H. Fischer, D. David, B. H. Crotty, M. Dierks and C. Safran	2014	Acceptance and use of health information technology by community-dwelling elders
189	R. Fleming and S. Sum	2014	Empirical studies on the effectiveness of assistive technology in the care of people with dementia: A systematic review
190	B. Florczak, A. Scheurich, J. Croghan, P. Sheridan Jr, D. Kurtz, W. McGill and B. McClain	2012	An observational study to assess an electronic point-of-care wound documentation and reporting system regarding user satisfaction and potential for improved care
191	M. Fossum, M. Ehnfors, A. Fruhling and A. Ehrenberg	2011	An evaluation of the usability of a computerized decision support system for nursing homes
192	K. Funate, R. Tasaki, T. Miyoshi, K. Kakihara and K. Terashima	2017	Motion control of novel power assist lift robot integrated with omnidirectional assist vehicle considering suppression of limit cycle at grounding
193	M. Gams, E. Dovgan, B. Cvetković, V. Mirćevska, B. Kaluža, M. Luštrek and I. Velez	2011	AAL for supporting elderly
194	J. P. García-Vázquez, M. D. Rodríguez, Á. G. Andrade and J. Bravo	2011	Supporting the Strategies to Improve Elders? Medication Compliance by Providing Ambient Aids
195	J. E. Garrido, V. M. R. Penichet, M. D. Lozano and J. A. F. Valls	2013	Automatic detection of falls and fainting
196	C. Garripoli, M. Mercuri, P. Karsmakers, P. J. Soh, G. Crupi, G. A. E. Vandenbosch, C. Pace, P. Leroux and D. Schreurs	2015	Embedded DSP-based telehealth radar system for remote in-door fall detection
197	M. Ghorbel, S. Betgé-Brezetz, M. P. Dupont, G. B. Kamga, S. Piekarec, J. Reerink and A. Vergnol	2013	Multimodal notification framework for elderly and professional in a smart nursing home
198	G. Gibson, C. Dickinson, K. Brittain and L. Robinson	2015	The everyday use of assistive technology by people with dementia and their family carers: A qualitative study
199	D. Gillham, K. Tucker, S. Parker, V. Wright and C. Kargillis	2015	CaseWorld™: Interactive, media rich, multidisciplinary case based learning
200	C. Göransson, I. Eriksson, K. Ziegert, Y. Wengström, A. Langius-Eklöf, M. Brovall, A. Kihlgren and K. Blomberg	2017	Testing an app for reporting health concerns-Experiences from older people and home care nurses
201	M. Gövercin, S. Meyer, M. Schellenbach, E. Steinhagen-Thiessen, B. Weiss, M. Haesner and M. Gövercin	2016	SmartSenior@home: Acceptance of an integrated ambient assisted living system. Results of a clinical field trial in 35 households

202	J. L. Grady	2011	The Virtual Clinical Practicum: An Innovative Telehealth Model for Clinical Nursing Education
203	T. Greenhalgh, J. Wherton, P. Sugarhood, S. Hinder, R. Procter and R. Stones	2013	What matters to older people with assisted living needs? A phenomenological analysis of the use and non-use of telehealth and telecare
204	P. M. Grice, M. D. Killpack, A. Jain, S. Vaish, J. Hawke and C. C. Kemp	2013	Whole-arm tactile sensing for beneficial and acceptable contact during robotic assistance
205	H. M. Gross, S. Mueller, C. Schroeter, M. Volkhardt, A. Scheidig, K. Debes, K. Richter and N. Doering	2015	Robot companion for domestic health assistance: Implementation, test and case study under everyday conditions in private apartments
206	H. M. Gross, C. Schroeter, S. Mueller, M. Volkhardt, E. Einhorn, A. Bley, T. Langner, M. Merten, C. Huijnen, H. v. d. Heuvel and A. v. Berlo	2012	Further progress towards a home robot companion for people with mild cognitive impairment
207	A. Grunerbl, G. Bahle, P. Lukowicz and F. Hanser	2011	Using Indoor Location to Assess the State of Dementia Patients: Results and Experience Report from a Long Term, Real World Study
208	P. Guitard, H. Sveistrup, A. Fahim and C. Leonard	2013	Smart grab bars: a potential initiative to encourage bath grab bar use in community dwelling older adults
209	C. Gustafsson, C. Svanberg and M. Müllersdorf	2015	Using a Robotic Cat in Dementia Care
210	R. M. Hall	2013	Effects of High Fidelity Simulation on Knowledge Acquisition, Self-Confidence, and Satisfaction with Baccalaureate Nursing Students Using the Solomon-Four Research Design
211	V. Hall, S. Conboy-Hill and D. Taylor	2011	Using virtual reality to provide health care information to people with intellectual disabilities: Acceptability, usability, and potential utility
212	M. Hanheide, D. Hebesberger and T. Krajnik	2017	The when, where, and how: an adaptive robotic info-terminal for care home residents ? a long-term study
213	C. Y. N. Hara, N. D. A. Aredes, L. M. M. Fonseca, R. C. d. C. P. Silveira, R. A. A. Camargo and F. S. N. de Goes	2016	Clinical case in digital technology for nursing students' learning: An integrative review
214	Hardin, Sr., J. Dienemann, P. Rudisill and K. Mills	2013	Inpatient fall prevention: use of in-room Webcams
215	C. S. Harmon, M. Fogle and L. Roussel	2015	Then and now: Nurses' perceptions of the electronic health record
216	A. Harris, H. True, Z. Hu, J. Cho, N. Fell and M. Sartipi	2016	Fall recognition using wearable technologies and machine learning algorithms
217	B. J. J. Hattink, F. J. M. Meiland, T. Overmars-Marx, M. de Boer, P. W. G. Ebben, M. van Blanken, S. Verhaeghe, I. Stalpers-Croeze, A. Jedlitschka, S. E. Flick, J. v/d Leeuw, I. Karkowski and R. M. Dröes	2016	The electronic, personalizable Rosetta system for dementia care: exploring the user-friendliness, usefulness and impact
218	H. Hawley-Hague, E. Boulton, A. Hall, K. Pfeiffer and C. Todd	2014	Older adults’ perceptions of technologies aimed at falls prevention, detection or monitoring: A systematic review
219	L. Hayden, S. Glynn, T. Hahn, F. Randall and E. Randolph	2012	The use of Internet technology for psychoeducation and support with dementia caregivers
220	K. Heidarizadeh, M. Rassouli, H. Manoochehri, M. Zagheri Tafreshi and R. Kashef Ghorbanpour	2017	Nurses' Perception of Challenges in the Use of an Electronic Nursing Documentation System
221	J. Helmy and A. Helmy	2016	The Alzimio App for Dementia, Autism & Alzheimer's: Using Novel Activity Recognition Algorithms and Geofencing
222	C. Henderson, M. Knapp, J. Fernández, J. Beecham, S. Hirani, M. Beynon, M. Cartwright, L. Rixon, H. Doll, P. Bower, A. Steventon, A. Rogers, R. Fitzpatrick, J. Barlow, M. Bardsley and S. Newman	2014	Cost-effectiveness of telecare for people with social care needs: the Whole Systems Demonstrator cluster randomised trial
223	V. M. Herbert and H. Connors	2016	Integrating an Academic Electronic Health Record: Challenges and Success Strategies
224	B. L. Hicken, C. Daniel, M. Luptak, M. Grant, S. Kilian and R. W. Rupper	2017	Supporting Caregivers of Rural Veterans Electronically (SCORE)
225	V. Hielscher	2014	Technikeinsatz und Arbeit in der_Altenpflege. Ergebnisse einer internationalen Literaturrecherche

226	V. Hielscher, L. Nock and S. Kirchen-Peters	2015	Technikeinsatz in der Altenpflege: Potenziale und Probleme in empirischer Perspektive
227	L. M. Hitt and P. Tambe	2016	Health care information technology, work organization, and nursing home performance
228	R. J. Holden, O. Asan, E. M. Wozniak, K. E. Flynn and M. C. Scanlon	2016	Nurses' perceptions, acceptance, and use of a novel in-room pediatric ICU technology: testing an expanded technology acceptance model
229	B. Holtz and S. Krein	2011	Understanding Nurse Perceptions of a Newly Implemented Electronic Medical Record System
230	E. Hoque, R. F. Dickerson, S. M. Preum, M. Hanson, A. Barth and J. A. Stankovic	2015	Holmes: A Comprehensive Anomaly Detection System for Daily In-home Activities
231	E. T. Horta, I. C. Lopes, J. J. P. C. Rodrigues and M. L. Proença	2013	A mobile health application for falls detection and biofeedback monitoring
232	M. A. Hossain and D. T. Ahmed	2012	Virtual Caregiver: An Ambient-Aware Elderly Monitoring System
233	Y. Hou, N. Li and Z. Huang	2012	Triaxial accelerometer-based real time fall event detection
234	T. V. How, R. H. Wang and A. Mihailidis	2013	Evaluation of an intelligent wheelchair system for older adults with cognitive impairments
235	J. Hsiao, H. Chang and R. Chen	2011	A study of factors affecting acceptance of hospital information systems: a nursing perspective
236	J.-L. Hsiao and R.-F. Chen	2012	An investigation on task-technology fit of mobile nursing information systems for nursing performance
237	S. H. Hsu, J. S. Sun, Y. J. Chou and C. W. Weng	2014	Developing intelligent human-machine interface for next generation ICU by using user-centered system development approach
238	Y. C. Hsu, C. H. Tsai, Y. M. Kuo, Lien and B. Ya-Hui	2016	Telecare services for elderly: Predictive factors of continued use intention
239	C. Hu, S. Kung, T. A. Rummans, M. M. Clark and M. I. Lapid	2015	Reducing caregiver stress with internet-based interventions: a systematic review of open-label and randomized controlled trials
240	N. Hu, R. Bormann, T. Zwölfer and B. Kröse	2014	Multi-user identification and efficient user approaching by fusing robot and ambient sensors
241	H. Huang and T.-t. Lee	2011	Evaluation of ICU nurses' use of the clinical information system in Taiwan
242	H.-Y. Huang and T.-T. Lee	2011	Impact of bar-code medication administration on nursing activity patterns and usage experience in Taiwan
243	Z. Huang, C. Lin, M. Kanai-Pak, J. Maeda, Y. Kitajima, M. Nakamura, N. Kuwahara, T. Ogata and J. Ota	2017	Impact of Using a Robot Patient for Nursing Skill Training in Patient Transfer
244	Z. Huang, A. Nagata, M. Kanai-Pak, J. Maeda, Y. Kitajima, M. Nakamura, K. Aida, N. Kuwahara, T. Ogata and J. Ota	2012	Development of a nursing self-training system for transferring patient from bed to wheelchair
245	Z. Huang, A. Nagata, M. Kanai-Pak, J. Maeda, Y. Kitajima, M. Nakamura, K. Aida, N. Kuwahara, T. Ogata and J. Ota	2014	Self-help training system for nursing students to learn patient transfer skills
246	H. Hung-Hsiou and W. Ya-Hui	2017	Investigation of the Effects of a Nursing Information System by Using the Technology Acceptance Model
247	G. B. Huq, J. Basilakis and A. Maeder	2016	Evaluation of Tri-axial Accelerometery Data of Falls for Elderly Through Smart Phone
248	I. Iacono and P. Marti	2016	Narratives and emotions in seniors affected by dementia: A comparative study using a robot and a toy
249	R. Igual, C. Medrano and I. Plaza	2013	Challenges, issues and trends in fall detection systems
250	P. Irwin and R. Coutts	2015	A Systematic Review of the Experience of Using Second Life in the Education of Undergraduate Nurses
251	C. Ishii, H. Yamamoto and D. Takigawa	2015	Development of a New Type of Lightweight Power Assist Suit for Transfer Work
252	T. Jacobs and B. Graf	2012	Practical evaluation of service robots for support and routine tasks in an elderly care facility
253	R. Janols and B. Göransson	2011	Same System?different Experiences: Physicians? and Nurses? Experiences in Using IT Systems
254	A. d. S. Jayatilaka	2017	Towards technologies for promoting nutritional health in older people with dementia living in their own home
255	C. Jayawardena, I. Kuo, C. Datta, R. Q. Stafford, E. Broadbent and B. A. MacDonald	2012	Design, implementation and field tests of a socially assistive robot for the elderly: HealthBot version 2

256	L. C. Jensen, K. Fischer, S. D. Suvei and L. Bodenhagen	2017	Timing of multimodal robot behaviors during human-robot collaboration
257	L. Jing and Z. Cheng	2017	Recognition of daily routines and accidental event with multipoint wearable inertial sensing for seniors home care
258	H. M. Johnsen, M. Fossum, P. Vivekananda-Schmidt, A. Fruhling and Å. Slettebø	2016	Teaching clinical reasoning and decision-making skills to nursing students: Design, development, and usability evaluation of a serious game
259	K. Johnson and P. Meskill	2012	Online Assessments - What do Students Prefer?
260	P. Jokinen and I. Mikkonen	2013	Teachers' experiences of teaching in a blended learning environment
261	N. Jøranson, I. Pedersen, A. M. M. Rokstad and C. Ihlebæk	2015	Effects on Symptoms of Agitation and Depression in Persons With Dementia Participating in Robot-Assisted Activity: A Cluster-Randomized Controlled Trial
262	N. Jøranson, I. Pedersen, A. M. M. Rokstad and C. Ihlebæk	2016	Change in quality of life in older people with dementia participating in Paro-activity: a cluster-randomized controlled trial
263	C. Jousselme, R. Vialet, E. Jouve, P. Lagier, C. Martin and F. Michel	2011	Efficacy and mode of action of a noise-sensor light alarm to decrease noise in the pediatric intensive care unit: a prospective, randomized study
264	R. Kachouie, S. Sedighadeli, R. Khosla and M. T. Chu	2014	Socially Assistive Robots in Elderly Care: A Mixed-Method Systematic Literature Review
265	E. Kańtoch	2015	BAN-based health telemonitoring system for in-home care
266	C. Karlsen, M. S. Ludvigsen, C. E. Moe, K. Haraldstad and E. Thygesen	2017	Experiences of community-dwelling older adults with the use of telecare in home care services: a qualitative systematic review
267	Y. Kashimoto, T. Morita, M. Fujimoto, Y. Arakawa, H. Suwa and K. Yasumoto	2017	Sensing Activities and Locations of Senior Citizens toward Automatic Daycare Report Generation
268	S. M. S. Khaksar, R. Khosla, M. T. Chu and F. S. Shahmehr	2016	Service Innovation Using Social Robot to Reduce Social Vulnerability among Older People in Residential Care Facilities
269	P. C. B. Khong, S. Y. Hoi, E. Holroyd and W. Wang	2015	Nurses' clinical decision making on adopting a wound clinical decision support system
270	R. Khosla and M. T. Chu	2013	Embodying care in matilda: An affective communication robot for emotional wellbeing of older people in Australian residential care facilities
271	R. Khosla, M. T. Chu, R. Kachouie, K. Yamada and T. Yamaguchi	2012	Embodying care in Matilda - An affective communication robot for the elderly in Australia
272	R. Khosla, M.-T. Chu, R. Kachouie, K. Yamada, F. Yoshihiro and T. Yamaguchi	2012	Interactive Multimodal Social Robot for Improving Quality of Care of Elderly in Australian Nursing Homes
273	P. Khosravi and A. H. Ghapanchi	2016	Investigating the effectiveness of technologies applied to assist seniors: A systematic literature review
274	A. Khunlertkit and P. Carayon	2013	Contributions of tele-intensive care unit (Tele-ICU) technology to quality of care and patient safety
275	B. Kikhia, T. G. Stavropoulos, S. Andreadis, N. Karvonen, I. Kompatsiaris, S. Sävenstedt, M. Pijl and C. Melander	2016	Utilizing a wristband sensor to measure the stress level for people with dementia
276	D. H. Kim, B. MacDonald, A. McDaid, S. Kawamura, H. Kim, E. T. Bean, F. Fraser and E. Broadbent	2016	User perceptions of soft robot arms and fingers for healthcare
277	S. Kim, K. H. Lee, H. Hwang and S. Yoo	2016	Analysis of the factors influencing healthcare professionals' adoption of mobile electronic medical record (EMR) using the unified theory of acceptance and use of technology (UTAUT) in a tertiary hospital
278	B. Kipping, S. Rodger, K. Miller and R. M. Kimble	2012	Virtual reality for acute pain reduction in adolescents undergoing burn wound care: a prospective randomized controlled trial
279	B. Klein and I. Schlömer	2018	A robotic shower system: Acceptance and ethical issues
280	E. Kobayashi, T. Yoshimi, N. Matsuhira, M. Mizukawa and Y. Ando	2015	A study of driving trajectory for standing-up motion support system
281	H. Kobayashi, Y. Harada and K. Tokoro	2014	Development of an independent support system capable of walking from recumbent position
282	T. Kobayashi, K. Katsuragi, T. Miyazaki and K. Arai	2017	SNS Agency Robot for Elderly People Using External Cloud-Based Services
283	Y. Kobayashi, M. Gyoda, T. Tabata, Y. Kuno, K. Yamazaki, M. Shibuya, Y. Seki and A. Yamazaki	2011	A considerate care robot able to serve in multi-party settings

284	Y. Kobayashi, Y. Kinpara, E. Takano, Y. Kuno, K. Yamazaki and A. Yamazaki	2011	Robotic Wheelchair Moving with Caregiver Collaboratively Depending on Circumstances
285	G. Koru, D. Alhuwail, M. Topaz, A. F. Norcio and M. E. Mills	2016	Investigating the Challenges and Opportunities in Home Care to Facilitate Effective Information Technology Adoption
286	N. M. Kosse, K. Brands, J. M. Bauer, T. Hortobagyi and C. J. C. Lamoth	2013	Sensor technologies aiming at fall prevention in institutionalized old adults: A synthesis of current knowledge
287	Y. Kowitlawakul	2011	The Technology Acceptance Model: Predicting Nurses' Intention to Use Telemedicine Technology (eICU)
288	Y. Kowitlawakul, S. W. C. Chan, J. Pulcini and W. Wang	2015	Factors influencing nursing students' acceptance of electronic health records for nursing education (EHRNE) software program
289	Y. Kowitlawakul, C. Moon Fai, S. Swee Lin Tan, A. Swee KitSoong and S. Wai Chi Chan	2017	Development of an e-Learning Research Module Using Multimedia Instruction Approach
290	A. J. Kozlowski, M. Fabian, D. Lad and A. D. Delgado	2017	Feasibility and Safety of a Powered Exoskeleton for Assisted Walking for Persons With Multiple Sclerosis: A Single-Group Preliminary Study
291	R. R. Kroll, J. G. Boyd and D. M. Maslove	2016	Accuracy of a wrist-Worn wearable device for monitoring heart rates in hospital inpatients:A prospective observational study
292	C. S. Kruse, M. Mileski, V. Alaytsev, E. Carol and A. Williams	2015	Adoption factors associated with electronic health record among long-term care facilities: a systematic review
293	G. Kumar, D. M. Falk, R. S. Bonello, J. M. Kahn, E. Perencevich and P. Cram	2013	The costs of critical care telemedicine programs: a systematic review and analysis
294	C. Kunkel, W. Kopp and M. Hanson	2016	A Matter of Life and Death: End-of-Life Simulation to Develop Confidence in Nursing Students
295	K.-M. Kuo, C.-F. Liu and C.-C. Ma	2013	An investigation of the effect of nurses? technology readiness on the acceptance of mobile electronic medical record systems
296	T. Kuroda, H. Noma, C. Naito, M. Tada, H. Yamanaka, T. Takemura, K. Nin and H. Yoshihara	2013	Prototyping sensor network system for automatic vital signs collection: Evaluation of a location based automated assignment of measured vital signs to patients
297	O. Kwon, J. M. Shim and G. Lim	2012	Single activity sensor-based ensemble analysis for health monitoring of solitary elderly people
298	T. Kymäläinen, J. Heinilä, T. Tuomisto, J. Plomp and T. Urhemaa	2012	Creating Scenes for an Intelligent Nursing Environment: Co-design and User Evaluations of a Home Control System
299	N. Laibhen-Parkes	2014	Web-Based evidence based practice educational intervention to improve EBP competence among BSN-prepared pediatric bedside nurses: A mixed methods pilot study
300	E. J. Lammers and C. G. McLaughlin	2017	Meaningful Use of Electronic Health Records and Medicare Expenditures: Evidence from a Panel Data Analysis of U.S. Health Care Markets, 2010-2013
301	R. L. N. Lang	2012	Evaluating the Effectiveness of Nurse-Focused Computerized Clinical Decision Support on Urinary Catheter Practice Guidelines
302	K. L. Lapane, C. M. Hughes, L. A. Daiello, K. A. Cameron and J. Feinberg	2011	Effect of a Pharmacist-Led Multicomponent Intervention Focusing on the Medication Monitoring Phase to Prevent Potential Adverse Drug Events in Nursing Homes
303	N. Lapierre, N. Neubauer, A. Miguel-Cruz, A. Rios Rincon, L. Liu and J. Rousseau	2018	The state of knowledge on technologies and their use for fall detection: A scoping review
304	S. Lapkin, T. Levett-Jones, L. Chenoweth and M. Johnson	2016	The effectiveness of interventions designed to reduce medication administration errors: a synthesis of findings from systematic reviews
305	A. S. M. Lau	2011	Hospital-based nurses' perceptions of the adoption of Web 2.0 tools for knowledge sharing, learning, social interaction and the production of collective intelligence
306	S. Lawn, X. Zhi and A. Morello	2017	An integrative review of e-learning in the delivery of self-management support training for health professionals
307	A. Lazar, G. Demiris and H. J. Thompson	2016	Evaluation of a multifunctional technology system in a memory care unit: Opportunities for innovation in dementia care
308	I. Lazarou, A. Karakostas, T. G. Stavropoulos, T. Tsompanidis, G. Meditskos, I. Kompatsiaris and M. Tsolaki	2016	A Novel and Intelligent Home Monitoring System for Care Support of Elders with Cognitive Impairment
309	C. L. Lear and C. Walters	2015	Use of Electronic Nurse Reminders to Improve Documentation
310	E. Lee	2015	Do Technology-Based Support Groups Reduce Care Burden Among Dementia Caregivers? A Review

311	S. J. Lee, S. S. Kim and Y. M. Park	2015	First experiences of high-fidelity simulation training in junior nursing students in Korea
312	S. Y. Lee and K. J. Cho	2017	A study on the cough augmentation using a belt-driven assistive
313	T. T. Lee and C. P. Chang	2016	Nurses' experiences of an initial and re-implemented electronic health record use
314	M. Leslie, E. Paradis, M. A. Gropper, S. Kitto, S. Reeves and P. Pronovost	2017	An Ethnographic Study of Health Information Technology Use in Three Intensive Care Units
315	M. Lexis	2013	Activity monitoring technology to support homecare delivery to frail and psychogeriatric elderly persons living at home alone
316	K. Li, S. Naganawa, K. Wang, P. Li, K. Kato, X. Li, J. Zhang and K. Yamauchi	2012	Study of the cost-benefit analysis of electronic medical record systems in general hospital in China
317	Y. Li, G. Chen, Y. Shen, Y. Zhu and Z. Cheng	2012	Accelerometer-based fall detection sensor system for the elderly
318	A. Liang, I. Piroth, H. Robinson, B. MacDonald, M. Fisher, U. M. Nater, N. Skoluda and E. Broadbent	2017	A Pilot Randomized Trial of a Companion Robot for People With Dementia Living in the Community
319	C. H. Liang, S. C. Chen, W. K. Lok, C. H. Luo and S. W. Lin	2011	A ZigBee-based electronic aid for daily living for quadriplegics
320	M. L. S. Lie, S. Lindsay and K. Brittain	2016	Technology and trust: Older people's perspectives of a home monitoring system
321	F. S. Lim, T. Wallace, M. A. Luszcz and K. J. Reynolds	2013	Usability of tablet computers by people with early-stage dementia
322	F. Lin, A. Wang, L. Cavuoto and W. Xu	2017	Toward Unobtrusive Patient Handling Activity Recognition for Injury Reduction among At-Risk Caregivers
323	H.-C. Lin	2017	Nurses' Satisfaction With Using Nursing Information Systems From Technology Acceptance Model and Information Systems Success Model Perspectives
324	H. H. Lin, Y. F. Chen, K. C. Lin and C. C. Yang	2014	Survey of satisfaction and usefulness for RFID-based clinical information system after system introduction
325	J. J. Lin, C. C. Lin and J. Wang	2011	Application of the electronic situated learning system for recognition of delirium in the elderly
326	Z.-C. Lin	2013	Comparison of technology-based cooperative learning with technology-based individual learning in enhancing fundamental nursing proficiency
327	L. Lind and D. Karlsson	2014	Telehealth for "the Digital Illiterate"-Elderly Heart Failure Patients Experiences
328	C. Lippincott	2014	The relationship between nursing excellence and electronic health record adoption
329	H. C. Liu, Y. J. Chen, Y. C. Lu, C. L. Wu, W. C. Huang and J. T. Huang	2013	Monitoring apnea in the elderly by an electromechanical system with a carbon Nanotube-based sensor
330	L. Liu, E. Stroulia, I. Nikolaidis, A. Miguel-Cruz and A. Rios Rincon	2016	Smart homes and home health monitoring technologies for older adults: A systematic review
331	C. C. Lo, T. Y. Chien, J. S. Pan and B. S. Lin	2016	Novel Non-Contact Control System for Medical Healthcare of Disabled Patients
332	Y. S. Lo, W. S. Lee, G. B. Chen and C. T. Liu	2014	Improving the work efficiency of healthcare-associated infection surveillance using electronic medical records
333	D. Lobach, G. D. Sanders, T. J. Bright, A. Wong, R. Dhurjati, E. Bristow, L. Bastian, R. Coeytaux, G. Samsa, V. Hasselblad, J. W. Williams, L. Wing, M. Musty and A. S. Kendrick	2012	Enabling health care decisionmaking through clinical decision support and knowledge management
334	M. Lobchuk, G. Halas, C. West, N. Harder, Z. Tursunova and C. Ramraj	2016	Development of a novel empathy-related video-feedback intervention to improve empathic accuracy of nursing students: A pilot study
335	A. Long, J. Edwards, R. Thompson, D. Lewis and A. Timoney	2014	A clinical evaluation of a sensor to detect blockage due to crystalline biofilm formation on indwelling urinary catheters
336	W. Y. G. Louie, D. McColl and G. Nejat	2012	Playing a memory game with a socially assistive robot: A case study at a long-term care facility
337	I. Lozano-Montoya, M. Vélez-Díaz-Pallarés, I. Abraha, A. Cherubini, R. L. Soiza, D. O'Mahony, B. Montero-Errasquín, A. Correa-Pérez and A. J. Cruz-Jentoft	2016	Nonpharmacologic Interventions to Prevent Pressure Ulcers in Older Patients: An Overview of Systematic Reviews (The Software ENgine for the Assessment and optimization of drug and non-drug Therapy in Older peRsons [SENATOR] Definition of Optimal Evidence-Based Non-drug Therapies in Older People [ONTOP] Series)
338	C.-H. Lu, J.-L. Hsiao and R.-F. Chen	2012	Factors determining nurse acceptance of hospital information systems

339	J. M. Luna, N. Yip, R. Pivovarov and D. K. Vawdrey	2016	Representativeness comparisons of nurse and computer charting of heart rate across nursing-intensity protocols
340	M. Lyngstad, D. Hofoss, A. Grimsmo and R. Hellesø	2015	Predictors for assessing electronic messaging between nurses and general practitioners as a useful tool for communication in home health care services: A cross-sectional study
341	B. Lyons, A. Lindauer, A. Seelye, K. Mincks, J. Kaye and D. Erten-Lyons	2016	Distance and intimacy: an ethnographic analysis of the strengths and limitations of video telemedicine care for dementia
342	S. Macis, D. Loi and L. Raffo	2016	The HEREiAM Tele-social-care Platform for Collaborative Management of Independent Living
343	K. Maclure, D. Stewart and A. Strath	2014	A systematic review of medical and non-medical practitioners' views of the impact of ehealth on shared care
344	K. Madara Marasinghe	2016	Assistive technologies in reducing caregiver burden among informal caregivers of older adults: a systematic review
345	Y. Maekawa, Y. Akiyama and S. Nishijima	2011	Development of an accident detection system for care service users by image and motion analysis
346	D. L. Magtibay, S. S. Chesak, K. Coughlin and A. Sood	2017	Decreasing Stress and Burnout in Nurses: Efficacy of Blended Learning With Stress Management and Resilience Training Program
347	M. Mahdavian, H. Nazarian, M. Mahdavian and N. Wattanapongsakorn	2014	An investigation of the success of hospital information systems implementation: A case study
348	É. Maillet, L. Mathieu and C. Sicotte	2015	Modeling factors explaining the acceptance, actual use and satisfaction of nurses using an Electronic Patient Record in acute care settings: An extension of the UTAUT
349	V. Makkapati, P. Raman and G. Pai	2016	Camera based respiration rate of neonates by modeling movement of chest and abdomen region
350	A. Mammen and R. Weeks	2014	Electronic Medical Record (EMR) technology acceptance by healthcare professionals in South Africa
351	E. Manias, A. Williams and D. Liew	2012	Interventions to reduce medication errors in adult intensive care: A systematic review
352	S. Manimaran and K. B. Lakshmi	2013	Development of model for assessing the acceptance level of users in rural healthcare system of Tamilnadu, India
353	S. Manrique-Rodríguez, A. Sánchez-Galindo, C. M. Fernández-Llamazares, J. López-Herce, L. Echarri-Martínez, V. Escudero-Vilaplana, M. Sanjuro-Sáez and Á. Carrillo-álvarez	2012	Smart pump alerts: All that glitters is not gold
354	S. Manrique-Rodríguez, A. C. Sánchez-Galindo, A. de Lorenzo-Pinto, L. González-Vives, J. López-Herce, Á. Carrillo-Álvarez, M. Sanjurjo-Sáez and C. M. Fernández-Llamazares	2015	Implementation of smart pump technology in a paediatric intensive care unit
355	S. Manrique-Rodríguez, A. C. Sánchez-Galindo, J. López-Herce, M. Á. Calleja-Hernández, F. Martínez-Martínez, I. Iglesias-Peinado, Á. Carrillo-Álvarez, M. Sanjurjo-Sáez and C. M. Fernández-Llamazares	2014	Implementing smart pump technology in a pediatric intensive care unit: A cost-effective approach
356	J. Mansfield and S. Jarrett	2013	Original article: Using smart pumps to understand and evaluate clinician practice patterns to ensure patient safety
357	K. M. Marasinghe	2015	Computerised clinical decision support systems to improve medication safety in long-term care homes: A systematic review
358	K. Marek, F. Stetzer, P. Ryan, L. Bub, S. Adams, A. Schlidt, R. Lancaster and A. O'Brien	2013	Nurse care coordination and technology effects on health status of frail older adults via enhanced self-management of medication: randomized clinical trial to test efficacy
359	K. D. Marek, F. Stetzer, S. J. Adams, L. D. Bub, A. Schlidt and K. J. Colorafi	2014	Cost Analysis of a Home-Based Nurse Care Coordination Program
360	E. Markowitz	2011	Evaluating the usability of the OpenVista Electronic Health Record EHR
361	A. R. Marra, T. Z. Sampaio Camargo, T. P. Magnus, R. P. Blaya, G. B. dos Santos, L. R. Guastelli, R. D. Rodrigues, M. Prado, E. d. S. Victor, H. Bogossian, J. C. M. Monte, O. F. P. o. dos Santos, C. K. Oyama and M. B. Edmond	2014	The use of real-time feedback via wireless technology to improve hand hygiene compliance

362	M. Marschollek, M. Becker, J. M. Bauer, P. Bente, L. Dasenbrock, K. Elbers, A. Hein, G. Kolb, H. Künemund, C. Lammel-Polchau, M. Meis, H. Meyer Zu Schwabedissen, H. Remmers, M. Schulze, E.-E. Steen, W. Thoben, J. Wang, K.-H. Wolf and R. Haux	2014	Multimodal activity monitoring for home rehabilitation of geriatric fracture patients - feasibility and acceptance of sensor systems in the GAL-NATARS study
363	M. Marschollek, A. Rehwald, K. H. Wolf, M. Gietzelt, G. Nemitz, H. M. Zu Schwabedissen and M. Schulze	2011	Sensors vs. experts - A performance comparison of sensor-based fall risk assessment vs. conventional assessment in a sample of geriatric patients
364	S. Martin, E. Armstrong and J. Daly	2015	A Brain Computer Interface to support independence and function of people with acquired brain injury living at home...39th annual conference and exhibition of the College of Occupational Therapists, Brighton and Sussex, England. June 30-July 2, 2015
365	A. Martínez, C. I. Ramirez-Salvador, A. José, R. L. Alejandra and B. Jiménez-Rodríguez	2017	An eService platform for the assistance and support of primary caregivers
366	R. Martinez-Maldonado, M. Pechenizkiy, S. Buckingham Shum, T. Power, C. Hayes and C. Axisa	2017	Modelling Embodied Mobility Teamwork Strategies in a Simulation-Based Healthcare Classroom
367	J. J. Mason, R. e. Roberts-Turner, V. Amendola, A. M. Sill and P. S. Hinds	2014	Patient Safety, Error Reduction, and Pediatric Nurses' Perceptions of Smart Pump Technology
368	S. D. Mazzacano, T. McSherry, M. Atterbury, E. Helmold, S. Gartner and C. Schulman	2016	Effect of virtual reality distraction therapy on pain and anxiety in adult patients undergoing complex dressing changes: a randomized controlled trial
369	S. McBride, M. Tietze, M. A. Hanley and L. Thomas	2017	Statewide Study to Assess Nurses' Experiences With Meaningful Use-Based Electronic Health Records
370	T. McDonald and F. Russell	2012	Impact of technology-based care and management systems on aged care outcomes in Australia
371	M. McGuckin and J. Govednik	2015	A Review of Electronic Hand Hygiene Monitoring: Considerations for Hospital Management in Data Collection, Healthcare Worker Supervision, and Patient Perception
372	M. S. McHenry, L. J. Fischer, Y. Chun and R. C. Vreeman	2017	A systematic review of portable electronic technology for health education in resource-limited settings
373	R. M. McKenna, D. Dwyer and J. A. Rizzo	2017	Is HIT a hit? The impact of health information technology on inpatient hospital outcomes
374	K. A. McKibbon, C. Lokker, S. M. Handler, L. R. Dolovich, A. M. Holbrook, D. O'Reilly, R. Tamblyn, J. H. B, R. Basu, S. Troyan, P. S. Roshanov, N. P. Archer and P. Raina	2011	Enabling medication management through health information technology (Health IT)
375	K. A. McKibbon, C. Lokker, S. M. Handler, L. R. Dolovich, A. M. Holbrook, D. O'Reilly, R. Tamblyn, B. J. Hemens, R. Basu, S. Troyan, P. S. Roshanov, K. A. McKibbon, C. Lokker, S. M. Handler, L. R. Dolovich, A. M. Holbrook, D. O'Reilly, R. Tamblyn, B. J. Hemens and R. Basu	2012	The effectiveness of integrated health information technologies across the phases of medication management: a systematic review of randomized controlled trials
376	R. Meehan	2017	Electronic Health Records in Long-Term Care: Staff Perspectives
377	S. Mehner, R. Klauck and H. Koenig	2013	Location-independent Fall Detection with Smartphone
378	Y. Y. Mei, J. Marquard, C. Jacelon and A. L. DeFeo	2013	Designing and evaluating an electronic patient falls reporting system: Perspectives for the implementation of health information technology in long-term residential care facilities
379	A. Meißner and W. Schnepp	2014	Staff experiences within the implementation of computer-based nursing records in residential aged care facilities: a systematic review and synthesis of qualitative research
380	L. Melby, B. J. Brattheim and R. Hellesø	2015	Patients in transition - improving hospital-home care collaboration through electronic messaging: providers' perspectives
381	S. Merilampi, A. Koivisto, A. Sirkka, P. Raumonen, J. Virkki, X. Xiao, Y. Min, L. Ye, X. Chujun and J. Chen	2017	The cognitive mobile games for older adults-A Chinese user experience study

382	S. Meyer, R. G. Heinze, M. Neitzel, M. Sudau and C. Wedemeier	2015	Technische Assistenzsysteme für ältere Menschen - eine Zukunftsstrategie für die Bau- und Wohnungswirtschaft Wohnen für ein langes Leben/AAL
383	C. Meyer-Delpho and H. J. Schubert	2014	Potential of Information and Communications Technology to Improve Intersectoral Processes of Care: A Case Study of the Specialised Outpatient Palliative Care
384	K. Mi Ok, E. Coiera, F. Magrabi and M. O. Kim	2017	Problems with health information technology and their effects on care delivery and patient outcomes: a systematic review
385	M. B. Michel-Verkerke and A. M. G. M. Hoogeboom	2012	Evaluation of an Electronic Patient Record in a Nursing Home: One Size Fits All?
386	S. Mickan, H. Atherton, N. W. Roberts, C. Heneghan and J. K. Tilson	2014	Use of handheld computers in clinical practice: A systematic review
387	L. Mierlo, F. Meiland, P. Ven, H. Hout and R. Dröes	2015	Evaluation of DEM-DISC, customized e-advice on health and social support services for informal carers and case managers of people with dementia; a cluster randomized trial
388	K. Miller, S. Rodger, B. Kipping and R. M. Kimble	2011	A novel technology approach to pain management in children with burns: A prospective randomized controlled trial
389	A. Mishra, S. Rani and U. D. Bhardwaj	2017	Effectiveness of E-learning Module on First Aid: A Study on Student Nurses
390	S. Mitchell and U. Yaylacicegi	2012	EHR prescription for small, medium, and large hospitals: an exploratory study of Texas acute care hospitals
391	M. Mittelman, C. Epstein and J. Hobday	2015	Efficacy of internet-based training of clinicians to implement an evidence-based intervention for dementia caregivers
392	T. L. Mitzner, C. C. Kemp, W. Rogers and L. Tiberio	2013	Investigating Healthcare Providers? Acceptance of Personal Robots for Assisting with Daily Caregiving Tasks
393	T. Miyoshi, H. Yamazoe and J. H. Lee	2015	Natural behavior based teleoperation for dual robot manipulators mounted on a wheelchair
394	E. Mlaver, J. L. Schnipper, R. B. Boxer, D. J. Breuer, E. F. Gershanik, P. C. Dykes, A. F. Massaro, J. Benneyan, D. W. Bates and L. S. Lehmann	2017	User-Centered Collaborative Design and Development of an Inpatient Safety Dashboard
395	J. Moeckli, P. Cram, C. Cunningham and H. S. Reisinger	2013	Staff acceptance of a telemedicine intensive care unit program: A qualitative study
396	S. Mohapatra and S. Murarka	2016	Improving patient care in hospital in India by monitoring influential parameters
397	C. Mollaret, A. A. Mekonnen, F. Lerasle, I. Ferrané, J. Pinquier, B. Boudet and P. Rumeau	2016	A multi-modal perception based assistive robotic system for the elderly
398	L. Montanini, L. Raffaeli, A. De Santis, A. Del Campo, C. Chiatti, G. Rascioni, E. Gambi and S. Spinsante	2016	Overnight supervision of Alzheimer's disease patients in nursing homes: System development and field trial
399	S. M. Montenery, M. Walker, E. Sorensen, R. Thompson, D. Kirklin, R. White and C. Ross	2013	Millennial Generation Student Nurses' Perceptions of the Impact of Multiple Technologies on Learning
400	L. M. Monti Fonseca, N. Del' Angelo Aredes, A. M. Fernandes, L. M. da Cunha Batalha, J. M. Amado Apóstolo, J. C. Amado Martins and M. Alves Rodrigues	2016	Computer and laboratory simulation in the teaching of neonatal nursing: innovation and impact on learning
401	S. S. Moreland, M. L. Lemieux and A. Myers	2012	End-of-life Care and the Use of Simulation in a Baccalaureate Nursing Program
402	L. Morente, J. M. Morales-Asencio and F. J. Veredas	2014	Effectiveness of an e-learning tool for education on pressure ulcer evaluation
403	M. J. Morón, R. Yáñez, D. Cascado, C. Suárez-Mejías and J. L. Sevillano	2014	A mobile memory game for patients with Acquired Brain Damage: A preliminary usability study
404	L. Mosalanejad, S. Shahsavari, S. Sobhanian and M. Dastpak	2012	The effect of virtual versus traditional learning in achieving competency-based skills
405	P. Moule, R. Ward and L. Lockyer	2011	Issues with e-learning in nursing and health education in the uk: Are new technologies being embraced in the teaching and learning environments?
406	W. Moyle, U. Arnautovska, T. Ownsworth and C. Jones	2017	Potential of telepresence robots to enhance social connectedness in older adults with dementia: an integrative review of feasibility

407	W. Moyle, M. Bramble, C. Jones and J. Murfield	2016	Care staff perceptions of a social robot called Paro and a look-alike Plush Toy: a descriptive qualitative approach
408	W. Moyle, M. Cooke, E. Beattie, C. Jones, B. Klein, G. Cook and C. Gray	2013	Exploring the effect of companion robots on emotional expression in older adults with dementia: a pilot randomized controlled trial
409	W. Moyle, C. Jones, M. Cooke, S. O. Dwyer, B. Sung and S. Drummond	2013	Social robots helping people with dementia: Assessing efficacy of social robots in the nursing home environment
410	W. Moyle, C. Jones, M. Cooke, S. O'Dwyer, B. Sung and S. Drummond	2014	Connecting the person with dementia and family: A feasibility study of a telepresence robot
411	W. Moyle, C. J. Jones, J. E. Murfield, L. Thalib, E. R. A. Beattie, D. K. H. Shum, S. T. O'Dwyer, M. C. Mervin and B. M. Draper	2017	Use of a Robotic Seal as a Therapeutic Tool to Improve Dementia Symptoms: A Cluster-Randomized Controlled Trial
412	S. Mu, S. Nakashima and K. Tanaka	2014	Applications of ultrasonic sensors and obrid-sensor in safety confirmation system for elders
413	F. Muheidat and H. W. Tyrer	2017	Deriving Information from Low Spatial Resolution Floor-Based Personnel Detection System
414	M. Mullen-Fortino, J. DiMartino, L. Entrikin, S. Mulliner, C. W. Hanson and J. M. Kahn	2012	BEDSIDE NURSES' PERCEPTIONS OF INTENSIVE CARE UNIT TELEMEDICINE
415	L. Müller, M. Sonnentag and S. Heuer	2013	Supporting reflection on dementia care using proximity sensors
416	W. C. Mundell, C. C. Kennedy, J. H. Szostek and D. A. Cook	2013	Simulation technology for resuscitation training: A systematic review and meta-analysis
417	M. Munstermann	2015	Technisch unterstützte Pflege von morgen - innovative Aktivitätserkennung und Verhaltensermittlung durch ambiente Sensorik
418	E. N. Munyisia, P. Yu and D. Hailey	2011	The changes in caregivers' perceptions about the quality of information and benefits of nursing documentation associated with the introduction of an electronic documentation system in a nursing home
419	E. N. Munyisia, P. Yu and D. Hailey	2012	The impact of an electronic nursing documentation system on efficiency of documentation by caregivers in a residential aged care facility
420	E. Murray, J. Burns, C. May, T. Finch, C. O'Donnell, P. Wallace and F. Mair	2011	Why is it difficult to implement e-health initiatives? A qualitative study
421	R. Musanti, M. Downing, D. A. Forrester, D. Fochesto and P. O'Keefe	2015	Staff perceptions of patient visibility systems in acute care settings
422	M. B. Muthuswamy, B. N. Thomas, D. Williams and J. Dingley	2014	Utility of optical facial feature and arm movement tracking systems to enable text communication in critically ill patients who cannot otherwise communicate
423	A. Nagata, Z. Huang, M. Kanai-Pak, J. Maeda, Y. Kitajima, M. Nakamura, K. Aida, N. Kuwahara, T. Ogata and J. Ota	2012	Supporting system for self training of bed-making using image processing with color and distance information
424	A. Nagler, J. Schlueter, C. Johnson, B. Griffith, J. Prewitt, R. Sloane and M. Adams	2014	Calling for collaboration: piloting smartphones to discover differences between users and devices
425	S. Nakagawa, D. P, J. Huang, K. Sekiyama and T. Fukuda	2013	Control of intelligent cane robot considering usage of ordinary cane
426	S. Nakrem, M. Solbjør, I. N. Pettersen and H. H. Kleiven	2018	Care relationships at stake? Home healthcare professionals' experiences with digital medicine dispensers - A qualitative study
427	M. Namnabati, F. Taleghani, M. Varzeshnejad, A. Yousefi, Z. Karjoo and S. Safiri	2017	Nursing care and documentation assistant with an electronic nursing management system in neonatal intensive care unit
428	R. F. Navarro and J. Favela	2011	Usability Assessment of a Pervasive System to Assist Caregivers in Dealing with Repetitive Behaviors of Patients with Dementia
429	T. Nef, P. Urwyler, M. Büchler, I. Tarnanas, R. Stucki, D. Cazzoli, R. Müri and U. Mosimann	2012	Evaluation of Three State-of-the-Art Classifiers for Recognition of Activities of Daily Living from Smart Home Ambient Data
430	M. Neggazi, L. Hamami and A. Amira	2014	Efficient compressive sensing on the shimmer platform for fall detection
431	C. P. Nemeth, J. Brown, B. Crandall and C. Fallon	2014	The mixed blessings of smart infusion devices and health care IT
432	J. Neuhaeuser, J. Diehl-Schmid and T. C. Lueth	2011	Evaluation of a radio based ADL interaction recognition system in a day hospital for old age psychiatry with healthy probands

433	B. B. Neves, R. L. Franz, C. Munteanu, R. Baecker and M. Ngo	2015	My Hand Doesn?T Listen to Me!: Adoption and Evaluation of a Communication Technology for the ?Oldest Old?
434	L. Nguyen, E. Bellucci and L. T. Nguyen	2014	Electronic health records implementation: An evaluation of information system impact and contingency factors
435	L. Nguyen, N. Wickramasinghe, B. Redley, P. Haddad, I. Muhammad and M. Botti	2017	Exploring nurses' reactions to electronic nursing documentation at the point of care
436	B. Ni, C. D. Nguyen and P. Moulin	2012	RGBD-camera based get-up event detection for hospital fall prevention
437	A. Nicolson, L. Moir and J. Millsteed	2012	Impact of assistive technology on family caregivers of children with physical disabilities: a systematic review
438	N. Nijhof, J. E. W. C. van Gemert-Pijnen, C. M. Burns and E. R. Seydel	2013	A personal assistant for dementia to stay at home safe at reduced cost
439	N. Nijhof, L. J. van Gemert-Pijnen, R. Woolrych and A. Sixsmith	2013	An evaluation of preventive sensor technology for dementia care
440	T. Nilpanapan and T. Kerdcharoen	2017	Social data shoes for gait monitoring of elderly people in smart home
441	H. E. Nilsson, J. Sidén and M. Gulliksson	2011	An incontinence alarm solution utilizing RFID based sensor technology
442	J. Nordheim, S. Hamm, A. Kuhlmey and R. Suhr	2015	Tablet computers and their benefits for nursing home residents with dementia: Results of a qualitative pilot study
443	L. L. Novak, S. Anders, C. S. Gadd, N. M. Lorenzi, L. L. Novak, S. Anders, C. S. Gadd and N. M. Lorenzi	2012	Mediation of adoption and use: a key strategy for mitigating unintended consequences of health IT implementation
444	B. T. Nukala, N. Shibuya, A. I. Rodriguez, J. Tsay, T. Q. Nguyen, S. Zupancic and D. Y. C. Lie	2014	A real-time robust fall detection system using a wireless gait analysis sensor and an Artificial Neural Network
445	B. Oakley and J. B. Hunter	2017	Implementing an electronic patient handover system
446	A. Odunmbaku, A. M. Rahmani, P. Liljeberg and H. Tenhunen	2016	Elderly monitoring system with sleep and fall detector
447	N. Ofek Shlomai, S. Rao and S. Patole	2015	Efficacy of interventions to improve hand hygiene compliance in neonatal units: a systematic review and meta-analysis
448	T. Ogura, T. Itami, K. Yano, I. Mori and K. Kameda	2017	An assistance device to help people with trunk impairment maintain posture
449	T. Ohiwa, H. Yamamoto and K. Yamazaki	2016	Sensor system to advice health-aware information for elderly people on daily living activities
450	T. Okano, D. Kitakoshi and M. Suzuki	2013	A Preliminary Study on Preventive Care System Based on Game Playing with Communication Robots
451	B. Okoniewska, A. Graham, M. Gavrilova, D. Wah, J. Gilgen, J. Coke, J. Burden, S. Nayyar, J. Kaunda, D. Yergens, B. Baylis and W. A. Ghali	2012	Multidimensional evaluation of a radio frequency identification wi-fi location tracking system in an acute-care hospital setting
452	N. Olchanski, M. A. Dziadzko, I. C. Tiong, C. E. Daniels, S. G. Peters, J. C. O'Horo and M. N. Gong	2017	Can a Novel ICU Data Display Positively Affect Patient Outcomes and Save Lives?
453	D. P. Oliver, G. Demiris, E. Wittenberg-Lyles, K. Washington, T. Day and H. Novak	2012	A systematic review of the evidence base for telehospice
454	C. K. Or, B. T. Karsh, D. J. Severtson, L. J. Burke, R. L. Brown, P. F. Brennan, C. K. L. Or, B.-T. Karsh, D. J. Severtson, L. J. Burke, R. L. Brown and P. F. Brennan	2011	Factors affecting home care patients' acceptance of a web-based interactive self-management technology
455	P. Ordonez, T. Oates, M. E. Lombardi, G. Hernandez, K. W. Holmes, J. Fackler and C. U. Lehmann	2012	Visualization of multivariate time-series data in a neonatal ICU
456	E. M. Orellano-Colón, W. C. Mann, M. Rivero, M. Torres, J. Jutai, A. Santiago and N. Varas	2016	Hispanic older adult's perceptions of personal, contextual and technology-related barriers for using assistive technology devices
457	V. Orto, C. C. Hendrix, B. Griffith and S. T. Shaikewitz	2015	Implementation of a Smart Pump Champions Program to Decrease Potential Patient Harm
458	A. A. A. Osaimi, K. A. Kadi and B. Saddik	2017	Role of radio frequency identification in improving infant safety and the extent of nursing staff acceptance of RFID at King Abdulaziz medical city in Riyadh

459	Y. Ouyang, K. Shan and F. M. Bui	2016	An RF-based wearable sensor system for indoor tracking to facilitate efficient healthcare management
460	J. Y. Pai, D. Liu, I. H. Lin and H. C. Lai	2017	Apply Information and Communications Technology to Improve the Quality of Day Care Center
461	E. Palm	2013	An interactive ethical assessment of surveillance-capable software within the home-help service sector
462	C. Panagopoulos, E. Kalatha, P. Tsanakas and I. Maglogiannis	2015	Evaluation of a mobile home care platform lessons learned and practical guidelines
463	D. Panzoli, C. Pons-Lelardeux and P. Lagarrigue	2015	Communication and Knowledge Sharing in an Immersive Learning Game
464	P. A. Pappas, L. Tirelli, J. Shaffer and S. Gettings	2016	Projecting Critical Care Beyond the ICU: An Analysis of Tele-ICU Support for Rapid Response Teams
465	S. O. Paranilam	2013	Effectiveness of an Electronic Pain Notification System on Postoperative Pain
466	G. Paré, P. Poba-Nzaou and C. Sicotte	2013	Home telemonitoring for chronic disease management: An economic assessment
467	G. Pare, C. Sicotte, M. P. Moreault, P. Poba-Nzaou, M. Templier and G. Nahas	2011	Effects of Mobile Computing on the Quality of Homecare Nursing Practice
468	C. Park, S. Kang, J. Kim and J. Oh	2012	A study on service robot system for elder care
469	J. L. Partin, T. A. Payne and M. F. Slemmons	2011	Students' perceptions of their learning experiences using high-fidelity simulation to teach concepts relative to obstetrics
470	F. L. Patmon, P. M. Gee, T. L. Rylee and N. L. Readdy	2016	Using Interactive Patient Engagement Technology in Clinical Practice: A Qualitative Assessment of Nurses' Perceptions
471	D. Patterson, M. Soltani, A. Teeley, D. Morse, S. Wiechman and N. Gibran	2012	Hypnosis delivered through immersive virtual reality for wound care: a randomized, controlled study
472	A. J. Pearce, B. Adair, K. Miller, E. Ozanne, C. Said, N. Santamaria and M. E. Morris	2012	Robotics to enable older adults to remain living at home
473	S. T. M. Peek, E. J. M. Wouters, J. van Hoof, K. G. Luijkx, H. R. Boeije and H. J. M. Vrijhoef	2014	Factors influencing acceptance of technology for aging in place: A systematic review
474	J. M. Peeters, A. J. E. de Veer, L. van der Hoek and A. L. Francke	2012	Factors influencing the adoption of home telecare by elderly or chronically ill people: a national survey
475	J. M. Peeters, T. A. Wiegers and R. D. Friele	2013	How technology in care at home affects patient self-care and self-management: A scoping review
476	V. Pemmassani, T. Paget, H. C. van Woerden and S. Pemmasani	2014	Hands-free communication to free up nursing time
477	N. Peng, R. Zhang, H. Zeng, F. Wang, K. Li, Y. Li and X. Zhuang	2016	Control of a nursing bed based on a hybrid brain-computer interface
478	P. Perego, G. Andreoni, R. Zanini and R. Bellù	2014	Wearable biosignal monitoring system for newborns
479	H. H. C. Peres, A. F. C. Lima, D. d. A. L. M. d. Cruz, R. R. Gaidzinski, N. B. Oliveira, D. C. F. Ortiz, M. M. e. Trindade and R. Tsukamoto	2012	Assessment of an electronic system for clinical nursing documentation
480	D. Peretz, A. Arnaert and N. N. Ponzoni	2018	Determining the cost of implementing and operating a remote patient monitoring programme for the elderly with chronic conditions: A systematic review of economic evaluations
481	M. B. Perrigino and B. B. Dunford	2016	The unique effects of general and specific support in health care technology: An empirical examination of the principle of compatibility
482	S. Perri-Moore, S. Kapsandoy, K. Doyon, B. Hill, M. Archer, L. Shane-McWhorter, B. E. Bray and Q. Zeng-Treitler	2016	Automated alerts and reminders targeting patients: A review of the literature
483	C. Peters, T. Hermann, S. Wachsmuth and J. Hoey	2014	Automatic Task Assistance for People with Cognitive Disabilities in Brushing Teeth - A User Study with the TEBRA System
484	S. Petersen, S. Houston, H. Qin, C. Tague and J. Studley	2017	The Utilization of Robotic Pets in Dementia Care
485	J. Petty	2013	Interactive, technology-enhanced self-regulated learning tools in healthcare education: A literature review
486	N. Philipsen, W. Carruthers, G. Chi, D. Ensey, A. Shmorhun and R. Valdez	2014	A mixed-methods assessment of time spent documenting by nurses using an electronic medical records system

487	D. Pickham, N. Berte, M. Pihulic, A. Valdez, B. Mayer and M. Desai	2018	Effect of a wearable patient sensor on care delivery for preventing pressure injuries in acutely ill adults: A pragmatic randomized clinical trial (LS-HAPI study)
488	P. Pierleoni, A. Belli, L. Palma, L. Pernini and S. Valenti	2014	A versatile ankle-mounted fall detection device based on attitude heading systems
489	L. Pigini, G. Bovi, C. Panzarino, V. Gower, M. Ferratini, G. Andreoni, R. Sassi, M. W. Rivolta and M. Ferrarin	2017	Pilot Test of a New Personal Health System Integrating Environmental and Wearable Sensors for Telemonitoring and Care of Elderly People at Home (SMARTA Project)
490	H. Pigot, P. Y. Nivollet, T. Zayani, Y. Adelise and L. Domus	2016	Ubiquitous reminders to manage timetable in a smart home
491	L. L. Pineles, D. J. Morgan, H. M. Limper, S. G. Weber, K. A. Thom, E. N. Perencevich, A. D. Harris and E. Landon	2014	Accuracy of a radiofrequency identification (RFID) badge system to monitor hand hygiene behavior during routine clinical activities
492	M. Pino, M. Boulay, F. Jouen and A. S. Rigaud	2015	Are we ready for robots that care for us? Attitudes and opinions of older adults toward socially assistive robots
493	K. Pitts, K. Pudney, K. Zachos, N. Maiden, B. Krogstie, S. Jones, M. Rose, J. MacManus and I. Turner	2015	Using mobile devices and apps to support reflective learning about older people with dementia
494	A. C. Polycarpou, A. Dimitriou, A. Bletsas, P. C. Polycarpou, L. Papaloizou, G. Gregoriou and J. N. Sahalos	2012	On the Design, Installation, and Evaluation of a Radio-Frequency Identification System for Healthcare Applications [Wireless Corner]
495	F. Portela, M. F. Santos, J. Machado, A. Abelha, J. Neves, A. Silva and F. Rua	2012	Intelligent decision support in intensive care - Towards technology acceptance
496	F. R. Portela, R. J. C. Correia, J. A. Fonseca and J. M. Andrade	2011	Wiitherapy on seniors — Effects on physical and metal domains
497	A. M. Pot, B. M. Willemse and S. Horjus	2012	A pilot study on the use of tracking technology: Feasibility, acceptability, and benefits for people in early stages of dementia and their informal caregivers
498	J. Powers	2016	Two Methods for Turning and Positioning and the Effect on Pressure Ulcer Development: a Comparison Cohort Study
499	J. Pripfl, T. Kortner, D. Batko-Klein, D. Hebesberger, M. Weninger and C. Gisinger	2016	Social service robots to support independent living : Experiences from a field trial
500	G. W. Pritchard and K. Brittain	2015	Alarm pendants and the technological shaping of older people's care. Between (intentional) help and (irrational) nuisance
501	S. Qian and P. Yu	2014	Fitting clinical workflow: The case for wound care in a residential aged care home
502	W. Quan, H. Niwa, N. Ishikawa, Y. Kobayashi and Y. Kuno	2011	Assisted-care robot based on sociological interaction analysis
503	A. Queirós, A. Silva, J. Alvarelhão, N. P. Rocha and A. Teixeira	2015	Usability, accessibility and ambient-assisted living: a systematic literature review
504	K. Radhakrishnan, B. Xie, A. Berkley and M. Kim	2016	Barriers and Facilitators for Sustainability of Tele-Homecare Programs: A Systematic Review
505	J. Raman	2015	Mobile technology in nursing education: where do we go from here? A review of the literature
506	V. R. Ramnath and N. Khazeni	2014	Centralized monitoring and virtual consultant models of tele-ICU care: a side-by-side review
507	R. Ranasinghe, L. Dantanarayana, A. Tran, S. Lie, M. Behrens and L. Liu	2014	Smart hoist: An assistive robot to aid carers
508	P. Rantanen, T. Parkkari, S. Leikola, M. Airaksinen and A. Lyles	2017	An In-Home Advanced Robotic System to Manage Elderly Home-Care Patients' Medications: a Pilot Safety and Usability Study
509	M. Rantz, L. J. Phillips, C. Galambos, K. Lane, G. L. Alexander, L. Despins, R. J. Koopman, M. Skubic, L. Hicks, S. Miller, A. Craver, B. H. Harris and C. B. Deroche	2017	Randomized Trial of Intelligent Sensor System for Early Illness Alerts in Senior Housing
510	M. J. Rantz, G. Alexander, C. Galambos, M. K. Flesner, A. Vogelsmeier, L. Hicks, J. Scott-Cawiezell, M. Zwygart-Stauffacher and L. Greenwald	2011	The use of bedside electronic medical record to improve quality of care in nursing facilities: a qualitative analysis
511	P. Ray, J. Li, A. Ariani and V. Kapadia	2017	Tablet-Based Well-Being Check for the Elderly: Development and Evaluation of Usability and Acceptability

512	S. J. Redmond, Z. Zhang, M. R. Narayanan and N. H. Lovell	2014	Pilot evaluation of an unobtrusive system to detect falls at nighttime
513	C. Reed, D. Fraley, J. Sharp, A. Hernandez, J. Proulx, A. Kattan, H. Williams and R. Wilson	2013	Video instruction increases accuracy in performance of nurse dysphagia screening
514	S. C. Reed, K. Kim, V. Ngo, W. Wait, E. Apesoa-Varano, J. Morgan, R. L. Whitney, E. Blackmon and J. Joseph	2016	Usability and acceptance of novel personal health technology to support early palliative care for patients with cancer and caregivers
515	B. Reeder, G. Demiris and K. Marek	2013	Older adults' satisfaction with a medication dispensing device in home care
516	I. T. Reierson, H. Solli and I. T. Bjørk	2015	Nursing students' perspectives on telenursing in patient care after simulation
517	Z. S. N. Reis, T. A. Maia, M. S. Marcolino, F. Becerra-Posada, D. Novillo-Ortiz and A. L. P. Ribeiro	2017	Is There Evidence of Cost Benefits of Electronic Medical Records, Standards, or Interoperability in Hospital Information Systems? Overview of Systematic Reviews
518	L. Ren, Q. Zhang and W. Shi	2012	Low-power Fall Detection in Home-based Environments
519	J. D. Restuccia, A. B. Cohen, J. N. Horwitt and M. Shwartz	2012	Hospital implementation of health information technology and quality of care: Are they related?
520	C. Ribeiro, M. Monteiro, J. B. Hauge, J. Pereira and T. Antunes	2016	Sepsis Fast Track: A simulation game for Clinical education based on the Sepsis Fast Track protocol
521	J. Richter, C. Wiede, E. Dayangac, A. Shahenshah and G. Hirtz	2017	Activity recognition for elderly care by evaluating proximity to objects and human skeleton data
522	J. River, J. Currie, T. Crawford, V. Betihavas and S. Randall	2016	A systematic review examining the effectiveness of blending technology with team-based learning
523	S. Robben, L. Bosch, P. Wiggers, J. Decancq and M. Kanis	2015	Managing Flexible Care with a Context Aware System for Ageing-in-place
524	P. Robert, E. Castelli, P. C. Chung, T. Chiroux, C. F. Crispim-Junior, P. Mallea and F. Bremond	2013	SWEET-HOME ICT technologies for the assessment of elderly subjects
525	S. Roberts, A. Marshall and W. Chaboyer	2017	Hospital staffs' perceptions of an electronic program to engage patients in nutrition care at the bedside: A qualitative study
526	S. Roberts, A. P. Marshall, R. Gonzalez and W. Chaboyer	2017	Technology to engage hospitalised patients in their nutrition care: a qualitative study of usability and patient perceptions of an electronic foodservice system
527	E. J. Robinson, M. R. Bergey, E. Brady, A. M. Mapp and J. C. Goldsack	2017	The Impact of an Electronic Medication Administration Record (eMAR) and Computerized Physician Order Entry (CPOE) on Nurse Extender and Unit Clerk Staffing
528	H. Robinson, B. MacDonald and E. Broadbent	2015	Physiological effects of a companion robot on blood pressure of older people in residential care facility: a pilot study
529	H. Robinson, B. MacDonald, N. Kerse and E. Broadbent	2013	The Psychosocial Effects of a Companion Robot: A Randomized Controlled Trial
530	H. Robinson, B. A. MacDonald, N. Kerse and E. Broadbent	2013	Suitability of Healthcare Robots for a Dementia Unit and Suggested Improvements
531	L. Robinson, G. Gibson, A. Kingston, L. Newton, G. Pritchard, T. Finch and K. Brittain	2013	Assistive technologies in caring for the oldest old: A review of current practice and future directions
532	C. S. Rodriguez	2016	ENHANCING THE COMMUNICATION OF SUDDENLY SPEECHLESS CRITICAL CARE PATIENTS
533	P. S. Roshanov, N. Fernandes, J. M. Wilczynski, B. J. Hemens, J. J. You, S. M. Handler, R. Nieuwlaat, N. M. Souza, J. Beyene, H. G. C. Van Spall, A. X. Garg and R. B. Haynes	2013	Features of effective computerised clinical decision support systems: Meta-regression of 162 randomised trials
534	G. Rouleau, M. P. Gagnon, J. Côté, J. Payne-Gagnon, E. Hudson and C. A. Dubois	2017	Impact of information and communication technologies on nursing care: Results of an overview of systematic reviews
535	R. Rozenblum, J. Donzé, P. M. Hockey, E. Guzdar, M. A. Labuzetta, E. Zimlichman and D. W. Bates	2013	The impact of medical informatics on patient satisfaction: A USA-based literature review
536	A. Rudolph, J. Vaughn, N. Crego, R. Hueckel, M. Kuszajewski, M. Molloy, R. Brisson Iii and R. J. Shaw	2017	Integrating Telepresence Robots Into Nursing Simulation

537	S. Rus, T. Grosse-Puppendahl and A. Kuijper	2014	Recognition of bed postures using mutual capacitance sensing
538	P. W. Rushton, B. W. Mortenson, P. Viswanathan, R. H. Wang, W. C. Miller and L. Hurd Clarke	2017	Intelligent power wheelchair use in long-term care: potential users' experiences and perceptions
539	T. Ryall, B. K. Judd and C. J. Gordon	2016	Simulation-based assessments in health professional education: A systematic review
540	J. Ryan, B. Doster, S. Daily, R. Ryan and C. Lewis	2015	Perioperative workflow and patient care documentation perpetuated through electronic medical records via integrated hospital information systems
541	S. Šabanović, C. C. Bennett, W. L. Chang and L. Huber	2013	PARO robot affects diverse interaction modalities in group sensory therapy for older adults with dementia
542	A. M. Sabelli, T. Kanda and N. Hagita	2011	A Conversational Robot in an Elderly Care Center: An Ethnographic Study
543	F. Sadoughi, K. Kimiafar, M. Ahmadi and M. T. Shakeri	2013	Determining of factors influencing the success and failure of hospital information system and their evaluation methods: A systematic review
544	O. Sahota, A. Drummond, D. Kendrick, M. J. Grainge, C. Vass, T. Sach, J. Gladman and M. Avis	2014	REFINE (REducing Falls in In-patieNt Elderly) using bed and bedside chair pressure sensors linked to radio-pagers in acute hospital care: a randomised controlled trial
545	A. Salekin, H. Wang, K. Williams and J. Stankovic	2017	DAVE: Detecting Agitated Vocal Events
546	J. Salinas, K. K. Chung, E. A. Mann, L. C. Cancio, G. C. Kramer, M. L. Serio-Melvin, E. M. Renz, C. E. Wade and S. E. Wolf	2011	Computerized decision support system improves fluid resuscitation following severe burns: An original study
547	V. L. Salyers, L. Carter, C. Antoniazzi and S. Johnson	2013	Evaluating the Effectiveness of a Clinical Tracking System for Undergraduate Nursing Students
548	C. Sanders, A. Rogers, R. Bowen, P. Bower, S. Hirani, M. Cartwright, R. Fitzpatrick, M. Knapp, J. Barlow, J. Hendy, T. Chrysanthaki, M. Bardsley and S. Newman	2012	Exploring barriers to participation and adoption of telehealth and telecare within the Whole System Demonstrator trial: a qualitative study
549	W. Sansrimahachai and M. Toahchoodee	2016	Mobile-phone based immobility tracking system for elderly care
550	J. Saunders, D. S. Syrdal, K. L. Koay, N. Burke and K. Dautenhahn	2016	“Teach Me–Show Me”—End-User Personalization of a Smart Home and Companion Robot
551	M. C. Schall, L. Cullen, P. Pennathur, H. Chen, K. Burrell and G. Matthews	2017	Usability Evaluation and Implementation of a Health Information Technology Dashboard of Evidence-Based Quality Indicators
552	L. Schiatti, J. Tessadori, G. Barresi, L. S. Mattos and A. Ajoudani	2017	Soft brain-machine interfaces for assistive robotics: A novel control approach
553	T. Schmidt, A. Lassen and U. K. Wiil	2016	A Patient Deterioration Warning System for Boosting Situational Awareness of Monitored Patients
554	R. Schnall	2015	Short message service use in clinical care through a simulation activity
555	R. R. Schoville	2017	Discovery of Implementation Factors That Lead to Technology Adoption in Long-Term Care
556	G. Schreier, M. Schwarz, R. Modre-Osprian, P. Kastner, D. Scherr and F. Fruhwald	2013	Design and evaluation of a multimodal mHealth based medication management system for patient self administration
557	J. Schuld, T. Schäfer, S. Nickel, P. Jacob, M. K. Schilling and S. Richter	2011	Impact of IT-supported clinical pathways on medical staff satisfaction. A prospective longitudinal cohort study
558	J. L. Scott, S. Dawkins, M. G. Quinn, K. Sanderson, K. E. Elliott, C. Stirling, B. Schuz and A. Robinson	2016	Caring for the carer: a systematic review of pure technology-based cognitive behavioral therapy (TB-CBT) interventions for dementia carers
559	Y. S. Sefidgar, K. E. MacLean, S. Yohanan, H. F. M. Van Der Loos, E. A. Croft and E. J. Garland	2016	Design and Evaluation of a Touch-Centered Calming Interaction with a Social Robot
560	H. H. Seibert, R. R. Maddox, E. A. Flynn and C. K. Williams	2014	Effect of barcode technology with electronic medication administration record on medication accuracy rates
561	J. K. Sheba, R. E. Mohan and E. A. Martínez García	2012	Easiness of acceptance metric for effective human robot interactions in therapeutic pet robots
562	A. W. Shee, B. Phillips, K. Hill and K. Dodd	2014	Feasibility, acceptability, and effectiveness of an electronic sensor bed/chair alarm in reducing falls in patients with cognitive impairment in a subacute ward

563	Z. Shen and Y. Wu	2016	Investigation of Practical Use of Humanoid Robots in Elderly Care Centres
564	H. Shin, S. Sok, K. S. Hyun and M. J. Kim	2015	Competency and an active learning program in undergraduate nursing education
565	M. A. Shinnick, M. A. Woo and J. C. Mentes	2011	Human Patient Simulation: State of the Science in Prelicensure Nursing Education
566	A. A. N. Shirehjini, A. Yassine and S. Shirmohammadi	2012	Equipment location in hospitals using RFID-based positioning system
567	J. T. Shuffitt	2011	Utilization and influence of health information technology on Kentucky advanced practice registered nurses' clinical decision making
568	J. Shukla, M. Barreda-Ángeles, J. Oliver and D. Puig	2017	Effectiveness of socially assistive robotics during cognitive stimulation interventions: Impact on caregivers
569	K. K. Shyu, Y. J. Chiu, P. L. Lee, M. H. Lee, J. J. Sie, C. H. Wu, Y. T. Wu and P. C. Tung	2013	Total Design of an FPGA-Based Brain–Computer Interface Control Hospital Bed Nursing System
570	S. R. Simon, C. A. Keohane, M. Amato, M. Coffey, B. Cadet, E. Zimlichman and D. W. Bates	2013	Lessons learned from implementation of computerized provider order entry in 5 community hospitals: A qualitative study
571	P. M. Sinclair, A. Kable, T. Levett-Jones and D. Booth	2016	The effectiveness of Internet-based e-learning on clinician behaviour and patient outcomes: A systematic review
572	M. M. Soares, K. Jacobs, Y.-C. Chen and C.-Y. Leung	2012	Exploring functions of the lost seeking devices for people with dementia
573	P. S. Sockolow, K. H. Bowles, H. P. Lehmann, P. A. Abbott and J. P. Weiner	2012	Community-based, interdisciplinary geriatric care team satisfaction with an electronic health record: a multimethod study
574	L. Song	2013	Evaluating the Relationship between Patient Safety Culture and the Behavioral Intention to Use Bar Code Medication Administration among Registered Nurses in Hospitals
575	V. D. Souza-Junior, I. A. C. Mendes, A. Mazzo and S. Godoy	2016	Application of telenursing in nursing practice: an integrative literature review
576	V. D. d. Souza-Junior, I. A. C. Mendes, A. Mazzo, S. d. Godoy and C. A. d. Santos	2017	Telenursing Intervention for Clean Intermittent Urinary Catheterization Patients: A Pilot Study
577	A. K. Sowan and L. S. Jenkins	2013	Designing, delivering and evaluating a distance learning nursing course responsive to students needs
578	F. Stertz, J. Mangler and S. Rinderle-Ma	2017	NFC-based task enactment for automatic documentation of treatment processes
579	K. Steurbaut, K. Colpaert, S. Van Hoecke, S. Steurbaut, C. Danneels, J. Decruyenaere and F. De Turck	2012	Design and evaluation of a service oriented architecture for paperless ICU tarification
580	A. Steventon, M. Bardsley, J. Billings, J. Dixon, H. Doll, M. Beynon, S. Hirani, M. Cartwright, L. Rixon, M. Knapp, C. Henderson, A. Rogers, J. Hendy, R. Fitzpatrick and S. Newman	2013	Effect of telecare on use of health and social care services: findings from the Whole Systems Demonstrator cluster randomised trial
581	I. Strand, L. Gulbrandsen, Å. Slettebø and D. Nåden	2017	Digital recording as a teaching and learning method in the skills laboratory
582	K. Strickland, C. Gray and G. Hill	2012	The use of podcasts to enhance research-teaching linkages in undergraduate nursing students
583	J. L. Styron	2013	The impact of technology attitudes and skills of rural health clinic nurses on the level of adoption of electronic health records in Mississippi
584	P. Subramaniam and B. Woods	2016	Digital life storybooks for people with dementia living in care homes: an evaluation
585	C. Suebsin and N. Gerdsri	2011	Lessons learned from IT adoption in healthcare organizations: A comparative study
586	M. R. Summerfield, F. J. Seagull, N. Vaidya and Y. Xiao	2011	Use of pharmacy delivery robots in intensive care units
587	C. Sunnqvist, K. Karlsson, L. Lindell and U. Fors	2016	Virtual patient simulation in psychiatric care – A pilot study of digital support for collaborate learning
588	R. Suzuki and N. Kobayashi	2014	Development of assistive devices for feeding gastrostomy
589	S. Suzuki, T. Yokoishi, H. Hada, J. Mitsugi, O. Nakamura and J. Murai	2011	Bidirectional medication support system for medical staff and home care patients

590	A. Takian, A. Sheikh and N. Barber	2012	We are bitter, but we are better off: Case study of the implementation of an electronic health record system into a mental health hospital in England
591	A. Talaei-Khoei, L. Lewis, T. T. Khoei, A. H. Ghapanchi and S. Vichitvanichphong	2015	Seniors' perspective on perceived transfer effects of assistive robots in elderly care: Capability approach analysis
592	L. T. Tam, A. C. Valera, H.-P. Tan and C. Koh	2016	Online Detection of Behavioral Change Using Unobtrusive Eldercare Monitoring System
593	P. Tangtisanon	2016	Healthcare system for elders with automatic drug label detection
594	L. Tapper, H. Quinn, J. Kerry and K. G. Brown	2012	Introducing Handheld Computers into Home Care
595	A. Tariq, J. Westbrook, M. Byrne, M. Robinson and M. T. Baysari	2017	Applying a human factors approach to improve usability of a decision support system in tele-nursing
596	J. Taylor, E. Coates, L. Brewster, G. Mountain, B. Wessels and M. S. Hawley	2015	Examining the use of telehealth in community nursing: identifying the factors affecting frontline staff acceptance and telehealth adoption
597	S. Taylor, M. J. Allsop, H. L. Bekker, M. I. Bennett and B. M. Bewick	2017	Identifying professionals' needs in integrating electronic pain monitoring in community palliative care services: An interview study
598	A. E. Tchalla, F. Lachal, N. Cardinaud, I. Saulnier, V. Rialle and P.-M. Preux	2013	Preventing and managing indoor falls with home-based technologies in mild and moderate Alzheimer's disease patients: pilot study in a community dwelling
599	H. E. Thomassen and B. A. Farshchian	2016	A technology-enhanced service for person-centered dementia care: Preliminary results from a field trial
600	D. Thompson, K. R. Fisher and R. Kayess	2012	The Role of Assistive Technology in Supporting People with Disabilities and Complex Care Needs: A Literature Review
601	G. Thompson, J. C. O'Horo, B. W. Pickering and V. Herasevich	2015	Impact of the Electronic Medical Record on Mortality, Length of Stay, and Cost in the Hospital and ICU: A Systematic Review and Metaanalysis
602	T. L. Thompson	2011	Meaningful use of simulation as an educational method in nursing programs
603	L. Tiberio, A. Cesta, G. Cortellessa, L. Padua and A. R. Pellegrino	2012	Assessing affective response of older users to a telepresence robot using a combination of psychophysiological measures
604	B. R. Tielbur, D. E. Rice Cella, A. Currie, J. D. Roach, B. Mattingly, J. Boone, C. Watwood, A. McGauran, H. S. Kirshner and P. D. Charles	2015	Discharge huddle outfitted with mobile technology improves efficiency of transitioning stroke patients into follow-up care
605	J. J. Tieman, K. Swetenham, D. D. Morgan, T. H. To and D. C. Currow	2016	Using telehealth to support end of life care in the community: a feasibility study
606	L. Tieu, U. Sarkar, D. Schillinger, J. D. Ralston, N. Ratanawongsa, R. Pasick and C. R. Lyles	2015	Barriers and facilitators to online portal use among patients and caregivers in a safety net health care system: A qualitative study
607	J. S. L. Ting, A. H. C. Tsang, A. W. H. Ip and G. T. S. Ho	2011	RF-Medisys: a radio frequency identification-based electronic medical record system for improving medical information accessibility and services at point of care
608	K. L. H. Ting, D. Voilmy, A. Iglesias, J. C. Pulido, J. García, A. Romero-Garcés, J. P. Bandera, R. Marfil and D. Á	2017	Integrating the users in the design of a robot for making Comprehensive Geriatric Assessments (CGA) to elderly people in care centers
609	P. Tiwari, J. Warren, K. Day, B. MacDonald, C. Jayawardena, I. H. Kuo, A. Igic and C. Datta	2011	Feasibility Study of a Robotic Medication Assistant for the Elderly
610	S. Torp, P. C. Bing-Jonsson and E. Hanson	2013	Experiences with using information and communication technology to build a multi-municipal support network for informal carers
611	M. Tower, S. Latimer and J. Hewitt	2014	Social networking as a learning tool: Nursing students' perception of efficacy
612	M. Trent, C. Gaydos, J. Perin, S. E. Chung, S. Huettner, J. Anders, R. Rothman and A. Butz	2017	Effectiveness of technology enhanced community health nursing (TECH-N) for adolescents and young adult women with pelvic inflammatory disease
613	C. Tsiourti, E. Joly, C. Wings, M. B. Moussa and K. Wac	2014	Virtual Assistive Companions for Older Adults: Qualitative Field Study and Design Implications
614	A. Tsuji, T. Yonezawa, H. Yamazoe, S. Abe, N. Kuwahara and K. Morimoto	2012	Proposal and evaluation of the toilet timing suggestion method for the elderly
615	N. Vadiei, C. Shuman, M. Murthy and M. Daley	2017	Optimization of intelligent infusion pump technology to minimize vasopressor pump programming errors

616	P. C. Vadillo and E. S. Rojo	2016	Maximizing Healthcare Professionals' Use of New Computer Technologies in a Small, Urban Hospital's Critical Care Unit
617	S. M. Valenti, L. Aguera-Ortiz, R. J. Olazaran, R. C. Mendoza, M. A. Perez, P. I. Rodriguez, R. E. Osa, S. A. Barrios, C. V. Herrero, C. L. Carrasco, R. S. Felipe, A. J. Lopez, S. B. Leon, P. J. Canas, R. F. Martin and M. P. Martinez	2015	Social robots in advanced dementia
618	T. Valerie, K. L. Choy, P. K. Y. Siu, H. Y. Lam, G. T. S. Ho and S. W. Y. Cheng	2016	An intelligent performance assessment system for enhancing the service quality of home care nursing staff in the healthcare industry
619	J.-W. van ?t Klooster, C. Combes and B.-J. van Beijnum	2012	Towards Decision Support for a Home Care Services Platform
620	L. A. van der Heide, C. G. Willems, M. D. Spreeuwenberg, J. Rietman and L. P. de Witte	2012	Implementation of CareTV in care for the elderly: The effects on feelings of loneliness and safety and future challenges
621	M. van der Lende, F. M. E. Cox, G. H. Visser, J. W. Sander and R. D. Thijs	2016	Value of video monitoring for nocturnal seizure detection in a residential setting
622	H. G. Van der Roest, J. Wenborn, C. Pastink, R. M. Droes and M. Orrell	2017	Assistive technology for memory support in dementia
623	A. E. Vandenberg, B.-J. van Beijnum, V. G. P. Overdevest, E. Capezuti and T. M. Iijohnson	2017	US and Dutch nurse experiences with fall prevention technology within nursing home environment and workflow: A qualitative study
624	A. Vankipuram, P. Khanal, A. Ashby, M. Vankipuram, A. Gupta, D. DrummGurnee, K. Josey and M. Smith	2014	Design and Development of a Virtual Reality Simulator for Advanced Cardiac Life Support Training
625	D. Vanneste, B. Vermeulen and A. Declercq	2013	Healthcare professionals' acceptance of BelRAI, a web-based system enabling person-centred recording and data sharing across care settings with interRAI instruments: A UTAUT analysis
626	F. Vannieuwenborg, F. Ongenae, P. Demyttenaere, L. V. Poucke, J. V. Ooteghem, S. Verstichel, S. Verbrugge, D. Colle, F. D. Turck and M. Pickavet	2014	Techno-economic evaluation of an ontology-based nurse call system via discrete event simulations
627	U. Varshney	2011	Wireless Medication Management System: Design and performance evaluation
628	I. Vedel, S. Akhlaghpour, I. Vaghefi, H. Bergman and L. Lapointe	2013	Health information technologies in geriatrics and gerontology: a mixed systematic review
629	M. Verkuyl, L. Atack, P. Mastrilli and D. Romaniuk	2016	Virtual gaming to develop students' pediatric nursing skills: A usability test
630	S. Vichitvanichphong, D. Kerr, A. Talaei-Khoei and A. H. Ghapanchi	2013	Analysis of research in adoption of assistive technologies for aged care
631	S. Vichitvanichphong, A. Talaei-Khoei, D. Kerr and A. H. Ghapanchi	2014	Adoption of Assistive Technologies for Aged Care: A Realist Review of Recent Studies
632	M. Vincze, W. Zagler, L. Lammer, A. Weiss, A. Huber, D. Fischinger, T. Koertner, A. Schmid and C. Gisinger	2014	Towards a Robot for Supporting Older People to Stay Longer Independent at Home
633	A. Voit, D. Weber, E. Stowell and N. Henze	2017	Caloo: An Ambient Pervasive Smart Calendar to Support Aging in Place
634	K. Vowden and P. Vowden	2013	A pilot study on the potential of remote support to enhance wound care for nursing-home patients
635	K. Wada, Y. Takasawa and T. Shibata	2014	Robot therapy at facilities for the elderly in Kanagawa prefecture - a report on the experimental result of the first month
636	E. Wagemaker, T. J. Dekkers, J. A. Agelink van Rentergem, K. M. Volkers and H. M. Huizenga	2017	Advances in Mental Health Care: Five N = 1 Studies on the Effects of the Robot Seal Paro in Adults With Severe Intellectual Disabilities
637	B. J. Wakefield and M. Vaughan-Sarrazin	2017	Home Telehealth and Caregiving Appraisal in Chronic Illness
638	G. S. Walia, A. L. Wong, A. Y. Lo, G. A. Mackert, H. M. Carl, R. A. Pedreira, R. Bello, C. S. Aquino, W. V. Padula and J. M. Sacks	2016	Efficacy of Monitoring Devices in Support of Prevention of Pressure Injuries: Systematic Review and Meta-analysis
639	K. Walsh and A. Callan	2011	Perceptions, Preferences, and Acceptance of information and communication technologies in older-adult community care settings in Ireland: A case-study and ranked-care program analysis

640	H. Wang, G. G. Grindle, J. Candiotti, C. Chung, M. Shino, E. Houston and R. A. Cooper	2012	The Personal Mobility and Manipulation Appliance (PerMMA): A robotic wheelchair with advanced mobility and manipulation
641	H. Wang, J. Xu, G. Grindle, J. Vazquez, B. Salatin, A. Kelleher, D. Ding, D. M. Collins and R. A. Cooper	2013	Performance evaluation of the personal mobility and manipulation appliance (PerMMA)
642	R. H. Wang, S. M. Gorski, P. J. Holliday and G. R. Fernie	2011	Evaluation of a Contact Sensor Skirt for an Anti-Collision Power Wheelchair for Older Adult Nursing Home Residents With Dementia: Safety and Mobility
643	R. H. Wang, P. C. Kontos, P. J. Holliday and G. R. Fernie	2011	The experiences of using an anti-collision power wheelchair for three long-term care home residents with mild cognitive impairment
644	R. H. L. Wang	2011	Enabling Power Wheelchair Mobility with Long-Term Care Home Residents with Cognitive Impairments
645	T. Wang, Y. Wang and J. Moczygemba	2014	Organizational factors influencing health information technology adoption in long-term-care facilities
646	L. Wanner, E. André, J. Blat, S. Dasiopoulou, M. Farrús, T. Fraga, E. Kamateri, F. Lingenfelser, G. Llorach, O. Martínez, G. Meditskos, S. Mille, W. Minker, L. Pragst, D. Schiller, A. Stam, L. Stellingwerff, F. Sukno, B. Vieru and S. Vrochidis	2017	Design of a Knowledge-Based Agent as a Social Companion
647	A. Weakley, J. W. Tam, C. Van Son and M. Schmitter-Edgecombe	2017	Effectiveness of a video-based aging services technology education program for health care professionals
648	L. Webb, J. Clough, D. O'Reilly, D. Wilmott and G. Witham	2017	The utility and impact of information communication technology (ICT) for pre-registration nurse education: A narrative synthesis systematic review
649	D. Webster and O. Celik	2014	Systematic review of Kinect applications in elderly care and stroke rehabilitation
650	G. Webster and V. L. Hanson	2014	Technology for Supporting Care Staff in Residential Homes
651	C. Weiß	2013	Unterstützung Pflegebedürftiger durch technische Assistenzsysteme (Abschlussbericht)
652	L. J. Wekre, L. Melby and A. Grimsmo	2011	Early experiences with the multidose drug dispensing system -- A matter of trust?
653	C. White, S. McIlfatrick, L. Dunwoody and M. Watson	2015	Supporting and improving community health services-a prospective evaluation of ECHO technology in community palliative care nursing teams
654	J. C. Whitehead, S. A. Gambino, J. D. Richter and J. D. Ryan	2015	Focus group reflections on the current and future state of cognitive assessment tools in geriatric health care
655	A. Wickramasinghe, D. C. Ranasinghe, C. Fumeaux, K. D. Hill and R. Visvanathan	2017	Sequence Learning with Passive RFID Sensors for Real-Time Bed-Egress Recognition in Older People
656	A. Wickramasinghe, R. L. Shinmoto Torres and D. C. Ranasinghe	2017	Recognition of falls using dense sensing in an ambient assisted living environment
657	M. Wieck, B. Blake, C. Sellick, D. Kenron, D. DeVries, S. Terry and S. Krishnaswami	2017	Utilizing technology to improve intraoperative family communication
658	J. J. Willemse and V. Bozalek	2015	Exploration of the affordances of mobile devices in integrating theory and clinical practice in an undergraduate nursing programme
659	W. Williams	2014	Factors that Affect Bar Code Medication Administration Technology Acceptance
660	B. Williamson, T. Aplin, D. de Jonge and M. Goyne	2017	Tracking down a solution: exploring the acceptability and value of wearable GPS devices for older persons, individuals with a disability and their support persons
661	S. Winslow, S. Jackson, K. Blakeney, L. Cook, J. W. Reed, K. Zimbro and C. Parker	2016	Multisite assessment of nursing continuing education learning needs using an electronic tool
662	J. T. Wiseman, S. Fernandes-Taylor, M. L. Barnes, A. Tomsejova, R. S. Saunders and K. C. Kent	2015	Conceptualizing smartphone use in outpatient wound assessment: Patients' and caregivers' willingness to use technology
663	R. A. Wittmann-Price, L. D. Kennedy and C. Godwin	2012	Use of personal phones by senior nursing students to access health care information during clinical education: Staff Nurses' and students' perceptions

664	K. H. Wolf, K. Hetzer, H. M. zu Schwabedissen, B. Wiese and M. Marschollek	2013	Development and pilot study of a bed-exit alarm based on a body-worn accelerometer
665	A. Wong Shee, B. Phillips, K. Hill and K. Dodd	2014	Feasibility, Acceptability, and Effectiveness of an Electronic Sensor Bed/Chair Alarm in Reducing Falls in Patients With Cognitive Impairment a Subacute Ward
666	J. Woo, K. Wada and N. Kubota	2012	Robot Partner System for elderly people care by using sensor network
667	J. L. Wood and J. S. Burnette	2012	Enhancing patient safety with intelligent intravenous infusion devices: Experience in a specialty cardiac hospital
668	K. Words	2014	A Web-Based Intelligent Tutoring System Teaching Health Care Technology
669	R. Wu, P. Rossos, S. Quan, S. Reeves, V. Lo, B. Wong, M. Cheung and D. Morra	2011	An evaluation of the use of smartphones to communicate between clinicians: A mixed-methods study
670	T. T. Wu, S. H. Huang, M. Y. Chung and Y. M. Huang	2013	Group Investigation Learning with Google Plus for Public Health Nursing Practice Course
671	Y.-H. Wu, M. Chetouani, V. Cristancho-Lacroix, J. L. Maître, C. Jost, B. L. Pevedic, D. Duhaut, C. Granata and A.-S. Rigaud	2011	ROBADOM: The Impact of a Domestic Robot on Psychological and Cognitive State of the Elderly with Mild Cognitive Impairment
672	D. Xie, Y. Lin, R. Grupen and A. Hanson	2011	Intention-based coordination and interface design for human-robot cooperative search
673	P. H. Yager, M. Clark, B. M. Cummings and N. Noviski	2017	Parent Participation in Pediatric Intensive Care Unit Rounds via Telemedicine: Feasibility and Impact
674	M. Yamamoto, N. Takabayashi, K. Ono, T. Watanabe and Y. Ishii	2014	Development of a nursing communication education support system using nurse-patient embodied avatars with a smile and eyeball movement model
675	N. Yamashita, H. Kuzuoka, K. Hirata, T. Kudo, E. Aramaki and K. Hattori	2017	Changing Moods: How Manual Tracking by Family Caregivers Improves Caring and Family Communication
676	H. J. Yazici	2014	An exploratory analysis of hospital perspectives on real time information requirements and perceived benefits of RFID technology for future adoption
677	B. Yeaman, K. J. Ko and R. A. d. Castillo	2015	Care Transitions in Long-term Care and Acute Care: Health Information Exchange and Readmission Rates
678	C. Yen-Ting, H. Chun-Ju, Z. Jia-Hong, H. Min-Wei and Z. Jia-Ying	2016	The development of image tracing technology in the surveillance system for elder's living in home
679	C. Yi-Sheng, L. Hsin-Ju and L. Yuan-Hsiang	2014	Using wireless measuring devices and Tablet PC to improve the efficiency of vital signs data collection in hospital
680	Y. Yixiao, C. Innocenti, G. Nero, H. L. én and G. Irene Yu-Hua	2015	Fall detection in RGB-D videos for elderly care
681	L. B. Young, P. S. Chan, P. Cram, L. B. Young, P. S. Chan and P. Cram	2011	Staff acceptance of tele-ICU coverage: a systematic review
682	M. Yu, Y. Yu, A. Rhuma, S. M. R. Naqvi, L. Wang and J. A. Chambers	2013	An Online One Class Support Vector Machine-Based Person-Specific Fall Detection System for Monitoring an Elderly Individual in a Room Environment
683	M. J. Yuan, G. M. Finley, J. Long, C. Mills and R. K. Johnson	2013	Evaluation of user interface and workflow design of a bedside nursing clinical decision support system
684	Y. Yun and I. Y. H. Gu	2015	Human fall detection via shape analysis on Riemannian manifolds with applications to elderly care
685	S. Yusif, J. Soar and A. Hafeez-Baig	2016	Older people, assistive technologies, and the barriers to adoption: A systematic review
686	M. M. Yusof	2015	A case study evaluation of a Critical Care Information System adoption using the socio-technical and fit approach
687	C. Zaccarelli, G. Cirillo, S. Passuti, R. Annicchiarico and F. Barban	2013	Computer-based cognitive intervention for dementia Sociable: motivating platform for elderly networking, mental reinforcement and social interaction
688	P. E. Zadeh	2015	Adoption and implementation of Health Information Exchange (HIE): An interpretative review
689	M. Zahabi, D. B. Kaber and M. Swangnetr	2015	Usability and Safety in Electronic Medical Records Interface Design: A Review of Recent Literature and Guideline Formulation

690	M. Zaidan, F. Rustom, N. Kassem, S. Al Yafei, L. Peters and M. I. M. Ibrahim	2016	Nurses' perceptions of and satisfaction with the use of automated dispensing cabinets at the Heart and Cancer Centers in Qatar: a cross-sectional study
691	A. Zaman and M. Bhuiyan	2014	Usabilty evaluation of the MumIES (Multimodal Interface based Education and Support) system for the children with special needs in Bangladesh
692	R. A. Zapatán, E. E. Armijos, L. Serpa-Andrade and E. Pinos	2017	Analysis of a nurse call system implementation using a wireless sensors network
693	N. Zayim and D. Ozel	2015	Factors affecting nursing students' readiness and perceptions toward the use of mobile technologies for learning
694	M. Zhang, K. Bingham, K. Kantarovich, J. Laidlaw, D. Urbach, S. Sockalingam and R. Ho	2016	Inter-professional delirium education and care: a qualitative feasibility study of implementing a delirium Smartphone application
695	N. Zhang, S. F. Lu, B. Xu, B. Wu, R. Rodriguez-Monguio and J. Gurwitz	2016	Health Information Technologies: Which Nursing Homes Adopted Them?
696	Y. Zhang, P. Yu and J. Shen	2012	The benefits of introducing electronic health records in residential aged care facilities: A multiple case study
697	W. Zhao, Q. Wu, D. D. Espy, M. A. Reinthal, X. Luo and Y. Peng	2017	A feasibility study on using a Kinect-based human motion tracking system to promote safe patient handling
698	W. Zhao, X. Zhou, H. Ni and Q. Lin	2014	A light-weight system for detecting indoor wandering of demented elders living alone
699	X. Zhao, A. M. Naguib and S. Lee	2014	Octree Segmentation Based Calling Gesture Recognition for Elderly Care Robot
700	J. Zhou, D. B. Liu, J. W. Zhong, Z. Y. Huang, S. Y. Qiu, Y. P. Zhou and X. H. Yi	2012	Feasibility of a remote monitoring system for home-based non-invasive positive pressure ventilation of children and infants
701	X. Zhou, X. Zhu, M. Huang and W. Chen	2013	Automatic monitoring of sleep behaviour in nursing home residents
702	C. Zhu, W. Sheng and M. Liu	2015	Wearable Sensor-Based Behavioral Anomaly Detection in Smart Assisted Living Systems
703	X. Zhu, X. Zhou, W. Chen, K. I. Kitamura and T. Nemoto	2014	Estimation of Sleep Quality of Residents in Nursing Homes Using an Internet-Based Automatic Monitoring System
704	J. Zhuang, R. Fang, X. Feng, X. Xu, L. Liu, Q. Bai, H. Tang, Z. Zhao and S. Chen	2013	The impact of human-computer interaction-based comprehensive training on the cognitive functions of cognitive impairment elderly individuals in a nursing home
705	M. Ziefle, C. Rocker and A. Holzinger	2011	Medical Technology in Smart Homes: Exploring the User's Perspective on Privacy, Intimacy and Trust
706	E. Zimlichman, J. Terrence, D. Argaman, Z. Shinar and H. Brown	2012	Effect of contactless continuous patient monitoring in a medical-surgical unit on intensive care unit transfers: a controlled clinical trial
707	C. Zimmermann, J. Zeilfelder, T. Bloecher, M. Diehl, S. Essig and W. Stork	2017	Evaluation of a smart drink monitoring device
708	A. Rocca, J. M. Pignat, L. Berney, J. Johr, D. Van de Ville, R. T. Daniel, M. Levivier, L. Hirt, A. R. Luft, E. Grouzmann and K. Diserens	2016	Sympathetic activity and early mobilization in patients in intensive and intermediate care with severe brain injuries: a preliminary prospective randomized study
709	P. Ewig	2016	Projekt Aaladin : Anwendung von akustischen und lautbasierten Erkennertechnologien zur Unterstützung pflegender Dienstleister : Schlussbericht : Laufzeit des Vorhabens: 01. Oktober 2012 - 31. Dezember 2015
710	S. C. Trukeschitz B., Ring-Dimitriou S.	2018	Smartes Betreutes Wohnen: Nutzung, Systemakzeptanz und Wirkungen von „meinZentrAAL"
711	N. Loepthien, T. Jehnichen, J. Hauser, B. Schullcke and K. Möller	2016	Development of a low-cost senor based aid for visually impaired people
712	B. Weber-Fiori, A. Rölle and M. Winter	2017	Geruchssensorik in der professionellen pflegerischen Langzeitversorgung (GeppV) – Chancen und Risiken für die Handlungspraxis Pflegender
713	S. Müller and A. Hein	2016	Multi-Target Data Association in Binary Sensor Networks for Ambulant Care Support
714	T. Frenken, R. Eckert, A. Jüptner and A. Hein	2015	AmbiAct - RRI Industry case study
715	S. Teipel, C. Heine, A. Hein, F. Krüger, A. Kutschke, S. Kernebeck, M. Halek, S. Bader and T. Kirste	2017	Multidimensional assessment of challenging behaviors in advanced stages of dementia in nursing homes—The insideDEM framework

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Measuring the effectiveness of digital nursing technologies: development of a comprehensive digital nursing technology outcome framework based on a scoping review

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Abstract

Background: Digital nursing technologies (DNT) comprise an expanding, highly diverse field of research, explored using a wide variety of methods and tools. Study results are therefore difficult to compare, which raises the question how effectiveness of DNT can be adequately measured. Methods currently used might not be sufficient for certain specific nursing contexts. A comprehensive outcome framework that shows the multitude of possible outcome areas could be useful to generate more comparable results. The aim of the present study is to develop an outcome framework for DNT and to indicate which outcome areas have been most frequently evaluated in previous studies and how this has been done.

Methods: We combined an inductive and deductive approach to develop the framework. The numerical analysis is based on a scoping review focussing on the effectiveness of DNT for persons in need of care, formal or informal caregivers or care institutions. Nine databases were included in the screening: Medline, Scopus, CINAHL, Cochrane Library, ACM Digital Library, IEEE Xplore, the Collection of Computer Science Bibliographies, GeroLit and CareLit. Additional literature searches and expert interviews were included.

Results: The developed framework comprises four outcome target groups and 47 outcome areas. There are considerable differences in the researched outcome areas for the individual outcome target groups. Persons in need of care were by far the most frequently surveyed, particularly with respect to their psychological health. There are much fewer studies on formal and informal caregivers, and it is particularly noticeable that the quality of life of both groups has rarely been investigated. Care process quality was most frequently researched for organisations.

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Conclusion: We were able to provide a comprehensive DNT outcome framework, thereby identifying the outcome tools used and the less researched outcome areas. We recommend a detailed investigation of all areas and tools in future research projects with a view to initiating a discussion on the differing importance of existing outcome areas and on a standardisation of outcome tools. We also recommend the development of outcome areas for the macro level of effectiveness assessment.

Keywords: Technology, Care, Nursing, Framework, Effectiveness, Effect, Digital, Outcome, Evidence

Background

Research on digital nursing technologies is an emerging field. An initial analysis of 715 articles on Digital nursing technologies (DNT) showed the existing variety of research. The field is highly diverse and is explored using a multitude of methods and instruments, which makes the measured effects very difficult to compare [1]. The question how effectiveness of DNT can be adequately measured is becoming increasingly relevant. There are no comprehensive systematisations that can help to structure this measurement, which is why only frameworks that cover partial areas [2] of the field or from other related healthcare contexts such as eHealth [3] or HTA [4] can be used.

Many systematic reviews in the field of technology and nursing conclude that solid evidence with respect to effectiveness is lacking [5–12], mainly due to a weak level of evidence and the incomparability of the study results. For this reason, a comprehensive outcome framework detailing the multitude of possible outcome areas could be useful for generating more comparable results. A systematisation of outcome areas and outcome tools for DNT could promote scientific exchange, improve the comparability of results and facilitate the identification of research gaps. Hence, the aim of this research is to systematically develop a comprehensive outcome framework for DNT and to indicate which outcome areas have been most frequently evaluated in previous studies, and on this basis to provide an overview on research focuses and possible gaps in current research on DNT. The development of the framework and the mapping of current research are based on a scoping review. The categories of the framework were further elaborated on the basis of additional literature and expert knowledge.

Other frameworks, like the evaluation framework for Health Information Systems (HOT-fit) [13], the General Framework for Evaluating Health Information Technology [14], the Canadian Health Information Performance Framework [15], the OECD Framework for Health System Performance Measurement [16], the Infoway Benefits Framework [17] or the MAST Framework [18], have been proposed to structure the process of effectiveness evaluation in health care areas using digital technologies. However, the existing frameworks and categorization systems have different focal points, and none of them are – from our point of view – adequately geared to the specific needs of the complex nursing care context. Outcomes relating to caregivers, and in particular informal caregivers, are often neglected or overlooked. The Infoway Benefits Evaluation Framework [17] that has been proposed for the analysis of health information systems in Canada, and the Model for Assessment of Telemedicine (MAST) [18], pose an exception here, as they are very well elaborated. Both frameworks were developed in a similar context, but for different purposes. The frameworks do not specifically consider informal caregivers, but they nevertheless indicate important subareas for the evaluation of DNT (such as, for example, patient safety, care quality, access to care or organisational productivity) that should be integrated into a comprehensive DNT framework. However, they are inadequate and inappropriate for a specific application relating to DNT, because they have been developed for different purposes. In addition to these two frameworks, there is also a framework which especially displays the impact of ICT solutions on nursing care. The adapted version of the Nursing Care Performance Framework [2] focusses on organisational issues, formal caregivers and aspects relating to people in need of care. This makes a helpful contribution in these areas. However, outcomes for technologies on informal caregivers are not represented in this framework. Besides these frameworks, there is also specific work on the measurement of the effectiveness of technology for ageing people in general, including effects on physical and psychological health, mobility, social connectedness, safety, everyday activities and leisure [19].

As we have established, therefore, a number of different instruments for categorizing outcome measures and tools in healthcare contexts have already been developed. To the best of our knowledge, however, there is no extensive analysis of relevant outcome areas and outcome tools pertaining to digital nursing technology published in the English nursing literature. We therefore decided to develop a new comprehensive outcome framework that is applicable to the design of effectiveness evaluation studies in the field of digital nursing technologies.

Definitions

In order to elucidate the conceptual differences between the individual terms in this study, we shall first define our understanding of the most important terms. The main subject of this article is digital nursing technologies (DNT). DNT are required i) to support the immediate action of a caregiver (e.g. decision support systems for guideline compliance [20]); ii) to contribute to the self-reliance of the person in need of care in such a way that direct on-site care assistance can be avoided (e.g. ambient assisted living support at home [21]); iii) to substitute the nursing support by using technology (e.g. robot that measures vital signs prior to consultation) [22]; or iv) to support the training or education of nurses (e.g. high fidelity simulator systems [23]) [1]. Technological support may relate to the person in need of care, formal or informal caregivers, or to an organisational process.

We also distinguish between the terms "outcome measure" and "outcome tool". An outcome measure is a specific measure used to quantify (quantitative) or gauge (qualitative) an effect, e.g., of an eHealth intervention, and an outcome tool is a specific instrument used to collect quantitative or qualitative data [24, 25]. Outcome tools or outcome measures are indicators that represent effects in a specific outcome area. A distinction is also made between the terms "outcome target group" and "outcome area". The outcome target group refers to the assignment of the outcome of a technology to a specific group of people (e.g. formal caregivers) or to an organisation (e.g. hospital). The outcome area specifies the content layer on which an effect occurs (e.g. well-being or functional health). There is also a distinction between the terms 'effectiveness' and 'efficacy'. Efficacy studies measure (expected) effects under ideal circumstances, effectiveness studies measure (beneficial) effects under "real world" conditions [26]. Since we have found an incoherent use of the terms in the studies included, we use the term "effectiveness" to cover both concepts. This decision will be further justified and discussed in the discussion section.

Objective and research question

The ultimate objective of this article is to develop an outcome framework for DNT that enables systematic classification into different outcome areas and can be used to support future effectiveness research. It is essential to the development of such a framework that past attempts to evaluate effectiveness in previous studies are understood. This review is thus guided by the following main research questions: (i) Which possible outcome areas for measuring effectiveness of digital nursing technologies can be identified? (ii) Which outcome areas have so far been the focal point of research on effectiveness of digital nursing technologies, and which areas have been researched less frequently or not at all? (iii) How has effectiveness been measured in previous studies?

Methods

Our analysis is based on a previous scoping review (phase one) [1], which we conducted on the basis of Arksey and O'Malley's scoping review framework [27]. We used processual advice drawn up by Levac, Colquhoun et al. [28] to enhance the scientific process. This was particularly important because the search of the previous scoping review generated a large number of titles, which made the identification, selection and charting of the relevant studies very time consuming and resource intensive. We have tried to counteract this by using the advice to refine the search and selection strategy in an iterative process. We also jointly developed, tested and updated a data charting form that allowed us to review and extract each full text by one researcher, a second author was consulted in case of uncertainties regarding the classification.

The scoping review included 715 studies focussing on acceptance, effectiveness or efficiency DNT. The full search strategy, analysis and results of the scoping review are published in Krick et al. 2019 [1]. The initial analysis of the scoping review yielded strong indications that a more in-depth analysis of tools and research areas could be useful for further research. Therefore, we decided to extend the evaluation to include methodological questions in a second research phase. In the following, the method of the initial scoping review will be briefly presented, followed by an explanation of the method used in the second phase.

Methodical foundation of the initial scoping review

We screened 19.510 titles, based on a search in nine electronic databases, covering studies published between 2011 and March 2018. The initial scoping review (phase one) was conducted with a view to a broader research question insofar as studies were included that related to the acceptance, the effectiveness or the efficiency of a digital nursing technology.

Eligibility criteria of the initial scoping review and the analysis of effectiveness

In order to understand how the preselection of articles for this review took place, the eligibility criteria of Phase one will now be explained briefly. Articles were included if they reported on study results relating to acceptance, effectiveness (on any evidence level) or efficiency (including cost analysis); target settings include residential long-term care, formal and informal care at home, hospital care, palliative inpatient care, intensive care unit care, day-care centre care and cross-sectoral care. Based on this preselection, all studies that reported on the effectiveness of DNT were included for the second phase of analysis. In the next step, as we aimed to focus on effects on persons in need of care, caregivers and care organisations, all studies that aimed primarily at an educational environment and studies conducted in a laboratory environment were excluded. Studies in a laboratory environment were excluded as most of them measure technical effectiveness, which is not the subject of our analysis. The remaining articles were analysed according to the outcome areas, outcome measures and outcome tools to create an empirical basis for the DNT outcome framework. Again, studies were excluded that focussed only on technical effectiveness. Based on these limitations, 123 individual studies were subjected to the analysis presented in this article.

Development of the outcome framework and data assignment

A combined inductive/deductive approach was used to develop the outcome framework. A basic model was developed by drawing on the analysis of the effectiveness articles (n = 123) of the initial scoping review [1]. Two authors screened the full texts to identify all relevant information. The identified outcome measures and outcome tools of the studies were used to inductively derive a preliminary systematic draft of outcome areas. In addition, a narrative literature search was carried out in the databases PubMed and Google Scholar in order to review whether further outcome areas could be found or identified that were not considered in the 123 studies. We combined the search terms "nursing", "framework", "outcome", "digital" and "technology" and decided which articles should be included in the analysis. The search focussed on studies that explicitly referred to specific frameworks, developed frameworks themselves or provided a systematic structure to measure effectiveness. We analysed the texts and reference lists for relevant frameworks or systematisations. This snowballing method is important for such complex search fields. It helped us to provide meaningful additional information as a supplement to the systematic approach [29]. The aim was to identify studies or other frameworks that describe or contain further outcome areas for DNT. All relevant information that could be used to determine further outcome areas was extracted.

Deductive reasoning was used to gather information from general frameworks and inductive reasoning was used for single studies. A definition of each potential outcome area was then drawn up by one author and discussed with the other authors as to their relevance and fit for the framework. The development process included a multi-stage discussion and iteration with multiple revisions to ensure high quality decisions on the outcome areas and their definitions. The outcome framework was then validated by a group of ten German experts in the measurement of effectiveness of DNT. At the time of the survey, the experts in question were all involved in projects evaluating different digital technologies in nursing in the German healthcare system. The experts were requested to report their own project experiences in order to supplement missing relevant outcome areas. This survey took place as part of a regular exchange among experts.

The final outcome areas of the framework described for persons in need of care were developed with strong references to the Nursing Outcomes Classification (NOC) criteria [30] and existing frameworks [17, 18]. The caregiver-related outcome areas were derived from the initial scoping review and supplemented by categories based on the literature review (e.g. [18, 31–38]), while the organisation-related outcome areas emanate from the literature review (e.g. [17, 18, 39–45]), supplemented by expert opinions. All information is included in the final definitions for each outcome area documented in the Additional files 1, 2, 3, 4.

Data assignment

In the last step of the second phase, the extracted outcome tools from all the studies included were assigned to the outcome areas in the outcome framework using the collectively developed criteria. One researcher re-reviewed all studies (n = 123) to ensure a consistent assignment of outcome measures to outcome areas based on the iteratively developed framework. As a result, the numerical analysis can be presented according to the DNT outcome framework.

Results

Analysis results

A total of 123 studies from the initial scoping review were included in the analysis. These studies refer to the following technology categories: ICT, robotics, monitoring, sensors, assistive devices, ambient assisted living and virtual reality as defined by Krick et al. (2019) [1]. A more detailed systematization of the included technologies together with a list of all included studies is provided in Additional file 5.

The PRISMA Flow Chart is presented in Fig. 1.

Digital nursing technology (DNT) outcome framework

We developed an outcome framework to provide a systematic classification and orientation scheme for outcome measures and outcome tools in the field of DNT (Fig. 2). The classification of the framework differentiates between the four outcome target groups: persons in need of care, formal caregivers, informal caregivers and healthcare organisations. For persons in need of care

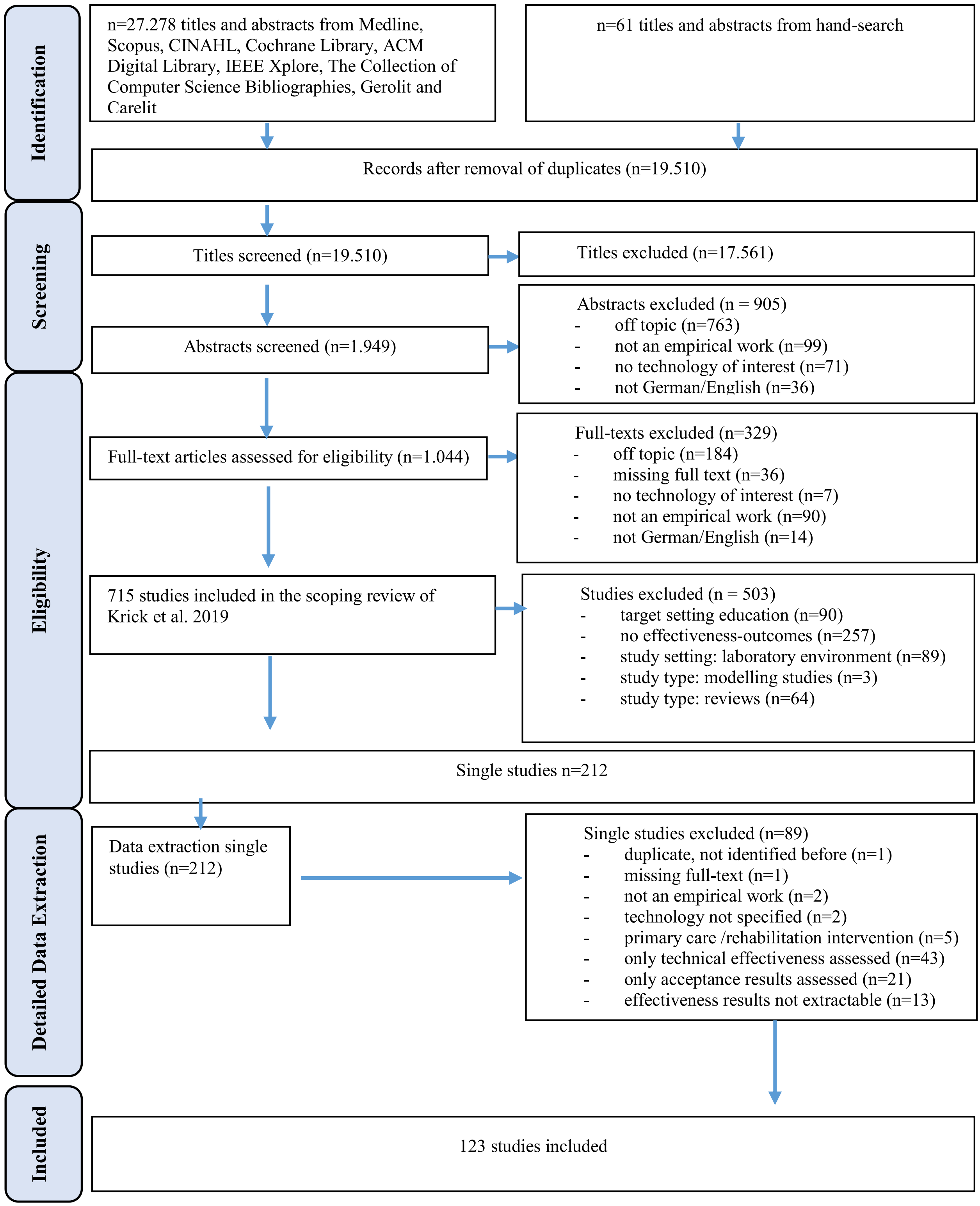

Fig. 1 Search results and publication selection process

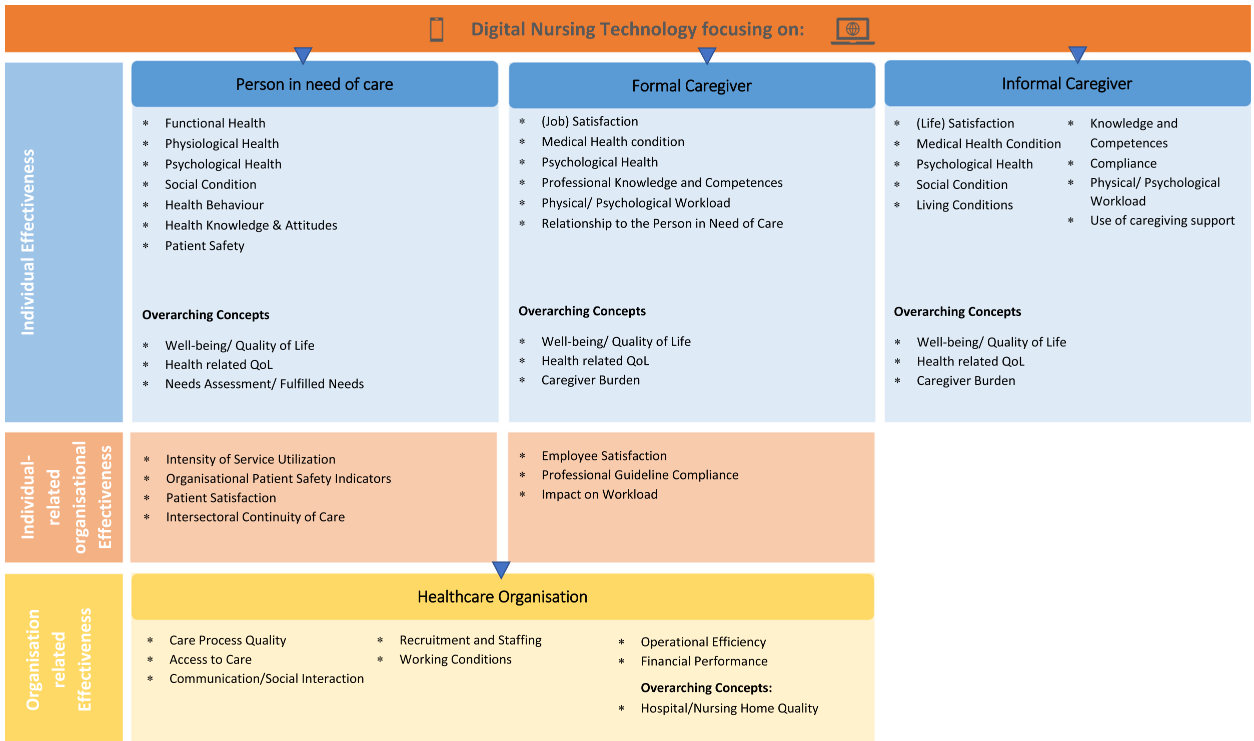

Fig. 2 Outcome Framework

and formal caregivers we also distinguish between individual effectiveness and individual-related organisational effectiveness. This distinction is used to categorize outcome measures or tools that clearly apply to an individual but are closely related to organisational effectiveness and thus in an intermediate area. Overall, the model comprises 47 different outcome areas (e.g. functional health, well-being, patient satisfaction). The outcome areas included in the framework refer to micro (individual) or meso (organisational) levels of evaluation [46]. The macro level is deliberately not included here because it implies different study perspectives and so far, has only been very rarely analysed in the field of DNT. Detailed definitions and examples for the individual categories are provided in Additional files 1, 2, 3, 4.

Overall outcome areas

This chapter comprises a detailed analysis of all outcome tools and measures used in the 123 studies included (Table 1). The numerical analysis shows which outcome areas have or have not been extensively analysed with the respective measures or tools. Each study that used an outcome tool or outcome measure in a specific area is only included once in this analysis. Most of the included studies investigated the effectiveness of the technologies in question on persons in need of care ($n = 77$). Aspects of organisational effectiveness were measured in 45 studies and only 30 studies referred to caregiver outcomes (formal $n = 20$; informal caregivers $n = 10$). There are substantial differences in the researched outcome areas for the individual outcome target groups. Psychosocial health ($n = 33$), intensity of service utilization ($n = 19$) and organisational patient safety indicators ($n = 19$) for persons in need of care were measured much more frequently than needs assessment/ fulfilled needs ($n = 3$), health knowledge & attitudes ($n = 3$) or intersectoral continuity of care ($n = 1$). For formal caregivers the outcome areas most frequently covered are relationship to person in need of care ($n = 7$), guideline compliance ($n = 7$) and physical/psychological workload ($n = 6$). Well-being/quality of life, health-related quality of life (QOL), medical condition and caregiver burden were not measured once in our sample. The other outcome areas were only rarely analysed.

For informal caregivers, caregiver burden is the most frequently analysed outcome area ($n = 7$), while all other outcome areas were rarely analysed or not at all (e.g. knowledge & competences $n = 0$; compliance $n = 0$; use of caregiving support $n = 0$). The most frequently analysed outcome areas for healthcare organisations are care process quality ($n = 21$), operational efficiency ($n = 21$) and communication/social interaction ($n = 15$). Little research has been done on financial performance ($n = 4$), access to care ($n = 1$) or working conditions ($n = 1$),

Table 1 Framework with overall results

Person in need of care	N	Formal Caregiver	N	Informal Caregiver	N	Healthcare Organisation	N
Functional Health	16	(Job) Satisfaction	3	(Life) Satisfaction	2	Care Process Quality	21
Physiological Health	11	Medical Health condition	0	Medical Health Condition	0	Access to Care	1
Psychosocial health	33	Psychosocial health	0	Psychosocial Health	4	Communication/Social Interaction	15
Social Condition	7	Professional Knowledge and Competences	2	Social Condition	3	Recruitment and Staffing	0
Health Behaviour	5	Physical/ Psychological Workload	6	Living Conditions	2	Working Conditions	1
Health Knowledge & Attitudes	3	Relationship to Person in Need of Care	7	Knowledge and Competences	0	Operational Efficiency	21
Patient Safety	11			Compliance	0	Financial Performance	4
				Physical/ Psychological Workload	2		
				Use of caregiving support	0		
Overarching Concepts		Overarching Concepts		Overarching Concepts		Overarching Concepts	
Well-being/ Quality of Life	17	Well-being/ Quality of Life	0			Hospital/Nursing Home Quality	4
Health-related QOL	13	Health-related QOL	0	Well-being/ Quality of Life	2		
Needs Assessment/ Fulfilled Needs	3	Caregiver Burden	0	Health-related QOL	0		
				Caregiver Burden	7		
Organisational		Organisational					
Intensity of Service Utilization	19	Employee Satisfaction	0				
Organisational Patient Safety Indicators	18	Professional Guideline Compliance	7				
Patient Satisfaction	6	Impact on Workload	2				
Intersectoral Continuity of Care	1						
Total number of studies*	77		20		10		45

*the total number of studies is lower than the amount (n) of the outcome areas from the above table, as single studies contain aspects from multiple outcome areas

while aspects of recruitment and staffing were not evaluated at all.

Outcome areas of tools

This section provides a numerical analysis of all outcome tools included in the 123 articles. The numbers in Table 2 indicate the outcome tools used in each outcome area. The psychosocial state of persons in need of care was evaluated broadly using different tools ($n = 69$), as well as well-being/quality of life ($n = 14$), whereas social condition ($n = 0$) or health knowledge & attitudes ($n = 0$) were not analysed using tools. Formal caregivers were seldom examined using tools. Looking at the distribution of the available studies, psychological health ($n = 3$) was proportionally the most frequently measured outcome area for formal caregivers. Individual-related outcome areas such as medical condition or relationship to the person in need of care, or organisation-related individual outcomes such as employee satisfaction or impact on workload were not measured at all using outcome tools. Outcomes for informal caregivers were also rarely analysed using tools. The most frequently used concept was caregiver burden ($n = 10$). This is an overarching concept, which includes many of the single outcome areas listed for informal caregivers. A similar picture emerges for organisational factors. Only communication/social interaction ($n = 4$) and hospital/nursing home quality were evaluated using tools ($n = 3$). In the next sections, a detailed analysis is carried out to show which tools were used in the individual result areas.

Outcome tools used for specific target groups

Effectiveness relating to persons in need of care

In order to establish how past studies have attempted to measure the effectiveness of care technologies, we have listed all outcome tools that have been used and categorized them according to the outcome framework. Most of the studies included here investigated the effectiveness of a technology on persons in need of care ($n = 77$). Almost half of these studies ($n = 38$) used standardised instruments for measuring effectiveness. All instruments are listed in Tables 3 and 4 (for psychological measures)

Table 2 Numerical analysis of outcome tools

Persons in need of care	N	Formal Caregiver	N	Informal Caregiver	N	Healthcare Organisation	N
Functional Health	7	(Job) Satisfaction	1	(Life) Satisfaction	2	Care Process Quality	0
Physiological Health	9	Medical Health condition	0	Medical Health Condition		Access to Care	0
Psychological Health	69	Psychological Health	3	Psychological Health	2	Utilization of Services	0
Social Condition	0	Professional Knowledge and Competences	1	Social Condition	0	Communication/Social Interaction	4
Health Behaviour	1	Physical/ Psychological Workload	2	Living Conditions	0	Recruitment and Staffing	0
Health Knowledge & Attitudes	0	Relationship to Person in Need of Care	0	Knowledge and Competences	0	Working Conditions	0
Patient Safety	0			Compliance	0	Operational Efficiency	0
				Physical/ Psychological Workload	0	Financial Performance	0
				Use of caregiving support	0		
Overarching Concepts		Overarching Concepts		Overarching Concepts		Overarching Concepts	
Well-being/ Quality of Life	14	Well-being/ Quality of Life	0		0	Hospital/Nursing Home Quality	3
Health-related QOL	7	Health-related QOL	1	Well-being/ Quality of Life	0		
Needs Assessment/ Fulfilled Needs	3	Caregiver Burden	0	Health-related QOL	1		
				Caregiver Burden	10		
Organisational		Organisational					
Intensity of Service Utilization	1	Employee Satisfaction	0				
Organisational Patient Safety Indicators	2	Professional Guideline Compliance	0				
Patient Satisfaction	3	Impact on Workload	0				
Intersectoral Continuity of Care	0						

with a reference to the studies that use them. The corresponding outcome area is indicated in the top row of both Tables. A total of 69 different instruments were identified, most of which measure the psychological health of the person in need of care: 40 different instruments were used to measure the psychological health condition. The change effect is most frequently measured in terms of a state of depression, for example by using the Geriatric Depression Scale (n = 8) or the Cornell Scale for Symptoms of Depressions in Dementia (n = 4). The most frequently used single instrument for cognition is the Mini-Mental-State Examination (n = 8). In addition to mental state, the impact of technology on the quality of life was also frequently measured. The Quality of Life in Alzheimer's Disease scale (QOL-AD) was most frequently used here (n = 7). Tools for the measurement of organisational patient safety indicators (n = 3) or intensity of service utilization (n = 3) were used less often. Most of the tools were only used in single studies.

Effectiveness relating to caregiver

Significantly fewer studies from our sample relate to results for caregivers. Only 30 studies referred to caregiver outcomes, and eleven of them used standardised instruments (Table 5). A total of 20 different instruments were found, four of them specifically for formal caregivers and, ten for informal caregivers; five are universal instruments. Though there are fewer studies on informal caregivers (n = 10) than on formal caregivers (n = 20), the informal caregiver burden was the most frequently addressed outcome area for outcome tools. The second most frequently used category of tools addresses psychological changes and the third most frequently used category of instruments evaluates changes in satisfaction. Instruments for QOL, knowledge and workload were the least used. We did not find any instruments for measuring the physical load of caregivers. No tool can be named that has been used particularly frequently for the evaluation of caregivers. Almost all tools were used only once in the sample.

Organisational effectiveness

Aspects of organisational effectiveness were measured in 45 studies. Seven studies used different standardised instruments. We found four instruments to analyse communication/social interaction in the respective organisation and three instruments to analyse hospital

Table 3 Outcome tools for person in need of care

N	Functional Health	N	Psychological Health	N	Organisational Patient Safety Indicators	N	Quality of Life	N	Health-related QOL	N	Needs Assessment/ Fulfilled Needs	N	Patient Satisfaction	N	Intensity of Service Utilization
2	IADL: Instrumental Activities of Daily Living Scale (Lawton) [47, 48]	1	BRADEN SCALE –For Predicting Pressure Sore Risk [49]	2	Agency for Health Research and Quality (AHRQ) Patient safety indicators [50, 51]	2	WHO-QOL: WHO Quality of Life Scale [21, 52]	2	EQ-5D (perceived level of health) [53, 54]	2	CANE: Camberwell Assessment of Need for the Elderly [21, 55]	2	HCAHPS: Hospital Consumer Assessments of Healthcare Providers and Systems [56, 57]	1	MCI: Medication Complexity Index [58]
1	GARS: Groningen Activity Restriction Scale [53]	1	PUSH Tool: Pressure Ulcer Scale for Healing [49]	1	AHRQ IQI: Inpatient Quality Indicators [51]	7	QOL-AD: Quality of Life - Alzheimer Disease [21, 55, 59–63]	2	SF-36: 36-Item Short Form Survey [58, 64]	1	IPPA: Individually Prioritized Problems Assessment score [12]	1	Frustration survey (Patak) [65]		
3	Barthel Index for Activities of Daily Living [54, 61, 64]	1	FACES: Wong Baker Faces Scale (Pain Measurement) [66]			3	QUALID-Scale: Quality of live in late-stage-dementia scale [67–69]	1	EQ-5D + c (perceived level of health and cognitive function) [55]						
1	ADL: Activities of Daily Living Scale (Lawton) [48]	1	PPT: Physical Performance Test [58]			1	ASCOT: Adult Social Care Outcomes Toolkit (well-being) [70]	1	SF-12: 12-Item Short Form Health Survey [71]						
1	MFES: Modified Falls Efficacy Scale [54]	1	Berg Balance Scale (physical performance) [64]					1	SF-8 Health Survey [72]						
								2	VAS: Visual analogue scale (pain intensity measure for adolescent self-report and caregiver observations [66, 73]						
								2	FLACC: Faces, Legs, Activity, Cry, Consolability) Pain Measurement [66, 73]						

Table 4 Psychological health outcome tools for person in need of care

N	Tools	Measurement of:
1	COOP/WONCA Mood scale [12]	Mood
8	GDS: Geriatric Depression Scale [47, 48, 58–60, 62, 69, 71]	Depression
3	CSDD: Cornell Scale for Symptoms of Depressions in Dementia [63, 74, 75]	Depression
1	PHQ-9: Patient Health Questionnaire (Depression) [52]	Depression
1	HAM-D: Hamilton Depression Rating Scale [47]	Depression
1	BDI: Beck Depression Inventory [47]	Depression
1	GDS-12R: Geriatric Depression Scale (residential) [76]	Depression
4	CMAI/CMAI-SF: Cohen-Mansfield-Agitation Inventory Instrument [67, 74, 77, 78]	Agitation
2	Raid: Rating Anxiety in Dementia Scale [60, 75]	Anxiety
1	BARS: Brief Agitation Rating Scale [77]	Agitation
1	BAI: Beck Anxiety Inventory [47]	Anxiety
1	Burn Specific Pain Anxiety Scale (BSPAS) [79]	Anxiety
1	AOL: Alertness Observation (check)-List [80]	Alertness
1	PSS: Perceived Stress Scale [47]	Stress
1	RAWS: Revised Algase Wandering Scales [60]	Wandering
1	APADEM-NH: Apathy scale [69]	Apathy
1	AI: Apathy Inventory [69]	Apathy
1	AES: Apathy Evaluation Scale [60]	Apathy
1	GSR: Galvanic skin Response (measuring emotional arousal) [75]	Affect
1	OERS: Observed Emotion Rating Scale [60]	Affect
2	UCLA: loneliness scale [52, 62]	Loneliness
1	DJGLS: De Jong Gierveld Loneliness Scale [81]	Loneliness
4	NPI: Neuropsychiatric Inventory [47, 55, 61, 69]	Psychological Symptoms
1	OQ-45 -questionnaire (psychological patient progress) [52]	Psychological Symptoms
1	BNT: Boston Naming Test [48]	Psychological Symptoms
1	NPI-Q: Neuropsychiatric Inventory Questionnaire [74]	Psychological Symptoms
1	Pearlin Mastery Scale (psychological resources) [21]	Psychological Resources
8	MMSE: Mini-Mental State Examination [21, 47, 48, 58, 61, 63, 64, 69]	Cognition
2	TMT: Trail Making Test A/B (Visual attention and task switching) [47] [48]	Cognition
1	sMMSE: Severe Mini Mental State Examination [69]	Cognition
1	MoCA: Montreal Cognitive Assessment [47]	Cognition
1	FUCAS: Functional Cognitive Assessment Scale [47]	Cognition
1	CDT: Clock Drawing Test (cognitive impairment) [48]	Cognition
1	GDS* Global Deterioration Scale (cognitive function) [75]	Cognition
1	ACE-R: Addenbrooke's Cognitive Examination-Revised [82]	Cognition
2	ROCF: Rey–Osterrieth complex figure (spatial visual construction and visual memory) [47, 48]	Memory
2	RAVLT: Rey Auditory Verbal Learning Test [47, 48]	Memory
1	RBMT: Rivermead Behavioral Memory Test [47]	Memory
1	Digit Span Memory Test [48]	Memory
1	TEA: Test of Everyday Attention [47]	Attention

quality (Table 6). Each tool was used only once in the sample.

Discussion

The aims of this scoping review are (i) to show which possible outcome areas for measuring effectiveness of DNT can be identified, (ii) to depict which areas have been the focal point of research on effectiveness of DNT so far, and which areas have been researched less, and (iii) to show how effectiveness has been measured in previous studies. The discussion section is structured around these research questions. Therefore, we divided the discussion section into three main parts: discussion of the framework development (i), critical reflection in

Table 5 Caregiver relevant outcome tools

n	Psychological Health	n	Caregiver Burden	n	(Job) Satisfaction	n	Health-related QOL	n	Professional Knowledge and Competences	n	Impact on Workload
1	PERI-D: Psychiatric Epidemiology Research Instrument[2] (Demoralization Scale) [59]	2	SSCQ: Short Sense of Competence questionnaire[2] (dealing with burden) [21, 55]	1	Job Satisfaction Score[1] (Hagopian et al.) [59]	1	SF-12: 12-Item Short Form Health Survey[1] [59]	1	Palliative and End of Life Care competency Assessment Tool[1] [83]	1	NASA-TLX: The NASA Task Load Index[1] [84]
1	MM-CGI: Marwit Meuser Caregiver Grief Inventor – short form[2] [85]	2	ZBI-12: Zarit Burden Interview - short form[2] [85, 86]	1	CSS: Caregiving Satisfaction Scale[2] [86]	1	EQ-5D + c (perceived level of health and cognitive function)[2] [55]			1	RUD-FOCA: Resource Utilization in Dementia – Formal Care [1] [63]
1	PHQ-9: Patient Health Questionnaire [2] (Depression) [85]	1	DIS: Desire to Institutionalize Scale[2] [85]	1	Press-Ganey™ patient satisfaction surveys[2] [87]						
1	NPI: Neuropsychiatric Inventory[2] [55]	1	NAC: National Alliance for Caregiving survey[2] [86]								
		1	CSI: Caregiver Strain Index[2] [53, 86]								
		1	SPPIC: Self-Perceived Pressure from Informal Care – Scale[2] [88]								
		1	OBM: Objective Burden Informal Caregiver[2] [53]								
		1	SRB: Self Rated Burden [2] [53]								

1: used for formal caregivers; 2: used for informal caregivers

relation to the scientific literature (i) and discussion of the quantitative analysis (ii & iii).

Framework development

The comprehensive DNT outcome framework was developed to show which possible outcome areas can be identified for the evaluation of DNT. This framework can be used by researchers to structure their effectiveness evaluation and to check whether essential outcome areas are considered in their evaluation. Thus, its purpose is thus to encourage researchers to focus on specific outcome areas or include additional outcome areas in their work. It is also intended to promote and structure discussion and reflection on desirable or necessary research objectives of DNT and may help to draw inferences on areas in which undesirable negative effects may emerge. The framework was developed using deductive and inductive methods, and therefore comprises elements that have already been researched specifically for the field of technology as well as a derivation from general nursing contexts to the specific context of DNT. Parts of the framework are therefore generic and could also be used for the evaluation of general nursing care interventions. We have also included both effectiveness and efficacy studies in the development of the Framework. Being aware of the differences of these two concepts, we assume that the incoherent use of the words within the analysed studies was caused by the fact that "efficacy and effectiveness exist on a continuum" [91] and the generalizability depends on the viewpoint of the observer and the observed condition [91]. The incorrect or incoherent classification of the two terms has already been described in the scientific literature [92]. In order to allow researchers to choose from a variety of possible

Table 6 Organisation-related outcome tools

n	Hospital/Nursing Home Quality	N	Communication/Social Interaction
1	QAS: Quality Improvement Activities Survey [57]	1	Perception of Communication Difficulty Questionnaire [65]
1	CPS: Clinicians' Perceptions of Quality Survey [57]	1	Frustration with Communication tool [65]
1	CalNOC: Medical Administration Accuracy Observation Codesheet [89]	1	CSACD: Formal Caregiver: Collaboration and Satisfaction About Care Decisions survey instrument [90]
		1	QCPR: quality of caregiving relationship [76]

outcomes adapted to the particular circumstances and context of the study, and to decide which outcome areas are to be evaluated, it is necessary to develop the most comprehensive framework possible. This led us to include studies referring to themselves as effectiveness studies and studies that refer to themselves as efficacy studies. We leave it to the judgement of the respective researchers to decide which are the optimal outcome areas and corresponding outcomes for their aspired studies.

Critical reflection of the framework in relation to the scientific literature

When comparing our framework with existing frameworks in the field of digital technologies in health care we can state that to the best of our knowledge there is no other such comprehensive framework with a special focus on nursing. As stated in the methods section, we incorporated other frameworks in the development of the DNT framework. To highlight the specific strengths of the newly developed framework, we shall now briefly describe the differences between the DNT framework and some other frameworks in similar contexts. The most comprehensive framework available (MAST) was incorporated in the design of the DNT framework [18]. MAST provides seven domains, including a focus on patients and a focus on the organisation. Five of the seven domains are highly relevant to the nursing context and were therefore included in the development of the DNT outcome framework (safety, clinical effectiveness, patient perspectives, economic aspects, organisational aspects). Formal caregivers are only rarely considered in MAST, and informal caregivers are not considered at all. These target groups are presented and highlighted in much greater detail in the DNT results framework. As a holistic framework, MAST also contains references to sociocultural, ethical and legal aspects. These are important areas for the evaluation of DNT in general, but they do not fit into the specific context of an effectiveness evaluation for DNT that we wanted to depict in this study. The analysis of ethical and socio-cultural effects requires different research approaches, which are not reflected in our sample. In order to cover these areas, it would be necessary to include a macro perspective underpinned by scientifically sound data. We have deliberately not focused on the macro level, but it would be a possibility to complement this with further research.

For a second comparison, the Infoway Benefits Evaluation Framework [17] is used. This framework divides the evaluation of health information systems into six main dimensions: system, information, service, use, satisfaction and net benefits. The "net benefits" dimension includes many outcome areas such as patient safety, health outcomes, access to care and productivity that were integrated into the DNT outcome framework. User (in this case patient) satisfaction was also integrated into the DNT outcome Framework, but we added areas relating to formal and informal carers, as they were not taken sufficiently into account in the Infoway Benefits Evaluation Framework. Other attributes such as accuracy, performance or functionality refer primarily to the effectiveness of the respective technology, so we therefore excluded them from the DNT Framework.

For another comparison we refer to the adapted version of the Nursing Care Performance Framework [2], which displays the impact of ICT solutions on nursing care. This framework shows important areas especially for formal caregiving, which can also be found in the DNT Outcome Framework. Informal caregivers are not represented, which is certainly due to the focus. The effects on patients are presented in a very specific way. Our DNT outcome frameworks can be helpful to complement some details on outcome areas, such as psychological health or health behaviour. The comparison of the DNT framework with the systematization in a systematic review of effectiveness studies in the field telemedicine [93], indicates that the DNT Framework covers all important outcome areas on the micro and meso level. Ekelanda et al. also include a few aspects on the macro level, e.g. in the area of politics [93]. This level was excluded in the DNT outcome framework, as it implies a different perspective of analysis, and none of the studies in the scoping review related to the macro level. The exploration of outcome areas, outcome tools and outcome measures on the macro level, however, is an interesting field for future research. In sum, it can be said that the developed DNT outcome framework closes an existing gap in nursing and technology research by including all important outcome areas relevant to nursing.

Reflection on the included outcome areas and outcome tools

We evaluated all outcome tools and measures of the included 123 articles with a view to establishing which outcome areas have so far been focused on by research on DNT effectiveness, and which areas have been researched less. There are considerable differences in the researched outcome areas for the individual outcome target groups. It should be pointed out, however, that no valuation of the significance of an outcome area can be made at present. This could be the topic of further research. The study presented here constitutes a first step towards summarizing existing trends.

Persons in need of care were by far the most frequently researched target group. Psychological health, intensity of service utilization, and organisational patient safety indicators were measured much more frequently than needs assessment/ fulfilled needs, health knowledge

& attitudes or intersectoral continuity of care. There might be several reasons for this. On the one hand, it might be more difficult to capture fulfilled needs, intersectoral continuity of care, or health knowledge & attitudes with the existing standardised instruments or outcome measures. On the other hand, it might simply not have been of such profound interest during the evaluation because the respective technologies did not target these areas. It is interesting to note that intersectoral care is an area that has so far largely been neglected. Intersectoral care in form of communication or collaboration between different healthcare sectors (e.g. ambulatory care and inpatient care) [94] could, for example, help to prevent hospitalisations [95]. One reason for the neglection of intersectoral care might be that while it is already difficult to implement digital technologies in a single sector, sector boundaries possible constitute a major challenge. The decision-making structures of a healthcare system might be seen to be a barrier to change in this context [96].

Overall in our sample, formal and informal caregivers have not been researched frequently in terms of the effectiveness of DNT. Relationship to person in need of care was most frequently measured among formal caregivers, along with guideline compliance and physical/psychological workload. Well-being/quality of life, health-related quality of life, medical condition and caregiver burden were not measured once in our sample. Several other outcome areas were very rarely analysed. This shows that these aspects were neglected in the past, while quality of life and caregiver burden on professional caregivers are still not being evaluated. The reasons for this should be clarified. It is unclear whether this is the case because these outcome areas are generally considered to be less important than others, or whether there are other reasons for non-evaluation. Assuming that an important goal of digital technologies in nursing care is to relieve nursing staff, it seems inappropriate to only evaluate the direct workload (e.g. physical load or psychological stress through direct work) and not evaluate the effects of digital technologies on the general burden on or the quality of life of formal caregivers. Existing instruments such as the Professional Care Team Burden (PCTB) scale harbour the potential to contribute to the evaluation of DNT in this context [97].

The caregiver burden of informal caregivers was the most frequently analysed outcome area, while all other outcome areas were analysed very seldom or not at all. One reason might be that most instruments for measuring caregiver burden have been developed for informal caregivers [97]. On the other hand, there seems to have been a socio-political interest in reducing the burden on family members through technology in the past. At the same time, the medical health condition, knowledge and competences or the use of caregiving support of informal caregivers have not been analysed in a single study. Medical health may not have been recorded for reasons of personal data protection. Specialised nursing knowledge and skills do not seem to play such a large role in research on technological support for informal carers. We expect enhanced support for informal caregivers to play a more important role in the future, and, hence, those research areas that are seldom examined now to become more important.

The most frequently analysed outcome areas for healthcare organisations were care process quality, operational efficiency and communication/social interaction. Little research has been done on financial performance, access to care and working conditions, while recruitment and staffing areas were not evaluated at all. The frequently researched areas correspond with the potential goal of technologies to improve efficiency while maintaining a high quality of care [98]. Aspects of working conditions or effects on the recruitment or staffing processes from an organisational perspective have apparently never been analysed. If it is assumed that, from an organisational point of view, the main purpose of the technologies is to increase efficiency while maintaining or improving the quality of care, factors such as working conditions for carers play a minor role. This is consistent with the results on formal caregivers. Nevertheless, it is interesting that the impact of existing technologies on recruitment has not been investigated, as technologies are often claimed to be beneficial in terms of enhancing the attractiveness of a healthcare organisation for prospective and current employees [99], which could be expressed in an evaluation of the effects of a technology on recruitment figures. In the light of the current lack of skilled workers, proof of such effects might be an interesting finding.

The third research question was addressed by showing which outcome areas were evaluated with outcome tools and which areas were more likely to be covered by other measures. At the same time, the variety and range of the tools used were presented. The wide range of outcome tools – especially in the field of psychological health - makes it difficult to compare the studies' results, and a common set of standards for using outcome tools shared by several studies would considerably help improve comparability To this end, further research is needed to assess and evaluate existing outcome tools.

Limitations

Limitations that refer to the underlying scoping review are described in Krick et al. 2019. Especially important for this additional methodological analysis are the following aspects:

Publication bias in particular should be considered here. Studies without positive results are often not published in journals. Outcome areas for which effects are difficult to prove may be underrepresented in this article due to this publication bias, whereby, there is a possibility that studies on certain technologies may have been over-represented, under-represented or not presented at all due to negative results. This may indirectly affect the presented outcome tools and measures.

The included outcome areas and outcome tools presented could also be influenced by the fact that we included both effectiveness and efficacy studies in the development of the framework. It could be criticised that a further breakdown of a framework for efficacy studies and a framework for effectiveness studies is necessary because they may differ in their outcomes and tools. However, we decided to combine these concepts for the reasons of applicability and comprehensiveness, as described in the discussion section. Based on the included publication period of 7 years, the question needs to be considered whether outcome tools or outcome measures are only mapped for the indicated period, and therefore relevant measures of the effectiveness of DNT applied outside that period are missing. There is also the possibility that outcome areas overlap or might have been composed differently by other researchers. Overall, we have tried to ensure the highest possible standard for the outcome framework, by combining literature and expert knowledge. The current version is very comprehensive, but the field of research on DNT is very dynamic, and future adaptions should be included.

Conclusion

This scoping review provides a broad overview on outcome areas and outcome tools used for the evaluation of digital nursing technologies. All outcome tools and measures have been categorised according to our newly developed DNT outcome framework to show which areas have been focused on by research on effectiveness of DNT so far and which areas have rather been neglected. We highly recommend the use of this framework (and the further explanations given in the Additional files) as a basis for future research. Researchers can use the DNT outcome framework as a tool to structure their effectiveness evaluations and to examine whether essential outcome areas have been overlooked in their evaluations. Currently, the DNT outcome framework mainly provides an overview of all outcome areas. The weighting of the importance or significance of the different outcome areas – especially those that have been less explored so far – should be subjected to further research. This would require a more detailed assessment of the individual outcome areas, including a valuation of the areas in the subsequent research. We also consider it important to investigate the heterogeneity of interventions in DNT and to deepen the understanding of different important outcomes linked to these DNTs.

Our systematized overview of the tools in the individual areas can be used as a starting point for further research, in order to share and compare information about appropriate tools and initiate a discussion on the standardisation of tools used for similar questions. An appropriate exchange would also certainly be helpful for outcomes measures used that are not listed here in detail due to the large number.

So far, our findings indicate that intersectoral continuity of care for persons in need of care, quality of life of formal and informal caregivers, caregiving support for informal caregivers and working conditions from an organisational perspective are outcome areas which have only been scantily researched so far and would benefit considerably from future research. At the same time, we recommend the development of outcome areas for the macro level of effectiveness assessment, which is not included in the current version of the DNT outcome framework. Overall, the DNT outcome framework already offers a very good overview of the possible outcome areas and we are confident that future research will benefit from this structured approach.

Supplementary information

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Additional file 1. Definitions and Examples for Outcome Areas for Persons in Need of Care.

Additional file 2. Definitions and Examples for Outcome Areas for Outcome Areas Formal Caregivers.

Additional file 3. Definitions and Examples for Outcome Areas for Outcome Areas Informal Caregivers.

Additional file 4. Definitions and Examples for Outcome Areas for Outcome Areas Organisation.

Additional file 5. Included Technologies.

Abbreviations

ACM: Association for Computing Machinery; DNT: Digital Nursing Technologies; MAST: Model for Assessment of Telemedicine; NOC: Nursing Outcomes Classification; QOL: Quality of life; QOL-AD: Quality of Life - Alzheimer Disease

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Authors' contributions

TK and KH conceptualized the study, developed the outcome framework, the data abstraction form and screened the studies with respect to outcomes measures and outcome tools. TK interpreted the results and wrote the first draft of the manuscript. KWO obtained funding for the study. TK, KH, DD, KS and KWO read and provided substantial edits on the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate
Not applicable.

Consent for publication
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Competing interests
There are no competing interests to declare.

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References
1. Krick T, Huter K, Domhoff D, Schmidt A, Rothgang H, Wolf-Ostermann K. Digital technology and nursing care: a scoping review on acceptance, effectiveness and efficiency studies of informal and formal care technologies. BMC Health Serv Res. 2019;19:400.
2. Rouleau G, Gagnon MP, Côté J, Payne-Gagnon J, Hudson E, Dubois CA. Impact of information and communication technologies on nursing care: Results of an overview of systematic reviews. J Med Internet Res. 2017;19:4.
3. Lau F. Kuziemsky C (eds.): handbook of eHealth evaluation: an evidence-based approach. Victoria: University of Victoria; 2016.
4. EUnetHTA. EUnetHTA Joint Action 2, Work Package 8. HTA Core Model ® version 3.0. In; 2016. p. 410.
5. Bemelmans R, Gelderblom GJ, Jonker P, de Witte L. Socially Assistive Robots in Elderly Care: A Systematic Review into Effects and Effectiveness. J Am Med Directors Assoc. 2012;13(2):114–20 e111.
6. Capurro D, Ganzinger M, Perez-Lu J, Knaup P. Effectiveness of eHealth interventions and information needs in palliative care: a systematic literature review. J Med Internet Res. 2014;16(3) e72.
7. Fleming R, Sum S. Empirical studies on the effectiveness of assistive technology in the care of people with dementia: a systematic review. J Assist Technol. 2014;8(1):14–34.
8. Van der Roest HG, Wenborn J, Pastink C, Droes RM, Orrell M. Assistive technology for memory support in dementia. Cochrane Database Syst Rev. 2017;6:Cd009627.
9. Khosravi P, Ghapanchi AH. Investigating the effectiveness of technologies applied to assist seniors: a systematic literature review. Int J Med Inform. 2016;85(1):17–26.
10. Peretz D, Arnaert A, Ponzoni NN. Determining the cost of implementing and operating a remote patient monitoring programme for the elderly with chronic conditions: a systematic review of economic evaluations. J Telemed Telecare. 2018;24(1):13–21.
11. Calvaresi D, Cesarini D, Sernani P, Marinoni M, Dragoni AF, Sturm A. Exploring the ambient assisted living domain: a systematic review. J Ambient Intell Humaniz Comput. 2017;8(2):239–57.
12. Bemelmans R, Gelderblom GJ, Jonker P, de Witte L. Effectiveness of robot Paro in intramural psychogeriatric care: a multicenter quasi-experimental study. J Am Med Dir Assoc. 2015;16(11):946–50.
13. Yusofa MM, Kuljis J, Papazafeiropouloub A, Stergioulasb LK. An evaluation framework for Health Information Systems: human, organization and technology-fit factors (HOT-fit). Int J Med Informatics. 2008;77:386–98.
14. Sockolow P, Crawford P, Lehmann HP. Health services research evaluation principles. Methods Inf Med. 2012;51(02):122–30.
15. Information CIfH. A performance measurement framework for the Canadian health system. In. Ontario: Canadian Institute for Health Information; 2012.
16. Carinci F, Van Gool K, Mainz J, Veillard J, Pichora EC, Januel JM, Arispe I, Kim SM, Klazinga NS. Group aoBoTOHCQIE *et al*: towards actionable international comparisons of health system performance: expert revision of the OECD framework and quality indicators. Int J Qual Health Care. 2015;27(2):137–46.
17. Francis Lau F, Hagens S, Muttitt S. A Proposed Benefits Evaluation Framework for Health Information Systems in Canada. Healthcare Quarterly. 2007;10:1.
18. Kidhom K, Bowes A, Dyrehauge S, Ekeland AG, Flottorp SA, Jensen LK, Pedersen CD, Rasmussen J. The MAST Manual. MAST - Model for ASsessment of Telemedicine. In: MethoTelemed team; 2010.
19. Schulz R, Wahl H-W, Matthews JT. Advancing the aging and technology agenda in gerontology. Gerontologist. 2015;55(5):724–34.
20. Lang RLN. Evaluating the effectiveness of nurse-focused computerized clinical decision support on urinary catheter practice guidelines: Gardner-Webb University; 2012.
21. Hattink BJJ, Meiland FJM, Overmars-Marx T, de Boer M, Ebben PWG, van Blanken M, Verhaeghe S, Stalpers-Croeze I, Jedlitschka A, Flick SE, et al. The electronic, personalizable Rosetta system for dementia care: exploring the user-friendliness, usefulness and impact. Disabil Rehabil. 2016;11(1):61–71.
22. Broadbent E, Orejana JR, Ahn HS, Xie J, Rouse P, MacDonald BA. The cost-effectiveness of a robot measuring vital signs in a rural medical practice. In: 2015 24th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN): Aug. 31 2015-Sept. 4 2015 2015; 2015. p. 577–81.
23. Kunkel C, Kopp W, Hanson M. A matter of life and death: end-of-life simulation to develop confidence in nursing students. Nurs Education Perspectives (Wolters Kluwer Health). 2016;37(5):285–6.
24. Scott R, Saeed A. Global eHealth - measuring outcomes: why, what, and how a report commissioned by the World Health Organization's global observatory for eHealth. In. Bellagio: World Health Organization's Global Observatory for eHealth; 2008.
25. Scott RE, McCarthy FG, Jennett PA, Perverseff T, Lorenzetti D, Saeed A, Rush B, Yeo M. Telehealth outcomes: a synthesis of the literature and recommendations for outcome indicators. J Telemed Telecare. 2007; 13(Suppl 2):1–38.
26. Gartlehnera G, Hansenb RA, Nissmanc D, Lohrd KN, Careye TS. A simple and valid tool distinguished efficacy from effectiveness studies. J Clin Epidemiol. 2006;59:1040e1048.
27. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. Int J Soc Res Methodol. 2005;8(1):19–32.
28. Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. Implement Sci. 2010;5(1):69.
29. Greenhalgh T, Peacock R. Effectiveness and efficiency of search methods in systematicreviews of complex evidence: audit of primary sources. BMJ. 2005; 331:1064–5.
30. Maas M, Swanson E, Herrmann M, Moorhead S, Johnson M, Aquilino M. Pflegeergebnisklassifikation (NOC) vol. 2., vollst. überarb. und erw. Aufl. Bern: Huber; 2013.
31. Nabbout R, Auvin S, Chiron C, Irwin J, Mistry A, Bonner N, Williamson N, Bennett B. Development and content validation of a preliminary core set of patient- and caregiver-relevant outcomes for inclusion in a potential composite endpoint for Dravet syndrome. Epilepsy Behav. 2018;78:232–42.
32. Schwartz S, Laura Darlak L, Whitlatch CJ. Selected caregiver Assessment measures: a resource inventory for practitioners. In., vol. 2nd edition. Cleveland: Margaret Blenkner Research Institute of the Benjamin Rose Institute on Aging; 2012.
33. Zendjidjian XY, Boyer L. Challenges in measuring outcomes for caregivers of people with mental health problems. Dialogues Clin Neurosci. 2014;16(2): 159–69.
34. Henriksson A, Arestedt K. Exploring factors and caregiver outcomes associated with feelings of preparedness for caregiving in family caregivers in palliative care: a correlational, cross-sectional study. Palliat Med. 2013; 27(7):639–46.
35. Deeken JF, Taylor KL, Mangan P, Yabroff KR, Ingham JM. Care for the caregivers: a review of self-report instruments developed to measure the burden, needs, and quality of life of informal caregivers. J Pain Symptom Manag. 2003;26(4):922–53.
36. Son J, Erno A, Shea DG, Femia EE, Zarit SH, Stephens MA. The caregiver stress process and health outcomes. J Aging Health. 2007;19(6):871–87.
37. Hoefman R, Al-Janabi H, McCaffrey N, Currow D, Ratcliffe J. Measuring caregiver outcomes in palliative care: a construct validation study of two

instruments for use in economic evaluations. Qual Life Res. 2015;24(5):1255–73.
38. Carod-Artal FJ, Mesquita HM, Ziomkowski S, Martinez-Martin P. Burden and health-related quality of life among caregivers of Brazilian Parkinson's disease patients. Parkinsonism Relat Disord. 2013;19(11):943–8.
39. Sim J, Crookes P, Walsh K, Halcomb E. Measuring the outcomes of nursing practice: a Delphi study. J Clin Nurs. 2018;27(1–2):e368–78.
40. Epstein MJ, Rejc A. Evaluating performance in information technology. In. Canada: The Society of Management Accountants of Canada; 2005.
41. Trierweiller AC, Peixe BC, Tezza R, Pereira VL, Pacheco W Jr, Bornia AC, de Andrade DF. Measuring organizational effectiveness in information and communication technology companies using item response theory. Work. 2012;41(Suppl 1):2795–802.
42. Jain R, Shermon G. Creating an optimized organisation key opportunities and challenges. In. India: KPMG; 2012.
43. Cascio W, Montealegre R. How technology is changing work and organizations. Ann Rev Org Psychol Organizational Behav. 2016;3:349–75.
44. Damberg CL, Sorbero ME, Lovejoy SL, Martsolf GR, Raaen L, Mandel D. Measuring success in health care value-based purchasing programs: findings from an environmental scan, literature review, and expert panel discussions. Rand Health Quarterly. 2014;4(3):9.
45. Jalagat R. Amur said Al-Habsi N: evaluating the impacts of IT usage on organizational performance. Eur Acad Res. 2017;5:5111–64.
46. Organisation WH: Innovative Care for Chronic Conditions: Building Blocks for Action In.: World Health Organisation; 2002.
47. Lazarou I, Karakostas A, Stavropoulos TG, Tsompanidis T, Meditskos G, Kompatsiaris I, Tsolaki M. A novel and intelligent home monitoring system for care support of elders with cognitive impairment. J Alzheimers Dis. 2016; 54(4):1561–91.
48. Zaccarelli C, Cirillo G, Passuti S, Annicchiarico R, Barban F. Computer-based cognitive intervention for dementia Sociable: motivating platform for elderly networking, mental reinforcement and social interaction. In: 2013 7th International Conference on Pervasive Computing Technologies for Healthcare and Workshops: 5–8 May 2013 2013; 2013. p. 430–5.
49. Florczak B, Scheurich A, Croghan J, Sheridan P Jr, Kurtz D, McGill W, McClain B. An observational study to assess an electronic point-of-care wound documentation and reporting system regarding user satisfaction and potential for improved care. Ostomy Wound Manag. 2012;58(3):46–51.
50. Appari A, Johnson EM, Anthony DL. Information technology and hospital patient safety: a cross-sectional study of US acute care hospitals. Am J Managed Care. 2014;20(17):eSP39–47.
51. Mitchell S, Yaylacicegi U. EHR prescription for small, medium, and large hospitals: an exploratory study of Texas acute care hospitals. Int J Electron Healthc. 2012;7(2):125–40.
52. Bennett CC, Sabanovic S, Piatt JA, Nagata S, Eldridge L, Randall N. A Robot a Day Keeps the Blues Away. In: 2017 IEEE International Conference on Healthcare Informatics (ICHI): 23–26 Aug. 2017 2017; 2017. p. 536–40.
53. Lexis M. Activity monitoring technology to support homecare delivery to frail and psychogeriatric elderly persons living at home alone. Technol Disabil. 2013;25(3):189–97.
54. Sahota O, Drummond A, Kendrick D, Grainge MJ, Vass C, Sach T, Gladman J, Avis M. REFINE (REducing falls in in-patieNt elderly) using bed and bedside chair pressure sensors linked to radio-pagers in acute hospital care: a randomised controlled trial. Age Ageing. 2014;43(2):247–53.
55. Mierlo L, Meiland F, Ven P, Hout H, Dröes R. Evaluation of DEM-DISC, customized e-advice on health and social support services for informal carers and case managers of people with dementia; a cluster randomized trial.In. Int Psychogeriatrics. 2015;27:1365–78.
56. Angst CM, Devaraj S, D'Arcy J. Dual role of IT-assisted communication in patient care: a validated structure-process-outcome framework. J Manag Inf Syst. 2012;29(2):257–92.
57. Restuccia JD, Cohen AB, Horwitt JN, Shwartz M. Hospital implementation of health information technology and quality of care: Are they related? BMC Med Informatics Decision Making. 2012;12(1).
58. Marek K, Stetzer F, Ryan P, Bub L, Adams S, Schlidt A, Lancaster R, O'Brien A. Nurse care coordination and technology effects on health status of frail older adults via enhanced self-management of medication: randomized clinical trial to test efficacy In. Nursing Res. 2013;62:269–78.
59. Broadbent E, Kerse N, Peri K, Robinson H, Jayawardena C, Kuo T, Datta C, Stafford R, Butler H, Jawalkar P, et al. Benefits and problems of health-care robots in aged care settings: a comparison trial. Australasian J Ageing. 2016; 35(1):23–9.
60. Moyle W, Cooke M, Beattie E, Jones C, Klein B, Cook G, Gray C. Exploring the effect of companion robots on emotional expression in older adults with dementia: a pilot randomized controlled trial In. J Gerontological Nurs. 2013; 39:46–53.
61. Nordheim J, Hamm S, Kuhlmey A, Suhr R. Tablet computers and their benefits for nursing home residents with dementia: results of a qualitative pilot study. Zeitschrift fur Gerontologie und Geriatrie. 2015;48(6):543–9.
62. Robinson H, MacDonald B, Kerse N, Broadbent E. The psychosocial effects of a companion robot: a randomized controlled trial. J Am Med Dir Assoc. 2013;14(9):661–7.
63. Lazar A, Demiris G, Thompson HJ. Evaluation of a multifunctional technology system in a memory care unit: opportunities for innovation in dementia care. Informatics Health Soc Care. 2016;41(4):373–86.
64. Portela FR, Correia RJC, Fonseca JA, Andrade JM. Wiitherapy on seniors - effects on physical and metal domains. In: 2011 IEEE 1st International Conference on Serious Games and Applications for Health (SeGAH): 16–18 Nov. 2011 2011; 2011. p. 1–5.
65. Rodriguez CS. Enhancing the communication of suddenly speechless critical care patients. Am J Crit Care. 2016;25(3):e40–7.
66. Miller K, Rodger S, Kipping B, Kimble RM. A novel technology approach to pain management in children with burns: A prospective randomized controlled trial. Burns (03054179). 2011;37(3):395–405.
67. Gustafsson C, Svanberg C, Müllersdorf M. Using a robotic cat in dementia care. J Gerontol Nurs. 2015;41(10):46–56.
68. Jøranson N, Pedersen I, Rokstad AMM, Ihlebæk C. Change in quality of life in older people with dementia participating in Paro-activity: a cluster-randomized controlled trial. J Adv Nurs. 2016;72(12):3020–33.
69. Valenti SM, Aguera-Ortiz L, Olazaran RJ, Mendoza RC, Perez MA, Rodriguez PI, Osa RE, Barrios SA, Herrero CV, Carrasco CL, et al. Social robots in advanced dementia. In: Frontiers in aging neuroscience, vol. 7; 2015.
70. Trukeschitz BSC, Ring-Dimitriou S. Smartes Betreutes Wohnen: Nutzung, Systemakzeptanz und Wirkungen von "meinZentrAAL". Norderstedt: Deutschland; 2018.
71. Rantz M, Phillips LJ, Galambos C, Lane K, Alexander GL, Despins L, Koopman RJ, Skubic M, Hicks L, Miller S, et al. Randomized trial of intelligent sensor system for early illness alerts in senior housing. J Am Med Dir Assoc. 2017; 18(10):860–70.
72. Chen ST, Huang YGL, Chiang IT. Using Somatosensory Video Games to Promote Quality of Life for the Elderly with Disabilities. In: 2012 IEEE Fourth International Conference On Digital Game And Intelligent Toy Enhanced Learning: 27–30 March 2012 2012; 2012. p. 258–62.
73. Kipping B, Rodger S, Miller K, Kimble RM. Virtual reality for acute pain reduction in adolescents undergoing burn wound care: a prospective randomized controlled trial. Burns (03054179). 2012;38(5):650–7.
74. Liang A, Piroth I, Robinson H, MacDonald B, Fisher M, Nater UM, Skoluda N, Broadbent E. A pilot randomized trial of a companion robot for people with dementia living in the community. J Am Med Dir Assoc. 2017;18(10):871–8.
75. Petersen S, Houston S, Qin H, Tague C, Studley J. The utilization of robotic pets in dementia care In. J Alzheimer's Dis. 2017;55:569–74.
76. Subramaniam P, Woods B. Digital life storybooks for people with dementia living in care homes: an evaluation In. Clinical Interventions Aging. 2016;11: 1263–76.
77. Jøranson N, Pedersen I, Rokstad AMM, Ihlebæk C. Effects on symptoms of agitation and depression in persons with dementia participating in robot-assisted activity: a cluster-randomized controlled trial. J Am Med Dir Assoc. 2015;16(10):867–73.
78. Moyle W, Jones CJ, Murfield JE, Thalib L, Beattie ERA, Shum DKH, O'Dwyer ST, Mervin MC, Draper BM. Use of a robotic seal as a therapeutic tool to improve dementia symptoms: a cluster-randomized controlled trial. J Am Med Dir Assoc. 2017;18(9):766–73.
79. Patterson D, Soltani M, Teeley A, Morse D, Wiechman S, Gibran N. Hypnosis delivered through immersive virtual reality for wound care: a randomized, controlled study. In. J Burn Care Res. 2012;33:S70.
80. Wagemaker E, Dekkers TJ. Agelink van Rentergem JA, Volkers KM, Huizenga HM: advances in mental health care: five N = 1 studies on the effects of the robot seal Paro in adults with severe intellectual disabilities. J Ment Health Res Intellect Disabil. 2017;10(4):309–20.
81. van der Heide LA, Willems CG, Spreeuwenberg MD, Rietman J, de Witte LP. Implementation of CareTV in care for the elderly: the effects on

feelings of loneliness and safety and future challenges. Technol Disabil. 2012;24(4):283–91.
82. Zhuang J, Fang R, Feng X, Xu X, Liu L, Bai Q, Tang H, Zhao Z, Chen S. The impact of human-computer interaction-based comprehensive training on the cognitive functions of cognitive impairment elderly individuals in a nursing home In. J Alzheimer's Dis. 2013;36:245–51.
83. White C, McIlfatrick S, Dunwoody L, Watson M. Supporting and improving community health services-a prospective evaluation of ECHO technology in community palliative care nursing teams. BMJ Support Palliat Care. 2015;0: 1–7. Published online first: 01.12.2015.
84. Shukla J, Barreda-Ángeles M, Oliver J, Puig D. Effectiveness of socially assistive robotics during cognitive stimulation interventions: Impact on caregivers. In: 2017 26th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN): Aug. 28 2017-Sept. 1 2017 2017; 2017. p. 62–7.
85. Hicken BL, Daniel C, Luptak M, Grant M, Kilian S, Rupper RW. Supporting caregivers of rural veterans electronically (SCORE). J Rural Health. 2017;33(3): 305–13.
86. Wakefield BJ, Vaughan-Sarrazin M. Home Telehealth and caregiving appraisal in chronic illness. Telemedicine E-Health. 2017;23(4):282–9.
87. Wieck M, Blake B, Sellick C, Kenron D, DeVries D, Terry S, Krishnaswami S. Utilizing technology to improve intraoperative family communication. In. Am J Surg (no pagination). 2017; vol. Date of Publication: January 10; 2017.
88. Pot AM, Willemse BM, Horjus S. A pilot study on the use of tracking technology: feasibility, acceptability, and benefits for people in early stages of dementia and their informal caregivers. Aging Ment Health. 2012;16(1): 127–34.
89. Ching JM, Williams BL, Idemoto LM, Blackmore CC. Using lean 'Automation with a human Touch' to improve medication safety: a step closer to the 'Perfect Dose'. Joint Commission J Qual Patient Safety. 2014;40(8):341–50.
90. Bettinelli M, Lei Y, Beane M, Mackey C, Liesching T. Does robotic Telerounding enhance nurse-physician collaboration satisfaction about care decisions? In. Telemedicine J E-Health. 2015;21:637–43.
91. Gartlehner G, Hansen R, Nissman D, Lohr K, Carey T. Criteria for distinguishing effectiveness from efficacy trials in systematic reviews. Technical review 12. In., vol. no. 06–0046. Rockville: Agency for Healthcare Research and Quality; 2006.
92. Dal-Ré R, Rosendaal F. Efficacy and effectiveness: the wrong use of different terms. Eur J Internal Med. 2018;54:e17–8.
93. Ekelanda AG, Bowes A, Flottorp S. Effectiveness of telemedicine: A systematic review of reviews. Int J Med Informatics. 2010;79:736–71.
94. Ommen O, Ullrich B, Janssen C, Pfaff H. The ambulatory-stationary interface in medical health care: problems, model of explanation, and possible solutions. Medizinische Klinik (Munich, Germany : 1983). 2007; 102(11):913–7.
95. Sundmacher L, Fischbach D, Schuettig W, Naumann C, Augustin U, Faisst C. Which hospitalisations are ambulatory care-sensitive, to what degree, and how could the rates be reduced? Results of a group consensus study in Germany. Health Pol (Amsterdam, Netherlands). 2015;119(11):1415–23.
96. Busse R, Blümel M. Germany: health system review. Health Syst Transition. 2014;16(2):1–296.
97. Auer S, Graessel E, Viereckl C, Kienberger U, Span E, Luttenberger K. Professional care team burden (PCTB) scale – reliability, validity and factor analysis. Health Qual Life Outcomes. 2015;13(1):17.
98. Health EEPoewoii. Assessing the Impact of digital transformation of health service - Expert Panel on effective ways of investing in Health (EXPH). Luxembourg: European Union; 2018.
99. Wiskow C, Albreht T. Pietro cd: how to create an attractive and supportive working environment for health professionals. In: *Policy Brief*. Copenhagen: World Health Organization; 2010.

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Additional File 1: Effectiveness Outcomes – Person in need of care related

Outcome Area	Examples for Subcategories or Indicators
Functional Health Outcomes that describe capacity for and performance of basic tasks of life*	- Mobility - Self-care (ADL/IADL) - Energy maintenance (i.e. sleep patterns) - Activity Level - Required care levels - Level of independence (perceived)
Physiological Health Outcome that describe organic functioning*	- Metabolic Regulation (vital signs) - Electrolyte & Acid/Base Balance - Tissue Integrity (i.e. wound healing) - Neurocognitive functions/condition - Therapeutic response (reactions to treatment)
Psychological Health Outcomes that describe psychological functioning*	- Psychological well-being (i.e. agitation, loneliness, stress-level) - Psychosocial adaption (i.e. Coping, acceptance of health status) - Self-control (challenging behaviour)
Social Condition Outcomes that describe social functioning and social inclusion	- social interactions (verbal and visual engagement) - social relation to caregiver - social participation/ social inclusion
Health Behaviour Outcomes that describe an individual's actions to promote or restore health*	- Therapy compliance - Dealing independently with requirements and strains caused by illness or therapy - Patient engagement
Health Knowledge & Attitudes Outcomes that describe an individual's understanding in applying information to promote maintain and restore health* (or an individual's ideas and perceptions that influence health behaviour*)	- Knowledge on health promotion, healthy lifestyle - Knowledge on medication (pain management) - Disease/health situation related knowledge - Perceived ability to perform
Patient Safety Outcomes that describe an individual's safety status*	- Fall prevention behaviour - Falls occurrence
Overarching Concepts (Comprise different aspects of the above-mentioned dimensions)	
Well-being/ Quality of Life Outcomes that describe an individual's perceived health status and life circumstances*	- General QoL-Indicators - Disease specific QoL-Indicators - Subgroup specific QoL-Indicators Indicators - ASCOT (Adult Social Care Outcomes Toolkit) - WHO-QoL (WHO-Quality of Life Scale) - QoL-AD (Quality of Life in Alzheimer Disease)
Health related QoL Outcomes that refer to a valuation of an individual's perceived physical, mental and (optionally) social well-being	- General self-perceived health status - Disease or symptom specific self-perceived health status (i.e. pain level, symptom severity)

	Indicators - EQ-5D, SF-36
Needs Assessment/ Fulfilled Needs Outcomes that relate to systematic processes for determining and addressing needs (discrepancies between current and wanted conditions)	Indicators - IPPA (Individually Prioritized Assessment score) - CANE (Camberwell Assessment of Need for the Elderly

Individual-related organisational Effectiveness

Intensity of Service Utilization Outcomes that describe the length or intensity of usage of a specific health care service	- Length of stay - Number of (re)admissions to specific institutions - Days in need of specific services/medication (i.e. number of days with antibiotics)
Organisational Patient Safety Indicators Outcomes that describe safety-related negative organisational incidents	- Mortality - Occurrence of medical complications (i.e. number of cardiac arrest calls, infection rates) - Occurrence of adverse events (i.e. falls)
Patient Satisfaction Outcomes that describe an individual's perception of the quality and adequacy of health/nursing care provided*	- Satisfaction with access to care resources - Satisfaction with performance of services - Satisfaction with adequacy of provided services
Intersectoral Continuity of Care Outcomes relating to patient transfers and the collaboration between different care providers or different units of care providers	- Continuity of care inside institutions (i.e. different units in hospitals) - Continuity of care between different institutions

*** Definitions based on NOC (5th edition)**

5th Edition:

https://www.academia.edu/38156239/Nursing_Outcomes_Classification_NOC_Moorhead_HERRY_.pdf

Additional File 2: Effectiveness Outcomes – Formal Caregivers

Outcome Area	Examples for Subcategories or Indicators
(Job) Satisfaction Outcomes that relate to the subjective evaluation of the current life or work situation/condition by a person him/herself	- General job satisfaction - Life satisfaction - Satisfaction with flexibility and autonomy - Satisfaction with professional status
Medical Health condition Outcomes that describe the health situation of the formal caregiver	- Occurring diseases - Symptoms (i.e. pain, fatigue) - Use of healthcare services
Psychological Health Outcomes that describe psychological functioning*	- Psychological well-being (self-confidence, stress, depression loneliness …) - Psychosocial Adaption (i.e. coping)
Professional Knowledge and Competences Outcomes that indicate the level of existing professional knowledge, skills and behavioural patterns necessary for the practice of professional nursing	- Knowledge on safety regulations (regarding patients) - Knowledge on disease related care - Knowledge on occupational safety - Professionalism

Physical/ Psychological Workload
Outcomes that describe the physical and/or mental effort during the performance of a specific care activity
	- Physical Workload (incl. tasks)
	  o Force required to handle Patient
	  o Walking distance
	- Psychological Load
	  o Stress in specific work situations

Relationship to the Person in Need of Care Outcomes that indicate the degree of personal and professional connection to the patient	- Relationship continuity - Empathic resonance - Trust - Interpersonal treatment - Time with patient (for building a relationship)
Overarching Concepts (Comprise different aspects of the above-mentioned dimensions)	
Well-being/ Quality of Life: Outcomes that describe an individual's perceived health status and life circumstances*	- General QoL-Indicators - Disease specific QoL-Indicators - Subgroup specific QoL-Indicators Indicator - WHO-QoL (WHO-Quality of Life Scale)
Health related QoL Outcomes that refer to a valuation of an individual's perceived physical, mental and (optionally) social well-being	- General self perceived health status - Disease or symptom specific self perceived health status (i.e. pain level, symptom severity) - Indicators - EQ-5D: EuroQol-5D - SF-36: 36-Item Short Form Health Survey
Caregiver Burden	

Multifactorial outcomes on work related burdens that a professional caregiver is exposed to	Indicators - Professional Care Team Burden (PCTB), Caregiver Burden Inventory (CBI)

Individual-related organisational Effectiveness

Outcome Area	Examples for Subcategories or Indicators
Employee Satisfaction Outcomes that indicate the well-being and general satisfaction with respect to the working conditions of all employees in an organizational unit	- Staff moral - Absenteeism - Attrition
Professional Guideline Compliance Outcomes that indicate the degree to which formal caregivers act according to professional guidelines	- Self-monitoring compliance - Documented compliance - Compliance awareness - Access to guideline information
Impact on Workload Outcomes that describe the functional load that the performance of a particular work activity of a professional caregiver implies, when it is considered at the organizational level	- Workload ○ Tasks ○ Frequency ○ Intensity (daily work hours) ○ Time spent on caregiving

*** Definitions based on NOC (5th edition)**

5th Edition:

https://www.academia.edu/38156239/Nursing_Outcomes_Classification_NOC_Moorhead_HERRY_.pdf

Additional File 3: Effectiveness Outcomes –Informal Caregiver

Outcome Area	Examples for Subcategories or Indicators
(Life) Satisfaction Outcomes that relate to the subjective evaluation of the current life or care situation/condition by a person him/herself.	- Satisfaction with life situation - Satisfaction with care situation - Satisfaction with care services
Medical Health Condition Outcomes that describe the health situation of the informal caregiver	- Use of healthcare services - Symptoms (i.e. pain, fatigue) - Occurring diseases
Psychological Health Outcomes that describe psychological functioning*	- Psychological well-being (i.e. depression, loneliness, stress-level) - Psychosocial adaption (i.e. Coping, acceptance of care situation)
Social Condition Outcomes that describe social functioning and social inclusion	- Social relation to care-receiver - Social participation/ social inclusion - (Social relation to family/significant others) - Family Health (health status, behaviour or functioning of the family, relationship to the patient)
Living Conditions Outcomes that describe the effects of the care situation on general life circumstances of a caregiving person	- Daily Activities - Work Life - Family well-being - Financial Situation
Knowledge and Competences Outcomes that describe a caregiver's understanding in applying information to promote maintain and restore health,* and to support and care for the care-receiver	- Knowledge on health promotion, healthy lifestyle - Disease/care situation related knowledge - Knowledge on supportive infrastructures?
Compliance Outcomes that describe the degree to which informal caregivers comply with professional advices	- Compliance awareness - Access to guideline information - Self-monitored compliance
Physical/ Psychological Workload: Outcomes that describe the physical and/or psychological effort during the performance of a specific care activity	- Physical Workload (incl. tasks) - Psychological Workload - Time spent on caregiving - Care performance
Use of caregiving support Outcomes that describe the amount of additional informal or professional care support that is needed in the care situation	- Use of professional care services - Use of non-professional care support resources (i.e. self-help groups)
Overarching Concepts (Comprise different aspects of the above-mentioned dimensions)	
Well-being/ Quality of Life Outcomes that describe an individual's perceived health status and life circumstances*	- General QoL-Indicators - Subgroup specific QoL-Indicators
Health related QoL Outcomes that refer to a valuation of an individual's perceived physical, mental and (optionally) social well-being	- General self-perceived health status - Disease or symptom specific self-perceived health status (i.e. pain level, symptom severity) Indicators

	- EQ-5D: EuroQol-5D - SF-36: 36-Item Short Form Health Survey
Caregiver Burden Outcomes that describe the strain perceived by caregivers due to a home care situation (caused by caregiving activities and responsibilities)	Indicators - ZBI-12: Zarit Burden Interview-short form - CSI: Caregiver Strain Index - OBM: Objective Burden Informal Caregiver'

*** Definitions based on NOC (5th edition)**

5th Edition:

https://www.academia.edu/38156239/Nursing_Outcomes_Classification_NOC_Moorhead_HERRY_.pdf

Additional File 4: Effectiveness Outcomes – Organisation

Outcome Area	Examples for Subcategories or Indicators
Care process quality Outcomes that indicate the general quality of the nursing process in an organisation	- Risk of poor treatment - Quality of assessment and documentation - Healing/Recovery rates - Readmission rates - Medication administration (errors, accuracy)
Access to care Outcomes that describe the degree of the access to and availability of certain services	- Accessibility (physical/remote) - Availability of services (geographic, timeliness, barriers)
Communication/Social interaction Outcomes that describe the communication between different groups within an organization and the social interactions and collaboration	- Relationship quality - Communication intensity - Communication errors - Interprofessional relationship
Recruitment and Staffing Outcomes that describe aspects related to the recruitment of employees and the maintenance of employee quantity and quality	- Recruitment related outcomes - Staff retention - Absenteeism - Personnel development
Working Conditions Outcomes that describe the general working conditions within an organisation	- Physical (noise, vibration) - Organisational (monotonicity, variety) - Working Hours (nightshifts, scheduling)
Operational Efficiency Outcome measures that indicate the degree to which efficient processes are designed by an organization to help improve productivity and performance	- Efficient usage of resources - Organisational workflow - Operational efficiency (staff per patient) - Efficiency of work processes - Productivity
Financial Performance Outcomes that indicate the financial result that an organization is capable of producing	- Profitability - Financial sustainability - Debts
Overarching Concepts (Comprise different aspects of the above-mentioned dimensions)	
Hospital/Nursing Home Quality Outcomes that summarise the quality of a care of an institution in different dimensions	Indicators: - QAS: Quality Improvement Activities Survey - CPS: Clinicians' Perceptions of Quality Survey

Additional File 5: Included Technologies

Technology subcategory / Specific technology	Authors/Year
1. Studies on ICT	
1.1. Studies on Health Institution Information System (HIS)	
HIS (hospital)	(Angst et al. 2012), (Appari et al. 2014), (McKenna et al. 2017), (Restuccia et al. 2012)
HIS (ICU)	(Steurbaut et al. 2012)
HIS (nursing home)	(Alexander et al. 2014), (Alexander et al. 2015), (Munyisia et al. 2012)
HIS (subsystem/ patient engagement)	(Patmon et al. 2016)
1.2. Studies on Electronic Health Records/Electronic Medical Records	
EMR in long-term care	(Hitt & Tambe 2016), (Meehan 2017), (Rantz et al. 2011)
EMR in hospitals in general	(Mitchell & Yaylacicegi 2012), (Bradley 2011), (Takian et al. 2012), (Yusof 2015)
Decision support/Data results management	(Lo et al. 2014)
Medication Administration	(Seibert et al. 2014), (Appari et al. 2012), (Chanyagorn et al. 2016), (Ching et al. 2014), (Huang & Lee 2011)
Patient handoff/health information exchange	(Clarke et al. 2017), (Oakley & Hunter 2017), (Yeaman et al. 2015), (Meyer-Delpho & Schubert 2014)
Patient information administration/Nurse reminding system	(Lear & Walters 2015), (Paranilam 2013)
1.3. Studies on Computerised Decision Support Systems	
Risk assessment	(Lapane et al. 2011), (Dykes et al. 2012)
Care Decisions	(Lang 2012), (Salinas et al. 2011)
1.4. Studies on Telecare	
Video-Telecare	(van der Heide et al. 2012), (Cady 2012), (Cady & Finkelstein 2014)
Video Telecare incl. remote monitoring	(Bowles et al. 2011)
Remote health-monitoring	(Steventon et al. 2013), (Wakefield & Vaughan-Sarrazin 2017) (Paré et al. 2013)
Telecare per Instant-Messaging	(Chiang & Wang 2016)
Telecare/ App supported	(Göransson et al. 2017)
Telecare/ Internet- vs. telephone-based support	(Hicken et al. 2017)
1.5. Studies on Communication Support Technologies	
1.5.1. Communication Support between professionals	
Cloud based smartphone nurse-call system	(Chuang et al. 2015)
Hands free communication	(Pemmassani et al. 2014)
Discharge huddle with mobile technology	(Tielbur et al. 2015)
Tele-conferencing for remote training of health care providers	(White et al. 2015)
Wireless call handling and task management system (out of hours)	(Blakey et al. 2012)
Hospital-home care collaboration by electronic messaging	(Melby et al. 2015)
Smartphone use in clinical communication	(Wu et al. 2011)
1.5.2. Communication support between professionals and patient/relatives	
Communication between formal caregiver and patient/ for suddenly speechless patients	(Rodriguez 2016)
Communication between professionals and relatives /intraoperative communication	(Wieck et al. 2017)
1.6. Studies on Specific Software/Apps	
1.6.1. Care support for professionals	
Provision of informa-tion about residents	(Webster & Hanson 2014)
Point of care documentation	(Yi-Sheng et al. 2014)
Point of care wound documentation	(Florczak et al. 2012)
Wound monitoring and remote support	(Vowden & Vowden 2013)

1.6.2. Care support for informal caregivers	
Dementia specific digital social chart	(Mierlo et al. 2015)
1.6.3. Patient support for everyday life	
Personal assistant for dementia	(Nijhof et al. 2013a)
1.6.4. Therapeutic support for patients/persons in need of care	
Cognitive stimulation	(Zaccarelli et al. 2013), (Zhuang et al. 2013), (Berenbaum et al. 2011), (Nordheim et al. 2015)
Digital life story books	(Subramaniam & Woods 2016)
Serious Games (Wii)	(Portela et al. 2011)
Serious Games (Xbox Kinect)	(Chen et al. 2012)
1.7. Studies on Process Planning/Work Process Management	
Software for planning and optimizing nursing processes	(Pare et al. 2011)
Intelligent performance assessment system	(Valerie et al. 2016)
1.8. Studies on Target Group Specific Interfaces	
Electronic Medical Record Interface for ICU-use	(Olchanski et al. 2017)
Interface for people with memory impairment/dementia	(Lazar et al. 2016)
Dashboard design within an electronic health record	(Schall et al. 2017)
2. Studies on Robotic Technologies	
Physical assistance (robotic lifting device)	(Ranasinghe et al. 2014)
Physical assistance (robotic wheelchair)	(Wang et al. 2011)
Physical assistance/ Transport (pharmacy delivery robot)	(Summerfield et al. 2011)
Social/service robot (Cafero)	(Broadbent et al. 2015)
Social/telepresence robot	(Bettinelli et al. 2015)
Socially interactive robot (Guide robot, Cafero)	(Broadbent et al. 2016)
Social/therapeutic robot (JustoCat)	(Gustafsson et al. 2015)
Social/therapeutic robot (Paro, Pleo)	(Baisch et al. 2018)
Social/therapeutic robot (Paro)	(Moyle et al. 2017), (Petersen et al. 2017), (Robinson et al. 2013), (Jøranson et al. 2015), (Jøranson et al. 2016), (Bemelmans et al. 2015), (Liang et al. 2017), (Moyle et al. 2013), (Bennett et al. 2015) (Birks et al. 2016), (Šabanović et al. 2013), (Wagemaker et al. 2017), (Iacono & Marti 2016), (Wada et al. 2014)
Social/therapeutic robot (Paro) / humanoid socially assistive robot (NAO)	(Valenti et al. 2015), (Shukla et al. 2017)
3. Studies on Sensors / Monitoring	
Behaviour Analysis / Emergency detection Behaviour Analysis / fall prevention	(van der Lende et al. 2016), (Hardin et al. 2013), (Sahota et al. 2014), (Shee et al. 2014), (Tchalla et al. 2013)
Behaviour Analysis / pressure ulcer prevention	(Pickham et al. 2018)
Behaviour Analysis of Carers/Hand hygiene	(Marra et al. 2014)
External risk detection /noise sensor	(Jousselme et al. 2011)
General Behaviour Analysis/ Decision support	(Lexis 2013), (Rantz et al. 2017), (Lazarou et al. 2016)
Tracking /GPS-Device	(Pot et al. 2012)
Tracking/RFID-Identification	(Osaimi et al. 2017)
Vital sign monitoring (patient)	(Brown et al. 2014), (Zhou et al. 2012), (Kuroda et al. 2013), (Pigini et al. 2017)
4. Studies on Assistive Devices	
Care support (multi-modal distraction)	(Miller et al. 2011)
Care support with treatment focus (smart pumps)	(Orto et al. 2015) (Vadiei et al. 2017)
Care support for Activities of Daily Living (Drink monitoring)	(Zimmermann et al. 2017)
Reminder System (medication dispenser)	(Marek et al. 2013), (Akiyama & Sasaki 2013), (Suzuki et al. 2011)
5. Studies on Ambient Assisted Living Solutions	
AAL at home	(Hattink et al. 2016), (Nijhof et al. 2013b)
AAL at home incl. formal care	(Trukeschitz B. 2018)

6. Studies on Virtual Reality	
Virtual Reality for distraction/pain reduction	(Kipping et al. 2012), (Mazzacano et al. 2016), (Patterson et al. 2012)

References

Akiyama, M. & Sasaki, Y. (2013). Efficacy of the drug administration support system for improving drug compliance in home-care. 2013 Proceedings of PICMET '13: Technology Management in the IT-Driven Services (PICMET).

Alexander, G.L., Pasupathy, K.S., Steege, L.M., Strecker, E.B. & Carley, K.M. (2014). Multi-disciplinary communication networks for skin risk assessment in nursing homes with high IT sophistication. International Journal of Medical Informatics, 83(8), 581-591.

Alexander, G.L., Steege, L.M., Pasupathy, K.S. & Wise, K. (2015). Case studies of IT sophistication in nursing homes: A mixed method approach to examine communication strategies about pressure ulcer prevention practices. International Journal of Industrial Ergonomics, 49, 156-166.

Angst, C.M., Devaraj, S. & D'Arcy, J. (2012). Dual role of IT-assisted communication in patient care: A validated structure-process-outcome framework. Journal of Management Information Systems, 29(2), 257-292.

Appari, A., Carian, E.K., Johnson, M.E. & Anthony, D.L. (2012). Medication administration quality and health information technology: a national study of US hospitals. Journal of the American Medical Informatics Association, 19(3), 360-367.

Appari, A., Johnson, E.M. & Anthony, D.L. (2014). Information technology and hospital patient safety: a cross-sectional study of US acute care hospitals. The American journal of managed care, 20(17), eSP39-eSP47.

Baisch, S., Kolling, T., Rühl, S., Klein, B., Pantel, J., Oswald, F. & Knopf, M. (2018). Emotional robots in a nursing context: Empirical analysis of the present use and the effects of Paro and Pleo. Zeitschrift für Gerontologie und Geriatrie, 51(1), 16-24.

Bemelmans, R., Gelderblom, G.J., Jonker, P. & de Witte, L. (2015). Effectiveness of Robot Paro in Intramural Psychogeriatric Care: A Multicenter Quasi-Experimental Study. Journal of the American Medical Directors Association, 16(11), 946-950.

Bennett, K., Grasso, F., Lowers, V., McKay, A. & Milligan, C. (2015). Evaluation of an App to Support Older Adults with Wounds. Proceedings of the 5th International Conference on Digital Health 2015, New York, NY, USA, ACM.

Berenbaum, R., Lange, Y. & Abramowitz, L. (2011). Augmentative Alternative Communication for Alzheimer?s Patients and Families? Using SAVION. Proceedings of the 4th International Conference on PErvasive Technologies Related to Assistive Environments, New York, NY, USA, ACM.

Bettinelli, M., Lei, Y., Beane, M., Mackey, C. & Liesching, T. (2015) Does Robotic Telerounding Enhance Nurse-Physician Collaboration Satisfaction About Care Decisions? Telemedicine journal and e-health 21, 637-643 10.1089/tmj.2014.0162: 10.1089/tmj.2014.0162.

Birks, M., Bodak, M., Barlas, J., Harwood, J. & Pether, M. (2016). Robotic Seals as Therapeutic Tools in an Aged Care Facility: A Qualitative Study. Journal of Aging Research, 2016.

Blakey, J.D., Guy, D., Simpson, C., Fearn, A., Cannaby, S., Wilson, P. & Shaw, D. (2012). Multimodal observational assessment of quality and productivity benefits from the implementation of wireless technology for out of hours working. BMJ Open, 2(2).

Bowles, K.H., Hanlon, A.L., Glick, H.A., Naylor, M.D., O'Connor, M., Riegel, B., Shih, N.W. & Weiner, M.G. (2011). Clinical effectiveness, access to, and satisfaction with care using a telehomecare substitution intervention: a randomized controlled trial. Int J Telemed Appl, 2011, 540138.

Bradley, S.L. (2011). A phenomenological exploration of nurses' perceptions of the effect of electronic documentation on healing relationships: University of Phoenix.

Broadbent, E., Kerse, N., Peri, K., Robinson, H., Jayawardena, C., Kuo, T., Datta, C., Stafford, R., Butler, H., Jawalkar, P., Amor, M., Robins, B. & MacDonald, B. (2016). Benefits and problems of health-care robots in aged care settings: A comparison trial. Australas J Ageing, 35(1), 23-29.

Broadbent, E., Orejana, J.R., Ahn, H.S., Xie, J., Rouse, P. & MacDonald, B.A. (2015). The cost-effectiveness of a robot measuring vital signs in a rural medical practice. 2015 24th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN).

Brown, H., Terrence, J., Vasquez, P., Bates, D.W. & Zimlichman, E. (2014). Continuous monitoring in an inpatient medical-surgical unit: a controlled clinical trial. The American journal of medicine, 127(3), 226-232.

Cady, R.G. (2012). Measuring the Impact of Technology on Nurse Workflow: A Mixed Methods Approach: University of Minnesota.

Cady, R.G. & Finkelstein, S.M. (2014). Task-technology fit of video telehealth for nurses in an outpatient clinic setting. Telemedicine journal and e-health : the official journal of the American Telemedicine Association, 20(7), 633-639.

Chanyagorn, P., Kungwannarongkun, B. & Chanyagorn, W. (2016). Design of electronic nursing Kardex system for medication error prevention in IPD patients. 2016 6th IEEE International Conference on Control System, Computing and Engineering (ICCSCE).

Chen, S.T., Huang, Y.G.L. & Chiang, I.T. (2012). Using Somatosensory Video Games to Promote Quality of Life for the Elderly with Disabilities. 2012 IEEE Fourth International Conference On Digital Game And Intelligent Toy Enhanced Learning.

Chiang, K.F. & Wang, H.H. (2016). Nurses' experiences of using a smart mobile device application to assist home care for patients with chronic disease: A qualitative study. Journal of Clinical Nursing, 25(13-14), 2008-2017.

Ching, J.M., Williams, B.L., Idemoto, L.M. & Blackmore, C.C. (2014). Using Lean 'Automation with a Human Touch' to Improve Medication Safety: A Step Closer to the 'Perfect Dose'. Joint Commission Journal on Quality & Patient Safety, 40(8), 341-350.

Chuang, S.T., Liu, Y.F., Fu, Z.X., Liu, K.C., Chien, S.H., Lin, C.L. & Lin, P.Y. (2015). Application of a smartphone nurse call system for nursing care. Telemedicine journal and e-health : the official journal of the American Telemedicine Association, 21(2), 105-109.

Clarke, C.N., Patel, S.H., Day, R.W., George, S., Sweeney, C., Monetes De Oca, G.A., Aiss, M.A., Grubbs, E.G., Bednarski, B.K., Lee, J.E., Bodurka, D.C., Skibber, J.M. & Aloia, T.A. (2017). Implementation of a standardized electronic tool improves compliance, accuracy, and efficiency of trainee-to-trainee patient care handoffs after complex general surgical oncology procedures. Surgery (United States), 161(3), 869-875.

Dykes, P.C., I-Ching, E.H., Soukup, J.R., Chang, F. & Lipsitz, S. (2012). A case control study to improve accuracy of an electronic fall prevention toolkit. AMIA ... Annual Symposium proceedings / AMIA Symposium. AMIA Symposium, 2012, 170-179.

Florczak, B., Scheurich, A., Croghan, J., Sheridan Jr, P., Kurtz, D., McGill, W. & McClain, B. (2012). An observational study to assess an electronic point-of-care wound documentation and reporting system regarding user satisfaction and potential for improved care. Ostomy Wound Management, 58(3), 46-51.

Göransson, C., Eriksson, I., Ziegert, K., Wengström, Y., Langius-Eklöf, A., Brovall, M., Kihlgren, A. & Blomberg, K. (2017). Testing an app for reporting health concerns-Experiences from older people and home care nurses. International Journal of Older People Nursing.

Gustafsson, C., Svanberg, C. & Müllersdorf, M. (2015). Using a Robotic Cat in Dementia Care. Journal of Gerontological Nursing, 41(10), 46-56.

Hardin, Sr., Dienemann, J., Rudisill, P. & Mills, K. (2013) Inpatient fall prevention: use of in-room Webcams. Journal of patient safety 9, 29-35 10.1097/PTS.0b013e3182753e4f: 10.1097/PTS.0b013e3182753e4f.

Hattink, B.J.J., Meiland, F.J.M., Overmars-Marx, T., de Boer, M., Ebben, P.W.G., van Blanken, M., Verhaeghe, S., Stalpers-Croeze, I., Jedlitschka, A., Flick, S.E., v/d Leeuw, J., Karkowski, I. & Dröes, R.M. (2016). The electronic, personalizable Rosetta system for dementia care: exploring the user-friendliness, usefulness and impact. Disability & Rehabilitation: Assistive Technology, 11(1), 61-71.

Hicken, B.L., Daniel, C., Luptak, M., Grant, M., Kilian, S. & Rupper, R.W. (2017). Supporting Caregivers of Rural Veterans Electronically (SCORE). Journal of Rural Health, 33(3), 305-313.

Hitt, L.M. & Tambe, P. (2016). Health care information technology, work organization, and nursing home performance. Industrial and Labor Relations Review, 69(4), 834-859.

Huang, H.-Y. & Lee, T.-T. (2011). Impact of bar-code medication administration on nursing activity patterns and usage experience in Taiwan. CIN: Computers, Informatics, Nursing, 29(10), 554-563.

Iacono, I. & Marti, P. (2016). Narratives and emotions in seniors affected by dementia: A comparative study using a robot and a toy. 2016 25th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN).

Jøranson, N., Pedersen, I., Rokstad, A.M.M. & Ihlebæk, C. (2015). Effects on Symptoms of Agitation and Depression in Persons With Dementia Participating in Robot-Assisted Activity: A Cluster-Randomized Controlled Trial. Journal of the American Medical Directors Association, 16(10), 867-873.

Jøranson, N., Pedersen, I., Rokstad, A.M.M. & Ihlebæk, C. (2016). Change in quality of life in older people with dementia participating in Paro-activity: a cluster-randomized controlled trial. Journal of Advanced Nursing, 72(12), 3020-3033.

Jousselme, C., Vialet, R., Jouve, E., Lagier, P., Martin, C. & Michel, F. (2011) Efficacy and mode of action of a noise-sensor light alarm to decrease noise in the pediatric intensive care unit: a prospective, randomized study. Pediatric critical care medicine 12, e69-72 10.1097/PCC.0b013e3181e89d91: 10.1097/PCC.0b013e3181e89d91.

Kipping, B., Rodger, S., Miller, K. & Kimble, R.M. (2012). Virtual reality for acute pain reduction in adolescents undergoing burn wound care: a prospective randomized controlled trial. Burns (03054179), 38(5), 650-657.

Kuroda, T., Noma, H., Naito, C., Tada, M., Yamanaka, H., Takemura, T., Nin, K. & Yoshihara, H. (2013). Prototyping sensor network system for automatic vital signs collection: Evaluation of a location based automated assignment of measured vital signs to patients. Methods of Information in Medicine, 52(3), 239-249.

Lang, R.L.N. (2012). Evaluating the Effectiveness of Nurse-Focused Computerized Clinical Decision Support on Urinary Catheter Practice Guidelines: Gardner-Webb University.

Lapane, K.L., Hughes, C.M., Daiello, L.A., Cameron, K.A. & Feinberg, J. (2011). Effect of a Pharmacist-Led Multicomponent Intervention Focusing on the Medication Monitoring Phase to Prevent Potential Adverse Drug Events in Nursing Homes. Journal of the American Geriatrics Society, 59(7), 1238-1245.

Lazar, A., Demiris, G. & Thompson, H.J. (2016). Evaluation of a multifunctional technology system in a memory care unit: Opportunities for innovation in dementia care. Informatics for Health & Social Care, 41(4), 373-386.

Lazarou, I., Karakostas, A., Stavropoulos, T.G., Tsompanidis, T., Meditskos, G., Kompatsiaris, I. & Tsolaki, M. (2016). A Novel and Intelligent Home Monitoring System for Care Support of Elders with Cognitive Impairment. Journal of Alzheimer's Disease, 54(4), 1561-1591.

Lear, C.L. & Walters, C. (2015). Use of Electronic Nurse Reminders to Improve Documentation. CIN: Computers, Informatics, Nursing, 33(12), 523-529.

Lexis, M. (2013). Activity monitoring technology to support homecare delivery to frail and psychogeriatric elderly persons living at home alone. Technology & Disability, 25(3), 189-197.

Liang, A., Piroth, I., Robinson, H., MacDonald, B., Fisher, M., Nater, U.M., Skoluda, N. & Broadbent, E. (2017). A Pilot Randomized Trial of a Companion Robot for People With Dementia Living in the Community. Journal of the American Medical Directors Association, 18(10), 871-878.

Lo, Y.S., Lee, W.S., Chen, G.B. & Liu, C.T. (2014). Improving the work efficiency of healthcare-associated infection surveillance using electronic medical records. Computer Methods and Programs in Biomedicine, 117(2), 351-359.

Marek, K., Stetzer, F., Ryan, P., Bub, L., Adams, S., Schlidt, A., Lancaster, R. & O'Brien, A. (2013) Nurse care coordination and technology effects on health status of frail older adults via enhanced self-management of medication: randomized clinical trial to test efficacy. Nursing research 62, 269-278 10.1097/NNR.0b013e318298aa55: 10.1097/NNR.0b013e318298aa55.

Marra, A.R., Sampaio Camargo, T.Z., Magnus, T.P., Blaya, R.P., dos Santos, G.B., Guastelli, L.R., Rodrigues, R.D., Prado, M., Victor, E.d.S., Bogossian, H., Monte, J.C.M., dos Santos, O.F.P.o., Oyama, C.K. & Edmond, M.B. (2014). The use of real-time feedback via wireless technology to improve hand hygiene compliance. American Journal of Infection Control, 42(6), 608-611.

Mazzacano, S.D., McSherry, T., Atterbury, M., Helmold, E., Gartner, S. & Schulman, C. (2016) Effect of virtual reality distraction therapy on pain and anxiety in adult patients undergoing complex dressing changes: a randomized controlled trial. Journal of burn care and research. 37, S157

McKenna, R.M., Dwyer, D. & Rizzo, J.A. (2017). Is HIT a hit? The impact of health information technology on inpatient hospital outcomes. Applied Economics, 1-13.

Meehan, R. (2017). Electronic Health Records in Long-Term Care: Staff Perspectives. Journal of Applied Gerontology, 36(10), 1175-1196.

Melby, L., Brattheim, B.J. & Hellesø, R. (2015). Patients in transition - improving hospital-home care collaboration through electronic messaging: providers' perspectives. Journal of Clinical Nursing, 24(23/24), 3389-3399.

Meyer-Delpho, C. & Schubert, H.J. (2014). Potential of Information and Communications Technology to Improve Intersectoral Processes of Care: A Case Study of the Specialised Outpatient Palliative Care. Gesundheitswesen, 77(8-9), 550-556.

Mierlo, L., Meiland, F., Ven, P., Hout, H. & Dröes, R. (2015) Evaluation of DEM-DISC, customized e-advice on health and social support services for informal carers and case managers of people with dementia; a cluster randomized trial. International Psychogeriatrics 27, 1365-1378 10.1017/S1041610215000423: 10.1017/S1041610215000423.

Miller, K., Rodger, S., Kipping, B. & Kimble, R.M. (2011). A novel technology approach to pain management in children with burns: A prospective randomized controlled trial. Burns (03054179), 37(3), 395-405.

Mitchell, S. & Yaylacicegi, U. (2012). EHR prescription for small, medium, and large hospitals: an exploratory study of Texas acute care hospitals. Int J Electron Healthc, 7(2), 125-140.

Moyle, W., Cooke, M., Beattie, E., Jones, C., Klein, B., Cook, G. & Gray, C. (2013) Exploring the effect of companion robots on emotional expression in older adults with dementia: a pilot randomized controlled trial. Journal of Gerontological Nursing 39, 46-53 10.3928/00989134-20130313-03: 10.3928/00989134-20130313-03.

Moyle, W., Jones, C.J., Murfield, J.E., Thalib, L., Beattie, E.R.A., Shum, D.K.H., O'Dwyer, S.T., Mervin, M.C. & Draper, B.M. (2017). Use of a Robotic Seal as a Therapeutic Tool to Improve Dementia Symptoms: A Cluster-Randomized Controlled Trial. Journal of the American Medical Directors Association, 18(9), 766-773.

Munyisia, E.N., Yu, P. & Hailey, D. (2012). The impact of an electronic nursing documentation system on efficiency of documentation by caregivers in a residential aged care facility. Journal of Clinical Nursing, 21(19/20), 2940-2948.

Nijhof, N., van Gemert-Pijnen, J.E.W.C., Burns, C.M. & Seydel, E.R. (2013a). A personal assistant for dementia to stay at home safe at reduced cost. Gerontechnology, 11(3), 469-479.

Nijhof, N., van Gemert-Pijnen, L.J., Woolrych, R. & Sixsmith, A. (2013b). An evaluation of preventive sensor technology for dementia care. Journal of Telemedicine and Telecare, 19(2), 95-100.

Nordheim, J., Hamm, S., Kuhlmey, A. & Suhr, R. (2015). Tablet computers and their benefits for nursing home residents with dementia: Results of a qualitative pilot study. Zeitschrift für Gerontologie und Geriatrie, 48(6), 543-549.

Oakley, B. & Hunter, J.B. (2017). Implementing an electronic patient handover system. British Journal of Hospital Medicine (17508460), 78(1), 16-19.

Olchanski, N., Dziadzko, M.A., Tiong, I.C., Daniels, C.E., Peters, S.G., O'Horo, J.C. & Gong, M.N. (2017). Can a Novel ICU Data Display Positively Affect Patient Outcomes and Save Lives? Journal of Medical Systems, 41(11).

Orto, V., Hendrix, C.C., Griffith, B. & Shaikewitz, S.T. (2015). Implementation of a Smart Pump Champions Program to Decrease Potential Patient Harm. Journal of Nursing Care Quality, 30(2), 138-143.

Osaimi, A.A.A., Kadi, K.A. & Saddik, B. (2017). Role of radio frequency identification in improving infant safety and the extent of nursing staff acceptance of RFID at King Abdulaziz medical city in Riyadh. 2017 International Conference on Informatics, Health & Technology (ICIHT).

Paranilam, S.O. (2013). Effectiveness of an Electronic Pain Notification System on Postoperative Pain: University of Maryland, Baltimore.

Paré, G., Poba-Nzaou, P. & Sicotte, C. (2013). Home telemonitoring for chronic disease management: An economic assessment. International Journal of Technology Assessment in Health Care, 29(2), 155-161.

Pare, G., Sicotte, C., Moreault, M.P., Poba-Nzaou, P., Templier, M. & Nahas, G. (2011). Effects of Mobile Computing on the Quality of Homecare Nursing Practice. 2011 44th Hawaii International Conference on System Sciences.

Patmon, F.L., Gee, P.M., Rylee, T.L. & Readdy, N.L. (2016). Using Interactive Patient Engagement Technology in Clinical Practice: A Qualitative Assessment of Nurses' Perceptions. J Med Internet Res, 18(11), e298.

Patterson, D., Soltani, M., Teeley, A., Morse, D., Wiechman, S. & Gibran, N. (2012) Hypnosis delivered through immersive virtual reality for wound care: a randomized, controlled study. Journal of burn care and research. 33, S70

Pemmassani, V., Paget, T., van Woerden, H.C. & Pemmasani, S. (2014). Hands-free communication to free up nursing time. Nursing Times, 110(13), 12-14.

Petersen, S., Houston, S., Qin, H., Tague, C. & Studley, J. (2017) The Utilization of Robotic Pets in Dementia Care. Journal of Alzheimer's Disease 55, 569-574 10.3233/JAD-160703: 10.3233/JAD-160703.

Pickham, D., Berte, N., Pihulic, M., Valdez, A., Mayer, B. & Desai, M. (2018). Effect of a wearable patient sensor on care delivery for preventing pressure injuries in acutely ill adults: A pragmatic randomized clinical trial (LS-HAPI study). International journal of nursing studies, 80, 12-19.

Pigini, L., Bovi, G., Panzarino, C., Gower, V., Ferratini, M., Andreoni, G., Sassi, R., Rivolta, M.W. & Ferrarin, M. (2017). Pilot Test of a New Personal Health System Integrating Environmental and Wearable Sensors for Telemonitoring and Care of Elderly People at Home (SMARTA Project). Gerontology, 63(3), 281-286.

Portela, F.R., Correia, R.J.C., Fonseca, J.A. & Andrade, J.M. (2011). Wiitherapy on seniors - Effects on physical and metal domains. 2011 IEEE 1st International Conference on Serious Games and Applications for Health (SeGAH).

Pot, A.M., Willemse, B.M. & Horjus, S. (2012). A pilot study on the use of tracking technology: Feasibility, acceptability, and benefits for people in early stages of dementia and their informal caregivers. Aging & Mental Health, 16(1), 127-134.

Ranasinghe, R., Dantanarayana, L., Tran, A., Lie, S., Behrens, M. & Liu, L. (2014). Smart hoist: An assistive robot to aid carers. 2014 13th International Conference on Control Automation Robotics & Vision (ICARCV).

Rantz, M., Phillips, L.J., Galambos, C., Lane, K., Alexander, G.L., Despins, L., Koopman, R.J., Skubic, M., Hicks, L., Miller, S., Craver, A., Harris, B.H. & Deroche, C.B. (2017). Randomized Trial of Intelligent Sensor System for Early Illness Alerts in Senior Housing. Journal of the American Medical Directors Association, 18(10), 860-870.

Rantz, M.J., Alexander, G., Galambos, C., Flesner, M.K., Vogelsmeier, A., Hicks, L., Scott-Cawiezell, J., Zwygart-Stauffacher, M. & Greenwald, L. (2011). The use of bedside electronic medical record to improve quality of care in nursing facilities: a qualitative analysis. CIN: Computers, Informatics, Nursing, 29(3), 149-156.

Restuccia, J.D., Cohen, A.B., Horwitt, J.N. & Shwartz, M. (2012). Hospital implementation of health information technology and quality of care: Are they related? BMC Medical Informatics and Decision Making, 12(1).

Robinson, H., MacDonald, B., Kerse, N. & Broadbent, E. (2013). The Psychosocial Effects of a Companion Robot: A Randomized Controlled Trial. Journal of the American Medical Directors Association, 14(9), 661-667.

Rodriguez, C.S. (2016). ENHANCING THE COMMUNICATION OF SUDDENLY SPEECHLESS CRITICAL CARE PATIENTS. American Journal of Critical Care, 25(3), e40-e47.

Šabanović, S., Bennett, C.C., Chang, W.L. & Huber, L. (2013). PARO robot affects diverse interaction modalities in group sensory therapy for older adults with dementia. 2013 IEEE 13th International Conference on Rehabilitation Robotics (ICORR).

Sahota, O., Drummond, A., Kendrick, D., Grainge, M.J., Vass, C., Sach, T., Gladman, J. & Avis, M. (2014). REFINE (REducing Falls in In-patieNt Elderly) using bed and bedside chair pressure sensors linked to radio-pagers in acute hospital care: a randomised controlled trial. Age Ageing, 43(2), 247-253.

Salinas, J., Chung, K.K., Mann, E.A., Cancio, L.C., Kramer, G.C., Serio-Melvin, M.L., Renz, E.M., Wade, C.E. & Wolf, S.E. (2011). Computerized decision support system improves fluid resuscitation following severe burns: An original study. Critical Care Medicine, 39(9), 2031-2038.

Schall, M.C., Cullen, L., Pennathur, P., Chen, H., Burrell, K. & Matthews, G. (2017). Usability Evaluation and Implementation of a Health Information Technology Dashboard of Evidence-Based Quality Indicators. CIN: Computers, Informatics, Nursing, 35(6), 281-287.

Seibert, H.H., Maddox, R.R., Flynn, E.A. & Williams, C.K. (2014). Effect of barcode technology with electronic medication administration record on medication accuracy rates. American Journal of Health-System Pharmacy, 71(3), 209-218.

Shee, A.W., Phillips, B., Hill, K. & Dodd, K. (2014). Feasibility, acceptability, and effectiveness of an electronic sensor bed/chair alarm in reducing falls in patients with cognitive impairment in a subacute ward. Journal of Nursing Care Quality, 29(3), 253-262.

Shukla, J., Barreda-Ángeles, M., Oliver, J. & Puig, D. (2017). Effectiveness of socially assistive robotics during cognitive stimulation interventions: Impact on caregivers. 2017 26th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN).

Steurbaut, K., Colpaert, K., Van Hoecke, S., Steurbaut, S., Danneels, C., Decruyenaere, J. & De Turck, F. (2012). Design and evaluation of a service oriented architecture for paperless ICU tarification. Journal of Medical Systems, 36(3), 1403-1416.

Steventon, A., Bardsley, M., Billings, J., Dixon, J., Doll, H., Beynon, M., Hirani, S., Cartwright, M., Rixon, L., Knapp, M., Henderson, C., Rogers, A., Hendy, J., Fitzpatrick, R. & Newman, S. (2013). Effect of telecare on use of health and social care services: findings from the Whole Systems Demonstrator cluster randomised trial. Age Ageing, 42(4), 501-508.

Subramaniam, P. & Woods, B. (2016) Digital life storybooks for people with dementia living in care homes: an evaluation. Clinical interventions in aging 11, 1263-1276 10.2147/CIA.S111097: 10.2147/CIA.S111097.

Summerfield, M.R., Seagull, F.J., Vaidya, N. & Xiao, Y. (2011). Use of pharmacy delivery robots in intensive care units. American Journal of Health-System Pharmacy, 68(1), 77-83.

Suzuki, S., Yokoishi, T., Hada, H., Mitsugi, J., Nakamura, O. & Murai, J. (2011). Bidirectional medication support system for medical staff and home care patients. 2011 5th International Symposium on Medical Information and Communication Technology.

Takian, A., Sheikh, A. & Barber, N. (2012). We are bitter, but we are better off: Case study of the implementation of an electronic health record system into a mental health hospital in England. BMC Health Services Research, 12(1).

Tchalla, A.E., Lachal, F., Cardinaud, N., Saulnier, I., Rialle, V. & Preux, P.-M. (2013) Preventing and managing indoor falls with home-based technologies in mild and moderate Alzheimer's disease patients: pilot study in a community dwelling. Dementia and geriatric cognitive disorders 36, 251-261 10.1159/000351863: 10.1159/000351863.

Tielbur, B.R., Rice Cella, D.E., Currie, A., Roach, J.D., Mattingly, B., Boone, J., Watwood, C., McGauran, A., Kirshner, H.S. & Charles, P.D. (2015). Discharge huddle outfitted with mobile technology improves efficiency of transitioning stroke patients into follow-up care. American Journal of Medical Quality, 30(1), 36-44.

Trukeschitz B., S.C., Ring-Dimitriou S. (2018). Smartes Betreutes Wohnen: Nutzung, Systemakzeptanz und Wirkungen von „meinZentrAAL“. Norderstedt, Deutschland.

Vadiei, N., Shuman, C., Murthy, M. & Daley, M. (2017) Optimization of intelligent infusion pump technology to minimize vasopressor pump programming errors. Expert opinion on drug safety, 1-5 10.1080/14740338.2017.1323866: 10.1080/14740338.2017.1323866.

Valenti, S.M., Aguera-Ortiz, L., Olazaran, R.J., Mendoza, R.C., Perez, M.A., Rodriguez, P.I., Osa, R.E., Barrios, S.A., Herrero, C.V., Carrasco, C.L., Felipe, R.S., Lopez, A.J., Leon, S.B., Canas, P.J., Martin, R.F. & Martinez, M.P. (2015) Social robots in advanced dementia. Frontiers in Aging Neuroscience 7, 10.3389/fnagi.2015.00133: 10.3389/fnagi.2015.00133.

Valerie, T., Choy, K.L., Siu, P.K.Y., Lam, H.Y., Ho, G.T.S. & Cheng, S.W.Y. (2016). An intelligent performance assessment system for enhancing the service quality of home care nursing staff in the healthcare industry. 2016 Portland International Conference on Management of Engineering and Technology (PICMET).

van der Heide, L.A., Willems, C.G., Spreeuwenberg, M.D., Rietman, J. & de Witte, L.P. (2012). Implementation of CareTV in care for the elderly: The effects on feelings of loneliness and safety and future challenges. Technology & Disability, 24(4), 283-291.

van der Lende, M., Cox, F.M.E., Visser, G.H., Sander, J.W. & Thijs, R.D. (2016). Value of video monitoring for nocturnal seizure detection in a residential setting. Epilepsia, 57(11), 1748-1753.

Vowden, K. & Vowden, P. (2013). A pilot study on the potential of remote support to enhance wound care for nursing-home patients. J Wound Care, 22(9), 481-488.

Wada, K., Takasawa, Y. & Shibata, T. (2014). Robot therapy at facilities for the elderly in Kanagawa prefecture - a report on the experimental result of the first month. The 23rd IEEE International Symposium on Robot and Human Interactive Communication.

Wagemaker, E., Dekkers, T.J., Agelink van Rentergem, J.A., Volkers, K.M. & Huizenga, H.M. (2017). Advances in Mental Health Care: Five N = 1 Studies on the Effects of the Robot Seal Paro in Adults With Severe Intellectual Disabilities. Journal of Mental Health Research in Intellectual Disabilities, 10(4), 309-320.

Wakefield, B.J. & Vaughan-Sarrazin, M. (2017). Home Telehealth and Caregiving Appraisal in Chronic Illness. Telemedicine and e-Health, 23(4), 282-289.

Wang, R.H., Gorski, S.M., Holliday, P.J. & Fernie, G.R. (2011). Evaluation of a Contact Sensor Skirt for an Anti-Collision Power Wheelchair for Older Adult Nursing Home Residents With Dementia: Safety and Mobility. Assistive technology, 23(3), 117-134.

Webster, G. & Hanson, V.L. (2014). Technology for Supporting Care Staff in Residential Homes. ACM Trans. Access. Comput., 5(3), 8-1.

White, C., McIlfatrick, S., Dunwoody, L. & Watson, M. (2015). Supporting and improving community health services-a prospective evaluation of ECHO technology in community palliative care nursing teams. BMJ Support Palliat Care.

Wieck, M., Blake, B., Sellick, C., Kenron, D., DeVries, D., Terry, S. & Krishnaswami, S. (2017) Utilizing technology to improve intraoperative family communication. American journal of surgery. (no pagination), 2017 Date of Publication: January 10, 10.1016/j.amjsurg.2017.03.014: 10.1016/j.amjsurg.2017.03.014.

Wu, R., Rossos, P., Quan, S., Reeves, S., Lo, V., Wong, B., Cheung, M. & Morra, D. (2011). An evaluation of the use of smartphones to communicate between clinicians: A mixed-methods study. Journal of Medical Internet Research, 13(3).

Yeaman, B., Ko, K.J. & Castillo, R.A.d. (2015). Care Transitions in Long-term Care and Acute Care: Health Information Exchange and Readmission Rates. Online Journal of Issues in Nursing, 20(3), 1-1.

Yi-Sheng, C., Hsin-Ju, L. & Yuan-Hsiang, L. (2014). Using wireless measuring devices and Tablet PC to improve the efficiency of vital signs data collection in hospital. 2014 IEEE International Symposium on Bioelectronics and Bioinformatics (IEEE ISBB 2014).

Yusof, M.M. (2015). A case study evaluation of a Critical Care Information System adoption using the socio-technical and fit approach. International Journal of Medical Informatics, 84(7), 486-499.

Zaccarelli, C., Cirillo, G., Passuti, S., Annicchiarico, R. & Barban, F. (2013). Computer-based cognitive intervention for dementia Sociable: motivating platform for elderly networking, mental reinforcement and social interaction. 2013 7th International Conference on Pervasive Computing Technologies for Healthcare and Workshops.

Zhou, J., Liu, D.B., Zhong, J.W., Huang, Z.Y., Qiu, S.Y., Zhou, Y.P. & Yi, X.H. (2012). Feasibility of a remote monitoring system for home-based non-invasive positive pressure ventilation of children and infants. International Journal of Pediatric Otorhinolaryngology, 76(12), 1737-1740.

Zhuang, J., Fang, R., Feng, X., Xu, X., Liu, L., Bai, Q., Tang, H., Zhao, Z. & Chen, S. (2013) The impact of human-computer interaction-based comprehensive training on the cognitive functions of cognitive impairment elderly individuals in a nursing home. Journal of Alzheimer's Disease 36, 245-251 10.3233/JAD-130158: 10.3233/JAD-130158.

Zimmermann, C., Zeilfelder, J., Bloecher, T., Diehl, M., Essig, S. & Stork, W. (2017). Evaluation of a smart drink monitoring device. 2017 IEEE Sensors Applications Symposium (SAS).

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Evaluation frameworks for digital nursing technologies: analysis, assessment, and guidance. An overview of the literature

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Abstract

Background: The evaluation of digital nursing technologies (DNT) plays a major role in gaining knowledge about certain aspects of a technology such as acceptance, effectiveness, or efficiency. Evaluation frameworks can help to classify the success or failure of a DNT or to further develop the technology. In general, there are many different evaluation frameworks in the literature that provide overviews of a wide variety of aspects, which makes this a highly diverse field and raises the question how to select a suitable framework. The aim of this article is to provide orientation in the field of comprehensive evaluation frameworks that can be applied to the field of DNT and to conduct a detailed analysis and assessment of these frameworks to guide field researchers.

Methods: This overview was conducted using a three-component search process to identify relevant frameworks. These components were (1) a systematized literature search in PubMed; (2) a narrative review and (3) expert consultations. Data relating to the frameworks' evaluation areas, purpose, perspectives, and success definitions were extracted. Quality criteria were developed in an expert workshop and a strength and weakness assessment was carried out.

Results: Eighteen relevant comprehensive evaluation frameworks for DNT were identified. Nine overarching evaluation areas, seven categories of purposes, five evaluation perspectives and three categories of success definitions could be identified. Eleven quality criteria for the strengths and weaknesses of DNT-related evaluation frameworks were developed and the included frameworks were assessed against them.

Conclusion: Evaluators can use the concise information and quality criteria of this article as a starting point to select and apply appropriate DNT evaluation frameworks for their research projects or to assess the quality of an evaluation framework for DNT, as well as a basis for exploring the questions raised in this article. Future research could address gaps and weaknesses in existing evaluation frameworks, which could improve the quality of future DNT evaluations.

Keywords: Framework, Evaluation, Digital, Technology, Care, Nursing

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Background

A large number of digital nursing technologies (DNTs) are currently being developed and tested in nursing practice [1, 2]. These technologies offer promising opportunities to address existing societal challenges such as the shortage of skilled workers or the increasing demand for long-term care [3].

This article refers to digital nursing technology (DNT) as defined by Krick et al. 2019 [2] and Krick et al. 2020 [4]. DNT are technologies that fulfil one or all of the following criteria: i) "support the immediate action of a caregiver"; or ii) "contribute to the self-reliance of the person in need of care in such a way that direct on-site care assistance can be avoided"; or iii) "substitute the nursing support by using technology", or iv) "support the training or education of nurses" [4]. The focal points of this article are the aspects i-iii. DNT's can, for example, be information and communication technologies, robots, sensors, monitoring technologies, assistive devices, ambient assisted living technologies, virtual reality or tracking technologies [1, 2].

Professional nurses point to the need for improved technological support in direct care to reduce physical strain and psychological stress [5], which e.g. could have a long-term impact on retention in the profession. On the other hand, use and acceptance in actual clinical support appears to be rather low [6, 7].

The reasons for the lack of acceptance and usage can be very diverse, since DNT are complex interventions [8]. Specific reasons for non-adoption can be that technologies are not user-friendly (low usability) [5] or have no obvious perceptible benefit for actual work practice (job relevance, perceived usefulness) [5]. Privacy issues or cost concerns may also bea major concern for persons in need of care [9]. Scientific evaluations that provide information on technologies from different perspectives and viewpoints could help us to understand the bigger picture of DNT success and provide important insights on specific impact factors. Evaluation results can, for example, help decisionmakers to facilitate the process of system implementation [10]. Evaluation conducted during the development process also has the potential to prevent system failures and misdevelopments [10].

Comprehensive evaluation frameworks that clearly present important aspects of evaluation play a significant role in supporting researchers, decisionmakers and developers in this process. Evaluation frameworks can be used to provide a structure for the evaluation of DNT as they provide information and definitions of technology success, evaluation areas, methods, and tools. In this way, they "facilitate a systematic approach" [11] in DNT evaluation. The information provided by evaluation frameworks can enable different stakeholders to gain a common understanding of the evaluation process and help identify and decide on appropriate objectives and methods. This can help mediate the fit between research and practice-oriented approaches to evaluation [11].

This article focusses on comprehensive evaluation frameworks that include information on multiple evaluation areas. There is a wide variety of frameworks in the literature and most of them are highly heterogeneous in content, approaches, and methodologies. Identifying and deciding on the appropriate evaluation framework can be very challenging, as there is no suitable overview of evaluation frameworks in the field of DNT available in the literature. It is also difficult to see how these frameworks differ in terms of purpose, and areas of evaluation, and their definition of success. Orientation must be provided on these possibilities, and this overview was conducted to this end.

Objective and research question

The objectives of this article are to provide orientation on existing comprehensive evaluation frameworks that can be applied in the field of DNT and to conduct a detailed analysis and assessment of these frameworks. The aim is to contribute to the discussion and understanding of what constitutes a good (DNT) evaluation framework and to offer field researchers guidance in the selection and application of evaluation frameworks.

This article is thus guided by the following research questions: (i) Which comprehensive evaluation frameworks that can be applied to DNT evaluation are available in the literature? (ii) What purposes, perspectives, and definitions of success are described in these frameworks? (iii) What are the strengths and weaknesses of the included frameworks? (iv) Which areas of evaluation are represented in the frameworks and where are the most overlaps and differences between these frameworks?

Methods

Search process

This overview [12] was conducted using three different search components (roman numerals). The goal was to identify frameworks of relevance to the nursing context according to the inclusion and exclusion criteria described further below. The search components comprised: (i) a systematized literature search conducted in PubMed; (ii) a narrative review was carried out by searching google scholar, screening already identified literature [4] and reference lists of the systematically identified articles; (iii) information on relevant frameworks collected from four experts in the field of evaluation from the German "Cluster Zukunft der Pflege" (Future of Care Cluster) [13]. In this joint project, regular evaluations of digital nursing technologies have been and are carried out over the period 2017–2022. The search terms of the systematized literature search can be found in Table 1. The complete search strategy, including all three components, is shown in Fig. 1.

Eligibility criteria for systematic search

Scientific papers included in the search had to have been published between 2005 and 2020 in English. A summary and full text had to be available. All information was gathered in March 2020, which limits the inclusion period from January 2005 to March 2020.

The studies in question had to (i) either apply an evaluation framework to a (nursing) technology or describe the development of an evaluation framework. The selected frameworks had to (ii) be at least based on either a literature study, an empirical evaluation, or an expert survey. They had to (iii) be directly related to technologies in (nursing) care, or comparable fields like the evaluation of digital health applications in general, but they had to be potentially suitable for the evaluation of DNT. (iv) The technology specific focus must lie on Information and Communication Technologies (ICT), telemedicine, telecare, sensor technology or robotics (or their sub-sectors), as these are the most common technology areas in nursing care (definitions by Krick et al. 2019) [2]. (v) The frameworks could refer to the evaluation of different stages of the life cycle of a technology [14] e.g. before, during or after implementation.

Exclusion criteria were: articles (i) focussing on frameworks for the evaluation of specific medical technology fields (e.g. radiology, surgery) with no relation to nursing; (ii) from developing countries or underdeveloped health systems; (iii) that described study protocols; (iv) with overviews that only present categorical systems without creating a framework; (v) focussing on frameworks related to technologies for education or training; (vi) focussing on fitness applications, wellness applications or applications for general disease prevention; (vii) in a psychiatric context; (viii) that are not comprehensive, i.e. only focus on individual areas such as economy or acceptance or satisfaction or usability; (ix) which refer exclusively to the implementation and not the evaluation of the implementation.

Table 1 Search terms of the systematic search in PubMed

Term		Term		Term	Hits
Framework	AND	Evaluation	AND	Technol*	1381
Framework		Evaluation		ICT	24
Framework		Evaluation		Robot	48
Framework		Evaluation		Sensor	135
Framework		Evaluation		Telecare	10
Framework		Evaluation		Telemed	97
Framework		Evaluation		Digital	260
					1955

Identifying relevant frameworks

All systematic search results were imported into EndNote X8 and reimported into the Excel screening workbook by VonVille [15]. A multi-step screening process was performed. The first step included screening 100 titles and 100 abstracts. The eligibility criteria were then refined. All titles were screened in the second step and the remaining abstracts in the third step. The eligibility criteria were then refined again before screening the full texts. If an identified article only applied a framework, for which the development is described in another article, this was an intermediate step for the identification of the framework. The original article describing the framework was than identified and included in the further steps of the analysis.

The narrative search was performed with the knowledge and eligibility criteria of the first screening process, which enabled a much more precise identification process. Google scholar was searched with the terms "framework" AND "evaluation" AND "nursing". Articles were screened and reference lists were also examined, snowballing through the reference lists of these articles. Reference lists of the systematically identified studies and literature from a previous search [4] were also included. This method of snowballing is important for such complex search fields. It helped to obtain all relevant information on frameworks as a supplement to those not found in the systematic approach [16].

The expert consultation additionally focussed on the identification of relevant frameworks. The experts were invited to name frameworks known to them and list all frameworks used in their projects to evaluate digital nursing technologies. The whole search and identification process can be found in Fig. 1.

Data extraction

Purpose, perspective, and success definitions

The first step for data extraction was to screen all full texts of the frameworks for the technology group to which they refer, the stated purpose and the evaluation perspective [17], as well as the success definition/description (ii). This article defines the purpose of a framework as the description of what the framework is intended to achieve. The perspective describes the viewpoint from which the framework was developed and thus the viewpoint from which the evaluation results could be interpreted. The analysis of "success" focused on the definitions or descriptions of what the articles mean by "success" or "successful technology". A qualitative synthesis was conducted to identify and categorize the included purposes, perspectives and success definitions by using textual narrative synthesis [18].

Strengths and weaknesses

A strengths and weaknesses analysis of the frameworks under consideration was also carried out to answer research question (iii). The criteria for evaluating the frameworks were developed in an expert workshop with experienced researcher in the field of evaluation. The criteria are listed in Table 2. This approach was chosen because there are no universal quality criteria for the strengths and weaknesses of DNT related evaluation frameworks in the literature.

Areas of evaluation

To answer research question (iv) all frameworks were screened for similarities in their categorization systems. Most frameworks used different sorting systems and systematization logics. An iteratively developed data extraction form was drawn up in Excel and piloted with three frameworks. It was decided to assign all evaluation topics of the frameworks to the generic categories "Top Category" "Subcategories" and "Specification" (Additional file 1). This step was necessary, because there is no universal systematization to categorize the content of evaluation frameworks, but there is a kind of hierarchy that can be found in these frameworks.

Charting the data

All extracted information on the technology group to which the frameworks refer, the stated purpose and the evaluation perspective, as well as the definition/description of success (research question ii), were charted in excel and listed with the respective framework.

To answer research question (iv) all identified top categories were analyzed to build overarching top categories that were used for the systematization of these

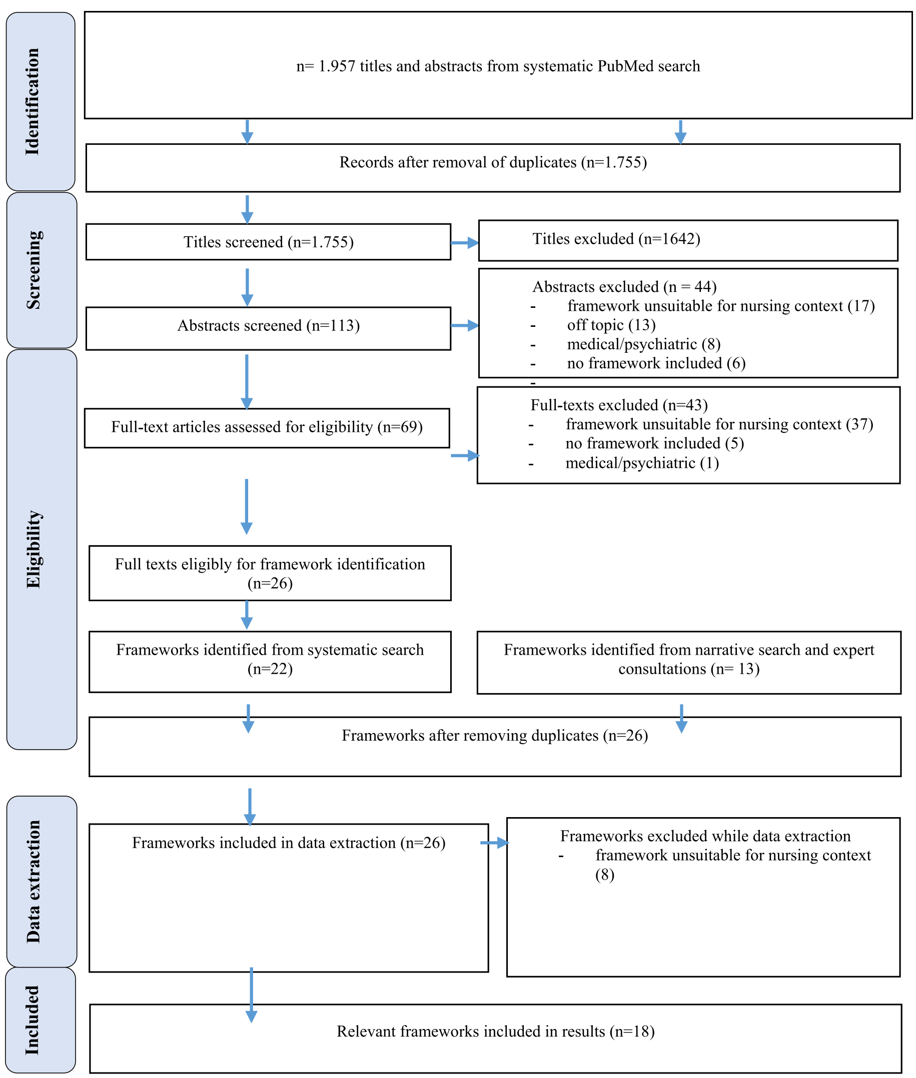

Fig. 1 Search results and framework selection process

Table 2 Guiding categories for assessing the strengths and weaknesses of the frameworks

Guiding Category	Content
Focus of the framework	Description of the specific focus of the framework. This can include a - description of the purpose (and the addressed question) - the application setting - the technology (area)
Illustration	- Clarity/ complexity of illustration - Visualization of connections and relationships within the framework
Terminology	- Transparent definitions of terms and key concepts
Instructions for use	- Concrete application strategy and instructions for use - Instruction on how the results can be interpreted
Scientific quality	- Transparency of development process - Reflection of the limitations of the framework - Transferability of the framework (Settings, technologies, questions)

frameworks. The analysis of all top categories of the 18 frameworks resulted in 9 generic top categories, which were then defined and formed the basis for further analysis. The definitions of these categories were generated inductively and iterative while analyzing all included evaluation aspects of the frameworks (analysis in Additional file 2; definitions in Table 3). Despite this process a non-overlapping categorization of these categories was not possible due to the complexity of the frameworks content and the interconnectedness of different categories.

In the next step, the extracted content of the subcategories from the frameworks (Additional file 2) was analyzed to identify similarities and differences related to the newly built top categories (Table 3). During the extraction of the category "specifications", these were found to be vastly diverse and, hence, not suitable for any standardization. Therefore, only the content of the subcategories was included in the mapping process. Where there were no subcategories, the top categories were included into this step. This was the case for the: Design and Evaluation of DHI Framework [14], Evaluation Framework for Fit-For-Purpose Connected Sensor Technologies [19], Digi-HTA [20], CISSM [21] (in parts because there were only specifications in the form of specific questions for the top categories).

If the subcategories corresponded to a completely different sorting logic as the other frameworks and therefore did not contain any evaluable information, the "specifications" were evaluated if they contained valid information. This was done for the: Khoja–Durrani–Scott Evaluation Framework [22], the layered telemedicine implementation model [23]; and the Comprehensive evaluation framework for telemedicine implementation [24].

All charting results can be found in (Additional file 2). The assignment may differ from their logic in the representation to the original assignment because the frameworks used different sorting systems and logics, which were unified in this representation. Models and frameworks often develop their own categorization logic. There is no uniformly recognized logic.

Results

Search results

The systematic search in PubMed generated 1957 hits. After removing the duplicates, 1.755 remained for screening the titles. The abstracts of 113 articles were chosen for screening, yielding 69 full-texts eligible for full-text screening. The systematic search generated a

Table 3 Definitions of the DNT evaluation areas

Focus	Product/Technology	Objective Value/Effect	Individual	Organization
This area includes what the technology focuses on in terms of its objectives and purpose and the problems and needs it aims to solve for a specific target group in a specific setting.	This area includes all aspects of the technology itself. This ranges from visual appearance to functionality and certain specific technological aspects such as interoperability. (However, there is also an interface to the category "individual", because certain individually perceived aspects are covered here, such as usability and access).	This category includes the relevant information on evidence, aspired values as well as intended and unintended effects of the technology.	This area includes reactions and perceived impressions, as well as the behaviour and the relationship of individuals towards the technology.	This area includes aspects that are relevant in the relationship between the technology and an organization.
Societal	**Ethics**	**Economics**	**Strategic**	
This area includes relevant aspects of the technology in a societal context (e.g. political, juridical, regulatory, or socio-cultural aspects - Overlaps with the area of ethics are possible).	This area includes relevant ethical standards and ethical implications to be considered in relation to the technology.	This area includes relevant economic aspects for the technology (e.g. business model, price, economic evaluation).	This area includes strategic aspects that may be relevant for the introduction and dissemination of the technology.	

total of 22 articles to be analyzed for relevant frameworks. The narrative search and the expert consultations yielded 13 articles with frameworks. There remained 26 frameworks for the final analysis process, after sorting out the duplicates generated by the different search processes. Eight further frameworks were discarded during the data extraction process because detailed analysis revealed that they did not meet the eligibility criteria. This left 18 frameworks filtered out for the final analysis (Fig. 1).

Analysis results

Eighteen comprehensive evaluation frameworks that can be applied to DNT are presented in the results section. According to the technology categories there are $n = 7$ frameworks related to information and communication technologies (with different sub-sectors), $n = 3$ frameworks for telemedicine/telecare, and $n = 1$ framework for sensor technologies. The remaining frameworks were generalistic frameworks from the areas of digital health (n = 3), health (and care) technologies ($n = 2$), e-health (n = 1) and clinical informatics (n = 1). The classification was based on the technologies derived from the articles with reference to the definitions of technology categories from Krick et al. 2019 [2] (Table 3). The final selection of frameworks can be found in Table 4.

Purpose and perspectives of the frameworks

The purposes and the perspectives of the selected frameworks were analyzed to answer research question (ii). Although these frameworks have the common purpose of assessing digital technologies using specific assessment categories, the purposes described beyond this differ. The detailed assessment can be found in Table 5. The qualitative synthesis identified 7 overarching categories of purposes:

1. Help and guide researchers (design and evaluation process) [14, 22, 25–27, 32–35]
2. Identify success and failure factors (and help to manage them) [14, 19, 21, 23, 27, 34]
3. Assess the performance/success of a technology (outcomes, impact, errors, deficiencies) [28–31]
4. Make the results comparable [19]
5. Contribute to the quality and development of the technology [31, 34, 35]
6. Support the implementation of a technology [33–35]
7. Help in decision-making [20, 24, 31]

A further classification of the purposes could be made by dividing them into two main categories. (A) knowledge-oriented purposes (1–4) that mainly indicate that the frameworks and their use serve to generate a certain form of knowledge. (B) practice-related purposes (5–7). Theses purposes could be summarized as application-oriented knowledge as they indicate that the knowledge will be used for a specific action such as development, implementation or decision making.

Table 4 Included Frameworks and technology categories

Information and Communication technologies	Infoway benefits evaluation Framework [25]
	Health Information Technology Evaluation Framework (HITREF) [26]
	Hospital Information System Success Framework [27]
	Development of an Evaluation Framework for Health Information Systems (DIPSA Framework) [28]
	Human, Organization, Process and Technology-fit (HOPT-FIT) [29]
	Clinical Information Systems Success Model (CISSM) [21]
	Adapted nursing care performance framework [30]
Telemedicine/Telecare	Model for Assessment of Telemedicine (MAST Manual) [31]
	Comprehensive evaluation framework for telemedicine implementation [24]
	The layered telemedicine implementation model [23]
Sensor Technologies	Evaluation Framework for Fit-For-Purpose Connected Sensor Technologies [19]
Digital Health	Design and Evaluation of DHI Framework [14]
	Health technology assessment framework for digital healthcare services (Digi HTA) [20]
	Digital Health Score Card [32]
Health (and care) technologies	Health Technology Adoption Framework [33]
	Nonadoption, Abandonment, Scale-up, Spread, and Sustainability Framework (NASSS Framework) [34]
E-health programs	Khoja–Durrani–Scott Framework for e-Health Evaluation [22]
Clinical informatic interventions	RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) (expanded to clinical informatics)) [35]

For a deeper understanding of the purpose of a framework, it is necessary to also analyze the perspective that the framework takes as it might have an influence on how the framework is intended to achieve that purpose.

Of the 18 frameworks, $n = 9$ had a universal perspective, which means that they can be applied to different perspectives or remain neutral thus leaving the decision to the evaluator. The remaining nine frameworks indicate or define for themselves, that they were developed from a specific viewpoint, and that the results could be interpreted from this viewpoint. Of these nine, $n = 4$ take the perspective of a healthcare organization, $n = 2$ describe the healthcare system as a perspective, n = 2 have the nurse's perspective as a viewpoint and $n = 1$ is developed from an investment program perspective.

Success definitions/descriptions

The frameworks were also scrutinized for definitions or descriptions of what is meant by "success" or "successful technology" in order to gain a better understanding of the differences that might exist (Table 5). Most of the frameworks do not have an explicit definition of success [19, 20, 22, 26, 28–33]. In such cases, the evaluation criteria described in the frameworks and the resulting interpretation of the evaluation results could be used to make a statement about whether or not the technology in question was successful.

The qualitative synthesis of the success definitions/ descriptions of success identified three categories:

1. Success is when the technology achieves its intended purpose [27]
2. Success means achieving implementation, dissemination and/or sustainability of a technology [14, 23, 24, 34]
3. A successful technology must generate a net benefit [21]

Strengths and weaknesses of the frameworks

The strengths and weaknesses of the frameworks under consideration were assessed in order to contribute to a better understanding of what constitutes a good (DNT) evaluation framework and answer research question (iii). Previously developed quality criteria for DNT Frameworks were used for the assessment (as described in the methods section). A detailed analysis of the assessment can be found in Table 6. (+) stands for strength and (−) denotes a weakness in a certain assessment area.

The assessment revealed differences and similarities between the frameworks under study. All frameworks included a description of their intended purpose and the question(s) addressed. Of the 18 frameworks, 14 do not explicitly describe an application setting, since these frameworks were developed with generic setting approaches. They therefore received a (+) in the evaluation for the universality of the setting and at the same time a (−) because they are not specifically related to a setting. However, most frameworks describe specific technology areas on which they focus. Only six have universal designs, for potentially different technologies, so that they have been assessed with a (+) for universality and a (−) for being non specific. Due to their elaboration, $n = 12$ of the frameworks are easily transferable to other contexts. $N = 11$ frameworks have a very clear visual presentation and $n = 9$ include a visual representation of connections and relationships of individual aspects within the framework. On the other hand, this means that $n = 7$ frameworks were not without visual weaknesses and n = 9 frameworks did not show visual connections between the aspects with which they were concerned. Almost all frameworks ($n = 15$) included transparent definitions of terms and key concepts and are transparent in terms of the development process ($n = 14$). However, many of the frameworks have weaknesses in applicability, clear guidance, and assistance for the interpretation of the results. Only $n = 9$ frameworks are strong in the description of an application strategy and instructions for use and only $n = 6$ include soundadvice on how to interpret the results. Furthermore, many articles on the frameworks do adequately discuss weaknesses and limitations - if at all($n = 11$). The frameworks with the highest scores across all assessment categories were:

(1.) Health Technology Adoption Framework [33] strengths n = 9, weaknesses n = 1 (no visualization of connections and relationships within the framework) and strength/weaknesses n = 1 (transferability limited to surgical context).
(2.) CISSM [21] strengths n = 9, weaknesses n = 1 (no description of the limitations) and strength/ weaknesses n = 1 (transferability limited to hospital context).
(3.) NASSS Framework [34] strengths $n = 8$, and strengths/weaknesses $n = 3$ (no clear focus on an application setting, no clear focus on a technology (area), and no applicable strategy using the framework.)

The detailed analysis of the assessment can be found in Table 6. More detailed descriptions of the strengths and weaknesses can be found in Additional file 3.

Areas of evaluation in relation to the assigned perspectives

A detailed analysis of the areas of evaluation included in the frameworks was carried out to answer research

Table 5 Analysis and assessment of the frameworks

	Analysis				
Technology Field	**Framework**	**Authors/ Year**	**Perspective**	**Stated Purpose**	**Success Definition/ Description**
Information and Communication technologies (Health Information Systems (HIS))	Infoway benefits evaluation Framework	Francis Lau et al. 2007 [25]	**Investment programs** for digital technologies (to guide evaluations)	1. Provide a high-level evidence based model to guide subsequent field evaluation	Success measured by analysing the results of the evaluation (Factors based on the van der Meijden et al. model [36])
Information and Communication technologies (Health Information Technologies (EHR))	Health Information Technology Evaluation Framework (HITREF)	Sockolow et al. 2012 [26]	**Universal perspective** (mainly influenced by health services research and informatics)	1. Conceptual tool for framing evaluations studies in assessing EHR-based implementations in organizational, systematic, and environmental contexts 2. Displaying evaluation criteria	No success definition (measuring the success by analysing the results of the evaluation)
Information and Communication technologies (Hospital Information Systems)	Hospital Information System HIS Success Framework	Sadoughi et al. 2013 [27]	**Universal perspective**	1.Identification of Hospital Information System success and failure factors and the evaluation methods of these factors	Success as a dynamic concept. Success is when the technology achieves its intended purpose. (+ time, budget, and user satisfaction)
Information and Communication technologies (Integrated Health Information Systems (IHIS))	Development of an Evaluation Framework for Health Information Systems (DIPSA Framework)	Stylianides et al. 2018 [28]	**Healthcare Organization**	1.Evaluation framework for hospitals utilizing IHIS to help identify any existing deficiencies in the system	No success definition (measuring the success by analysing the results of the evaluation)
Information and Communication technologies (Health Information Systems)	Human, Organization, Process and Technology-fit (HOPT-FIT)	Yusof 2019 [29]	**Healthcare Organization** (focus on technology induced errors)	1. Evaluate HIS performance and efficiency 2. Systematically guide error evaluation 3. Describing the Human-Organization-Process-Technology fit	No success definition (measuring success with the included dimensions of HIS success)
Information and Communication technologies (Clinical Information Systems (CIS))	Clinical Information Systems Success Model (CISSM)	Garcia-Smith & Effken 2013 [21]	**Nurse's perspective**	1. Framework for evaluating CIS success from the nurse's perspective	Success = net benefit ("degree to which a nurse believes that using a particular system enhances job performance")
Information and Communication technologies (Information and Communication technologies for nurses)	Adapted nursing care performance framework	Rouleau et al. 2017 [30]	**Nurse's perspective**	1. Illustrate how ICTs interventions influence nursing care and impact health outcomes	No success definition (measuring the success by analysing the results of the evaluation)
Telemedicine/ Telecare	Model for Assessment of Telemedicine (MAST Manual)	Kidhom et al. 2010 [31]	**Universal perspective** (user-based decision making, research)	1. Describe effectiveness 2. Contribution to quality of care of telemedicine applications 3. Produce a basis for decision making	No success definition (measuring the success by analysing the results of the evaluation)
Telemedicine/ Telecare	Comprehensive evaluation framework for telemedicine implementation	Chang 2015 [24]	**Universal perspective** (decision making for individuals, organizations, and communities)	1. Summarising important themes for the evaluation of telemedicine systems 2. Support related stakeholders' decision-making by promoting general understanding, and resolving arguments and controversies	Long-term implementation
Telemedicine/	The layered	Broens et al.	**Universal perspective**	1. Detailed classification of the	Successful implementation

Table 5 Analysis and assessment of the frameworks *(Continued)*

	Analysis				
Technology Field	**Framework**	**Authors/ Year**	**Perspective**	**Stated Purpose**	**Success Definition/ Description**
Telecare	telemedicine implementation model	2007 [23]	(the focus on individual determinants/ perspectives changes throughout the development life cycle)	determinants of the success of future telemedicine implementations	("putting an idea or a concept into actual practice")
Sensor Technologies (Connected Sensor Technologies: including wearables. biosensors)	Evaluation Framework for Fit-For-Purpose Connected Sensor Technologies	Coravos et al. 2020 [19]	**Healthcare System Perspective** (users and other stakeholders)	1. Working evaluation framework that reflects different types of risks 2. Framework is conducted to better manage these risks 3. Make information on sensor technologies more comparable and understandable	No success definition (success could be measured by analysing the results of the evaluation and comparing them with the standards for connected sensors)
Digital Health (Digital Health Interventions (DHI))	Design and Evaluationof DHI Framework	Kowatsch et al. 2019 [14]	**Universal perspective** (researchers and practitioners)	1. Framework for the design and evaluation of DHI 2. Showing evaluation criteria and implementation barriers to be considered during the life cycle phases of DHI 3. Support researchers and practitioners from conception to large-scale implementations	A successful DHI needs to consider "the selection of suitable evaluation criteria and the overcoming of implementation barriers"
Digital Health (Digital Healthcare Services: mHealth, AI, and robotics)	Health technology assessment framework for digital healthcare services (Digi HTA)	Jari et al. 2019 [20]	**Healthcare System Perspective** (decision making)	1. Inform decisionmakers in order to better support the introduction of new health technologies	No success definition (success could be measured by analysing the results of the evaluation)
Digital Health (Digital Health Technologies)	Digital Health Score Card	Mathews et al. 2019 [32]	**Universal perspective** (multi-stakeholder approach)	1. Multi-stakeholder approach to objectively evaluate digital health solutions	Measuring the success by analysing the results of the evaluation (Success as the successful delivery of validated digital health solutions)
Health (and care) technologies	Health Technology Adoption Framework	Poulin et al. 2013 [33]	**Healthcare Organization**	1. Framework with clear, user-validated criteria for evaluating new health technologies for adoption at the local level	No success definition (success could be measured by analysing the results of the evaluation)
Health (and care) technologies	Nonadoption, Abandonment, Scale-up, Spread, and Sustainability Framework (NASSS Framework) [34]	Greenhalgh et al. 2017	**Universal perspective**	1. Framework to help predict and evaluate the success of a technology-supported health or social care program 2. Help to design, develop, implement, scale up, spread, and sustain technology-supported health or social care programs by identifying key challenges in different domains and the interactions between them	Adoption, scale-up, spread, and sustainability of a technology
E-health programs	Khoja–Durrani–Scott Framework for e-Health Evaluation	Khoja et al. 2013 [22]	**Universal perspective** (included tools usable for managers, healthcare providers, and clients)	1. Comprehensive Framework to show relevant themes for e-health evaluation	No success definition (measuring the success by analysing the results of the evaluation)
Clinical informatic interventions	RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) (expanded to clinical informatics)	Bakken & Ruland 2009 [35]	**Healthcare Organization** (implementation in organizational practice)	1. Used to design, implementation, evaluation, and reporting of clinical informatics with a goal of translation of research into practice	No success definition (measuring the success by analysing the results of the evaluation)

Table 6 Strengths and Weaknesses

	+ = strength					- = weakness			+/− = strength and weakness					
	Criteria											Summary		
Frameworks	Description of the purpose (and the addressed question(s)	Description of the application setting	Description of the technology (area)	Clarity/ complexity of illustration	Visualization of connections and relationships within the framework	Transparent definitions of terms and key concepts	Concrete application strategy and instructions for use	Instruction on how the results can be interpreted	Transparency of development process	Reflection of the limitations of the framework	Transferability of the framework (Settings, technologies, questions)	+	−	+/−
Health Technology Adoption Framework [33]	+	+	+	+	−	+	+	+	+	+	+/−	9	1	1
Clinical Information Systems Success Model (CISSM) [21]	+	+	+	+	+	+	+	+	+	−	+/−	9	1	1
Nonadoption, Abandonment, Scale-up, Spread, and Sustainability Framework (NASSS Framework) [34]	+	+/−	+/−	+	+	+	+/−	+	+	+	+	8	0	3
Health Information Technology Evaluation Framework (HITREF) [26]	+	+/−	+	+	+	+	+	−	+	−	+	8	2	1
Evaluation Framework for Fit-For-Purpose Connected Sensor Technologies [19]	+	+/−	+	+	−	+	+	+	+	−	+	8	2	1
Hospital Information System Success Framework [27]	+	+	+	−	−	+	+	−	+	+	+	8	3	0
Adapted nursing care performance framework [30]	+	+/−	+	+	+	+	−	+/−	−	+	+	7	2	2
The layered telemedicine implementation model [23]	+	+/−	+	+	+	+	+/−	−	+	+	−	7	2	2
Model for Assessment of Telemedicine (MAST Manual) [31]	+	+/−	+	−	−	+	+	−	+	+	+	7	3	1
Health technology assessment framework for digital healthcare services (Digi HTA) [20]	+	+/−	+	−	−	+	+	+	+	−	+	7	3	1
Infoway benefits evaluation Framework [25]	+	+/−	+/−	+	+	+	−	−	+	−	+	6	3	2

Table 6 Strengths and Weaknesses *(Continued)*

			+ = strength			- = weakness			+/− = strength and weakness			
			Criteria									Summary
Design and Evaluation of DHI Framework [14]	+	+/−	+/−	−	−	+	+	−	+	+	+	6 3 2
RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) (expanded to clinical informatics)) [35]	+	+/−	+/−	−	−	+	+	+	+	−	+	6 3 2
Development of an Evaluation Framework for Health Information Systems (DIPSA Framework) [28]	+	+	+	−	−	+	−	−	+	−	+	6 5 0
Khoja–Durrani–Scott Framework for e-Health Evaluation [22]	+	+/−	+/−	−	+	+	−	−	+	−	+	5 4 2
Digital Health Score Card [32]	+	+/−	+/−	+	+	+	−	−	−	−	−	4 5 2
Human, Organization, Process and Technology-fit (HOPT-FIT) [29]	+	+/−	+	+	+	−	−	−	−	−	−	4 6 1
Comprehensive evaluation framework for telemedicine implementation [24]	+	+/−	+	+	−	−	−	−	−	−	−	3 7 1

Table 7 Frameworks with evaluation areas and perspectives

Framework	Perspective	Focus	Product/ technology	Objective Value/ Effect	Individual	Organization	Societal	Ethics	Economic	Strategic
		Evaluation Areas								
Health Information Technology Evaluation Framework (HITREF) [26]	**Universal perspective** (mainly influenced by health services research and informatics)		■	■	■	■	■		■	■
Hospital Information System Success Framework [27]	**Universal perspective**		■	■	■	■	■	■	■	■
Model for Assessment of Telemedicine (MAST Manual) [31]	**Universal perspective** (user-based decision making, research)	■	■	■	■	■	■	■	■	■
Comprehensive evaluation framework for telemedicine implementation [13]	**Universal perspective** (decision making for individuals, organizations, and communities)	■	■	■	■	■	■		■	■
The layered telemedicine implementation model [24]	**Universal perspective** (the focus on individual determinants changes throughout the development life cycle)		■	■	■	■	■		■	
Design and Evaluation of DHI Framework [16]	**Universal perspective** (researchers and practitioners)	■	■	■	■	■	■	■		
Digital Health Score Card [32]	**Universal perspective** (multi-stakeholder approach)		■	■		■			■	
Khoja–Durrani–Scott Framework for e-Health Evaluation [23]	**Universal perspective** (included tools usable for managers, healthcare providers, and clients)	■	■	■	■	■	■	■	■	■
Nonadoption, Abandonment, Scale-up, Spread, and Sustainability Framework (NASSS Framework) [34]	**Universal perspective**	■	■	■	■	■	■		■	
Development of an Evaluation Framework for Health Information Systems (DIPSA Framework) [28]	**Healthcare Organization**		■	■	■	■				
Human, Organization, Process and Technology-fit (HOPT-FIT) [29]	**Healthcare Organization** (focus on technology induced errors)		■		■	■				
RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) (expanded to clinical informatics) [35]	**Healthcare Organization** (implementation in organizational practice)			■	■	■			■	
Health Technology Adoption Framework [33]	**Healthcare Organization**		■	■		■			■	■
Clinical Information Systems Success Model (CISSM [22]	**Nurse's perspective**		■	■	■	■				
Adapted nursing care performance framework [30]	**Nurse's perspective**			■	■					
Evaluation Framework for Fit-For-Purpose Connected Sensor Technologies [21]	**Healthcare System Perspective** (users and other stakeholders)		■	■			■		■	
Health technology assessment framework for digital healthcare services (Digi HTA)[12]	**Healthcare System Perspective** (decision making)		■	■			■		■	
Infoway benefits evaluation Framework [25]	**Investment programs** for digital technologies (to guide evaluations)		■	■	■	■			■	

question (iv). The analysis resulted in definitions for nine evaluation areas that are described in Table 3.

Table 7 shows a comparison of the frameworks regarding the evaluation areas they cover. The results of the analysis of these areas indicate where the frameworks have their main areas of focus. The colour coding in the table signals that a framework covers a certain area. The allocation was based on the definitions and the sorting logic described in the Methods section above. The specific perspective described for the frameworks was also included in the table to crosscheck whether it is possible to make generalized statements about the existence of certain evaluation areas in relation to the perspective taken.

Most frameworks ($n = 17$) contained evaluation aspects of the area of objective value/effect. Also, the evaluation of the specific product/technology aspects ($n = 16$), aspects of the organization ($n = 15$) and the relationship of individuals to the technology ($n = 14$) was largely represented.

Societal ($n = 10$) and strategic ($n = 6$) aspects, as well as ethical aspects ($n = 4$), were not as frequent. A closer look reveals that these aspects are particularly rare when the perspective described is the healthcare organization or the nurses. At the same time, these aspects are jointly represented three times in the assessment if the perspective "universal" was assigned (in the HIS Success Framework [27], MAST Manual [31] and the Khoja–Durrani–Scott Framework for e-Health Evaluation [22]).

Overall the evaluation area "focus" is not as frequently represented. Only $n = 5$ frameworks contain aspects of this areas. All frameworks containing this aspect come from the "universal" perspective. The area covers evaluation aspects that can be used as starting point for the design of a DNT or DNT evaluation by conducting a "needs analysis" (related to the addressed problems and needs of a target group).

Frameworks for which a universal perspective has been described ($n = 9$) also cover more areas more often in general (coverage of 7,2 areas on average). While frameworks for which a healthcare organization perspective is described ($n = 4$) only cover 4 areas on average (none of them covers the areas focus, societal or ethics), and frameworks covering the nurse's perspective ($n = 2$) only cover 2 and 4 areas respectively (none of them covers the focus, societal, ethics, economic or strategic aspects). The frameworks with a healthcare system perspective (n = 2) cover 4 areas on average (none of them covers the focus, individual, organization, ethics, or strategic areas) and the only framework with an investment program perspective covers 5 areas (does not include the areas focus, societal, ethics or strategic). A mapping of the content of the frameworks to the evaluation areas was carried out and can be found in Table 6.

Discussion

The aim of this study was to contribute to a better understanding of what constitutes a good (DNT) evaluation framework and to guide field researchers in the selection and application of evaluation frameworks. This aim resulted in four research questions: (i) Which comprehensive evaluation frameworks that can be applied to DNT evaluation are available in the literature? (ii) What purposes, perspectives, and definitions of success are described in these frameworks? (iii) What are the strengths and weaknesses of the included frameworks? (iv) Which areas of evaluation are represented in the frameworks and where are the most overlaps and differences between these frameworks?

Eighteen different comprehensive evaluation frameworks were identified that met the inclusion criteria in the field of DNT. Unlike other overviews of evaluation frameworks, which either had a very technology-specific focus (e.g. on health information systems [37]) or a different thematic orientation (e.g. on HTA [38]), this article took a broad approach on comprehensive frameworks for DNT.

This led to the identification of technology-specific frameworks $n = 11$ (Information and Communication technologies, telemedicine/telecare, and sensor technologies) – as well as more generalistic frameworks addressing digital health ($n = 3$), health (and care) technologies ($n = 2$), e-health (n = 1) or clinical informatics (n = 1). The identified frameworks and their main features are listed in the Tables 4–7. These may serve as a good overview and starting point for researchers to select an appropriate framework.

It should be noted, however, that although a specific definition of DNT was used, there is inevitably an overlap to other different themes like e-health or digital health which makes a general distinction very difficult. The frameworks for specific technology categories in this article only cover a part of the technologies that can be subsumed under DNT. For example, evaluation frameworks for monitoring technologies, assistive devices or ambient assisted living, are not included [2]. This is so as to avoid too much heterogeneity of technologies in this article and the technologies included make up a significant proportion of the DNTs discussed in the literature [2]. Also, the generic frameworks can potentially be used for the evaluation of further technologies.

To distinguish, differentiate and select relevant frameworks, researchers should look at specific assessment categories and the frameworks content. Some important aspects regarding the frameworks are covered in this article. The perspective of a framework is essential to put the definitions of success in a framework into context and to understand a potential interpretation of the evaluation categories. There should also be clarity about the purpose of the framework to apply it appropriately, and transparency about where frameworks have their respective strengths and weaknesses. All these issues were analyzed and are discussed in the following.

Purposes

It is important to understand that although the common purpose of the frameworks dealt with here is to assess digital technologies using specific evaluation categories, the purposes described beyond this differ. Most frameworks included here were developed (i) to help and guide researchers in the design and realisation of an evaluation [14, 22, 25–27, 32–35], and/or (ii) to support the identification of success and failure factors (and to help manage them) [14, 19, 21, 23, 27, 34]. (iii) Four frameworks were specifically designed to assess the performance/success of a technology (outcomes, impact, errors, deficiencies) [28–31], but only one framework (iv) was drawn up to help to make the results comparable [19]. This could be since the other articles simply assume the comparability issue to be implicitly logical and therefore do not name it explicitly as a purpose. These four purpose categories (with the exception of the management of success and failure factors) could be summarized as knowledge-oriented purposes, indicating that the frameworks mainly serve to generate a certain form of knowledge.

Some frameworks indicate a more practice-related purpose such as (v) contributing to the quality and development of the technology [31, 34, 35], (vi) supporting the implementation of a technology [33–35] or (vii) providing help in decision-making [20, 24, 31]. These purposes can be summarized as application-oriented knowledge generation. As the classification shows, a DNT framework can have several purposes in both categories: knowledge generation and application orientation. The knowledge-oriented categories i, ii, iii, iv and the practice-related category vi are in line with seven out of eight general attributes of evaluation frameworks in healthcare identified by Bradford et al. (2019) These are 1. simplify a complex (evaluation) process, 2. provide structure (for an evaluation), 3. facilitate the evaluation process, 4. promote meaningful evaluation, 5. identify and explain outcomes, 6. generate transferable lessons, 7. identify mechanisms driving or inhibiting change [39]. Bradford and colleagues also consider it an important element that frameworks help to identify relevant stakeholders [39]. This element was not mentioned as a purpose by any of the frameworks in the present study. In general, DNT evaluation and DNT relevant evaluation frameworks can consider knowledge-oriented and application-oriented purposes. It does not make a framework better or worse if it includes only one of the categories, but having a clearly defined purpose is a quality criterion when choosing a reliable framework. Researchers must be aware of the intended purpose of a framework when choosing their evaluation approach.

Perspective and evaluation areas

A closer look at the perspectives of the frameworks discussed here raises the question whether the perspective under which a framework has been developed, may have an impact on the evaluation categories included. The analysis of the frameworks revealed five perspectives: universal, healthcare system, healthcare organization, nurses, and investment program perspective.

Of the 18 frameworks, $n = 9$ had a universal perspective, which means that they can be applied to different perspectives, leavingthe decision is left to the evaluator. Frameworks for which a universal perspective has been described cover more evaluation areas in general (coverage of 7,2 areas on average), what supports this assumption. Frameworks for which a healthcare organization perspective is described only cover 4 areas on average (none of them covers the areas focus, societal or ethics), and frameworks with the nurse's perspective only cover 3 areas on average (none of them covers the aspects focus, societal, ethics, economic or strategic). Those frameworks with a healthcare system perspective ($n = 2$) cover 4 areas on average (with none of them covering the areas focus, individual, organization, ethics, or strategic) and the only framework with an investment program perspective covers 5 areas (does not include the areas focus, societal, ethics or strategic). The perspective with which a framework has been developed is therefore always an important feature to consider when selecting a framework, as this could influence the evaluation aspects included.

In addition, there are several stakeholder perspectives that were not taken as the main perspective in the frameworks. These perspectives are the payors perspective, the perspective of the patient / person in need of care and the perspective of the informal caregiver. All these perspectives are particularly important in the context of DNTs. However, it should be mentioned that these perspectives are often included in the universal frameworks like the patient perspective in the MAST [31] or the 3rd party payment aspect in the comprehensive evaluation framework for telemedicine implementation [24]. In summary, when selecting and using a comprehensive evaluation framework to evaluate a DNT, the perspective of the chosen framework and the intended perspective of the evaluation should always be reflected and contrasted, as there may be a relationship between the perspective and the evaluation areas included in the framework. The frameworks with a narrow perspective, such as the nurses' perspective, cover fewer evaluation areas overall in this study, while those with a universal perspective cover significantly more. Three examples explaining this in more detail can be found in the discussion section entitled "Discussion of the three most relevant frameworks". If researchers require a comprehensive framework with as many evaluation areas as possible, they must choose a framework with a universal evaluation perspective.

Success definitions/descriptions

It is not easy to define a successful digital nursing technology. Nguyen et al. (2014) argue that the success of a technology may be "disputed depending on the interests of the evaluating party." [40] This is in line with the success description of Lau (2009) who sees it in the context of an "ongoing negotiation and adaptation of interrelationships" of the healthcare professionals involved [41]. A large multi stakeholder Delphi study conducted by McNair and colleagues (2006) [42] concluded that "success cannot be characterized along one single axis" and therefore defined success as the fulfilment or non-fulfilment of five consensus based aspects, namely (1) the wide usage in daily practice, (2) the fulfilment of the role and tasks it was planned for (in a specific environment), (3) the support of good medical practice (benefitting the patient), (4) the benefits to the healthcare organization and working conditions, (5) easy upgradability to adapt to the developments in practice [42].

Aspects 1–4 from McNair and colleagues were also identified as success definitions in the analyzed frameworks in this article (1. Success is when the technology achieves its intended purpose [27]; 2. Success means achieving implementation, dissemination and/or sustainability of a technology [14, 23, 24, 34]; 3. A successful technology must generate a net benefit [21]). This suggests that these aspects could be universal definitions of success for digital nursing technologies. Aspect 5 of the McNair study could be added as equally important.

However, looking at success from a certain perspective in a specific context might lead to additional perceptions or definitions of success – which could influence the evaluation.

In view of these differences in definition, it must be concludedthat the "success" of a DNT is a relative term, made up of various aspects and depths of success definitions, the selection of which depends strongly on the evaluation perspective. This insight is decisive for the evaluation of a DNT because it should always be reflected for whom and from which perspective an evaluation is conducted and what is considered as successful.

Strengths and weaknesses of the frameworks

The strengths and weaknesses analysis process in this article identified framework components where more guidance would be beneficial, and which are important to consider when selecting a DNT evaluation framework. The assessment included the focus of a framework, the illustration, terminology, instructions for use and scientific quality. The strengths and weaknesses criteria were created especially for DNT evaluation frameworks although there are other quality criteria that could be applied from other healthcare fields. For example, Bradford et al. (2019) [39] provide 6 quality criteria for frameworks, most of which are similar to the criteria in this article. Bradford et al. also suggest assessing whether the frameworks help to identify and include stakeholders as well as mechanisms that drive or inhibit change – which might be also helpful selecting a framework.

The results of the framework assessment presented in this article need to be seen in a wider context. The evaluation was carried out with a view to assessing of perceived strengths and weaknesses in general. Several aspects mighthave been rated differently in other contexts, e.g., assessing the transferability of a framework to only onespecific context, as with the Health Technology Adoption Framework [33] and the CISSM [21] as a strength or a weakness depends on the viewpoint of the planned evaluation. If the context is surgical the Health Technology Adoption Framework might be the perfect choice, although it is not transferable to other contexts.

By showing and applying assessment possibilities for DNT frameworks this article gives guidance for the selection of appropriate DNT evaluation frameworks. An assessment of strengths and weaknesses in combination with the other important information presented in this article is crucial.

Discussion of the three most relevant frameworks

This section describes the three highest rated frameworks of the strengths and weakness analysis in more detail in order to give researchers insights into the analytical dimensions described in this article. The complete data for all frameworks are summarized in Tables 4–7. The description is written in an application-oriented way to support researchers. Problematic aspects in the selection of DNT frameworks are also discussed.

Framework 1: health technology adoption framework [33]

The Health Technology Adoption Framework shows validated criteria for assessing new health technologies for adoption at local level with a hospital focus in the surgical context. It is developed generically with respect to the technology to be assessed and can therefore be applied to several DNTs.

The evaluation categories presented focus on the product/technology, its objective value/effect in the adoption process, the evaluation of organizational aspects as well as economic and strategic aspects with respect to the (potential) adoption process. Individual, societal, ethical and aspects of the area "focus" are not covered. This distribution of the aspects considered could be related to the fact that the framework was developed from the perspective of the healthcare organization and is intended to help decision makers (e.g., nurse managers) to evaluate the suitability of new technologies as well as to facilitate smooth adoption from the perspective of the organization. This means that while aspects such as security, costs and strategic fit in the organization are considered, individual aspects like usability or acceptance are not. The Health Technology Adoption Framework covers more evaluation areas ($n = 5$) than the other three frameworks in this study with a health organization perspective (see Table 7). Overall, however, all frameworks with this perspective cover fewer areas than those with a universal perspective. This limitation regarding the evaluation areas should always be considered, when deciding on a framework.

The Health Technology Adoption Framework performs very well in the framework quality assessment. The descriptions and definitions are accurate and complete. An evaluation tool with appropriate evaluation categories, an application strategy, relevant questions, and a scoring logic is provided. The development process of the framework is also presented transparently, and the corresponding limitations are named in the article. Only the transferability to other settings is limited and there is no visual presentation of the framework. It is displayed in a table and not as a graphic. Overall, the Health Technology Adoption Framework provides a very good evaluation basis with valid assessment criteria.

Framework 2: clinical information systems success model (CISSM) [21]

The CISSM framework is designed to assess the success of clinical information systems (CIS) from the nurses' perspective. The framework is suitable for all DNTs from the CIS category in the hospital setting. CISSM focusses only on a specific selection of evaluation areas: product/technology, objective value/ effect, individual aspects, and aspects of the healthcare organization. The societal, ethical, economic and strategic aspects are not considered.

Compared to the second framework with the nurses' perspective from this study (Adapted nursing care performance framework) [30], the CISSM covers two more evaluation areas. The Adapted nursing care performance framework [30] only covers the areas of the objective value/ effect and individual aspects of technology. By comparison, CISSM is the more comprehensive framework - but overall, both cover only a few of the possible evaluation areas. It is certainly critical that none of the two frameworks covers ethical aspects. This should be considered when selecting and applying them, as the ethical aspects are also important in this context. Additional ethical evaluation criteria from other frameworks could be added to fill this gap.

When selecting a framework with such a narrow perspective it should be borne in mind that aspects of the "bigger picture" might not be depicted. The specific success definition of a technology in this framework focusses solely on the nurses' net benefit. Success in this case is the "degree to which a nurse believes that using a particular system enhances job performance". This makes the CISSM framework particularly suitable for use when the nurses' perspective is the object of research. If a broader spectrum of evaluation aspects is to be researched, then this framework would not be the right choice.

At the same time, however, the framework scores very well in the strengths and weaknesses assessment for this specific perspective. It has a very clear description of purpose, target setting, and technology addressed. It is very well illustrated, and the connections are visualized. The key concepts and terms a are completely defined. A procedure and evaluation matrix are provided as well as examples for the interpretation of an evaluation. The development process was fully explained.

The main shortcoming of the article on this framework is that no explanation is given about its limitations. Overall, the CISSM framework is a good basis to assess the success of clinical information systems (CIS) from the nurses' perspective and the article provides a good basis and example for the methodology.

Framework 3: nonadoption, abandonment, scale-up, spread, and sustainability framework (NASSS framework) [34]

The Nonadoption, Abandonment, Scale-up, Spread, and Sustainability Framework (NASSS) was designed to help predict and evaluate the success of health and care technologies and to support the design, development, implementation, scale up, spread, and sustainability of technology-supported health or social care programs by identifying key challenges in different domains and the interactions between them. As the description shows, this is the most comprehensive and generic framework of the three described. The framework does not focus on any specific technology or setting which makes it suitable for any DNT. The comprehensiveness of the framework is also reflected in the included evaluation aspects. The framework considers aspects of the focus, product/ technology, objective value/ effect, individual aspects, aspects of the organization, societal aspects, and economic aspects – which makes it a compendium of evaluation options for DNTs. Only the ethics and strategic aspects as defined in this review are not covered by the NASSS Framework. Thus, among all the frameworks covered in this study, the NASSS framework is one that covers the most evaluation areas.

A special feature of this framework is that it addresses the issue of complexity. It categorizes the interpretation of the evaluation domains as simple, complicated, or complex. The level of complexity of each evaluation aspect is seen as the greatest challenge to scale-up, spread, and sustainability. No specific evaluation perspective is given, which makes it a universally applicable framework. However, this universality is also accompanied by a limitation. As no specific setting, technology or perspective is given, the researcher using it must always reflect on the individual application strategy. The NASSS Framework is not a directly applicable or formulaic instrument, which is reflected by the authors of the framework themselves. Specific additional tools to solve this problem have been published recently [43].

Apart from this, the NASSS framework scores very well in the strengths and weaknesses assessment.

Looking at all three frameworks in comparison, the question arises whether a framework with a specific perspective is always preferable to a universal framework. This question can only be answered on a case-by-case basis when assessing the fit of a framework to the research situation.

Limitations of the article

It is important to discuss the limitations of such an extensive procedure as described in this article. A three-component search process was chosen for this article., namely (1) a Systematic search in PubMed, (2) a narrative search in Google Scholar and reference lists, (3) expert consultations. Additional databases could have been systematically searched. Experience from previous systematic search processes in such complex fields has shown that a combination of systematic searches and other methods is a good way to identify relevant articles [4]. However, with such a search procedure there is always a chance that something is left undiscovered. There is also a limitation associated with a single researcher conducting a study that may have affected the search and analysis process. Single studies with frameworks might have been overlooked [44] or specific biases in interpretation could have occurred in the analysis process [12]. These limitations were sought to be minimised through expert workshops and consultations to identify relevant frameworks and discuss the methodology and the analysis process of this article. Also, the exclusion criteria were very strict. Only literature published in the English language was included. The DNT related criteria were based on the knowledge of Krick et al. 2019 [2] and Krick et al. 2020 [4] but still led to a heterogeneity of frameworks due to the broadness of the field.

Only comprehensive, technology related frameworks were included, which ruled out many specific frameworks that could potentially also have been included. Frameworks focussing exclusively on special fields like health economics or acceptance could have been included, because they are certainly relevant for DNT, but were excluded due to their specificity and the large number of different frameworks available. Generalistic evaluation frameworks for (complex) healthcare interventions like the Consolidated Framework for Implementation Research (CFIR) [45] or on HTA Frameworks could have also been included (e.g. Integrate HTA [46]) – but it was necessary to limit the included frameworks to allow statements on this specific field of research.

The framework analysis itself has further limitations. Due to the heterogeneity of the frameworks and the difference in their content the categories and the assignment of the framework content to these categories is subjective. Even though the process of evaluation and classification was carried out with the utmost care, a non-overlapping categorization of these categories was not possible due to the complexity of the frameworks content and the interconnectedness of different categories. There are overlaps between the category of technology and individual as well as ethical and societal aspects. It should also be considered that the generalized statements made in this article can only provide initial indications in this specific field. No statistical analysis was carried out, but a qualitative and hypothesis-generating analysis. Despite these limitations, this article makes an important contribution to further research in the field of DNT evaluation.

Conclusion

This research article provides orientation in the complex field of DNT evaluation. Eighteen relevant comprehensive evaluation frameworks for DNT have been identified. These frameworks focussed on different purposes and included various evaluation perspectives. The analysis and mapping in this article provide a good overview of the frameworks under consideration, their similarities and differences, evaluation areas, success definitions, strengths, and weaknesses. The assessment whether a DNT evaluation framework is good should be based on the clarity of the description of these aspects and the fulfilment of the quality criteria described.

The information on DNT evaluation frameworks provided in this review can therefore help in communication between decision makers and researchers to improve the evaluation process [11], by providing systematic information and a structure for the evaluation of a DNT. This can facilitate system implementation or provide helpful information in the technology development process. Comprehensive evaluation has the potential to avoid early system failures, prevent wrong investment decisions [10] or contribute to the development and implementation of better, more useful DNTs from a societal perspective. The general question what evaluation frameworks can contribute to this process should be further analyzed. The diversity and heterogeneity of frameworks presented in this article shows, that there is not one sole definition of the term "evaluation framework" in the field of DNT. The question of what constitutes a good DNT framework could also be further explored taking the criteria developed in this article as a starting point.

Future research could also address questions regarding what makes a successful DNT. The definition of a "successful" DNT, the role of the evaluation perspective and the purpose of the evaluation should be discussed when analyzing this question.

Overall, evaluators can use the concise information and quality criteria of this article as a starting point to select DNT evaluation frameworks for their research projects or to assess the quality of an evaluation framework for DNT, as well as a basis for exploring the open research questions raised.

Abbreviations

CFIR: Consolidated Framework for Implementation Research; CIS: Clinical Information Systems; CISSM: Clinical Information Systems Success Model; DHI: Digital Health Interventions; DIPSA: Development of an Evaluation Framework for Health Information Systems; DNT: Digital nursing technologies; EHR: Electronic Health Records; HIS: Health Information System; HTA: Health Technology Assessment; HITREF: Health Information Technology Evaluation Framework; HOPT-FIT: Human, Organization, Process and Technology-fit; IS: Information System; ICT: Information and Communication Technology; IHIS: Integrated Health Information Systems; MAST: Model for Assessment of Telemedicine; mHealth: Mobile health; NASSS: Nonadoption, abandonment, scale-up, spread, and sustainability; NCPF: Nursing care performance framework; RE-AIM: Reach, Effectiveness, Adoption, Implementation, and Maintenance

Supplementary Information

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Additional file 1. Framework Analysis.
Additional file 2. Evaluation Areas.
Additional file 3. Detailed strength and weakness analysis.

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Author's contributions

TK conceptualized and conducted the study. The author authorized the final version of the manuscript that was submitted. The author read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are included in this published article and the Additional files.

Declarations

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There are no competing interests to declare.

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References

1. Huter K, Krick T, Domhoff D, Seibert K, Wolf-Ostermann K, Rothgang H. Effectiveness of digital technologies to support nursing care: results of a scoping review. J Multidiscip Healthc. 2020;13:1905–26. https://doi.org/10.2147/JMDH.S286193.
2. Krick T, Huter K, Domhoff D, Schmidt A, Rothgang H, Wolf-Ostermann K. Digital technology and nursing care: a scoping review on acceptance, effectiveness and efficiency studies of informal and formal care technologies. BMC Health Serv Res. 2019;19(400).
3. Isfort M, Rottländer R, Weidner F, Tucman D, Gehlen D, Hylla J. Pflege-thermometer. Eine bundesweite Befragung von Leitungskräften zur situation der Pflege und Patientenversorgung in der ambulanten Pflege. Köln: Deutsches Institut für angewandte Pflegeforschung e.V. (dip); 2016.
4. Krick T, Huter K, Seibert K, Domhoff D, Wolf-Ostermann K. Measuring the effectiveness of digital nursing technologies: development of a comprehensive digital nursing technology outcome framework based on a scoping review. BMC Health Serv Res. 2020;20(1):243. https://doi.org/10.1186/s12913-020-05106-8.
5. Seibert K, Domhoff D, Huter K, Krick T, Rothgang H, Wolf-Ostermann K. Application of digital technologies in nursing practice: results of a mixed methods study on nurses' experiences, needs and perspectives. *Zeitschrift fur Evidenz, Fortbildung und Qualitat im Gesundheitswesen*; 2020.
6. Alexander GL, Madsen RW, Miller EL, Schaumberg MK, Holm AE, Alexander RL, et al. A national report of nursing home information technology: year 1 results. J Am Med Inform Assoc. 2017;24(1):67–73. https://doi.org/10.1093/jamia/ocw051.
7. Merda M, Schmidt K, Kähler B. Pflege 4.0 – Einsatz moderner Technologien aus der Sicht professionell Pflegender. Forschungsbericht. Hamburg: Berufsgenossenschaft für Gesundheitsdienst und Wohlfahrtspflege (BGW); 2017.
8. Craig P, Petticrew M. Developing and evaluating complex interventions: reflections on the 2008 MRC guidance. Int J Nurs Stud. 2013;50(5):585–7. https://doi.org/10.1016/j.ijnurstu.2012.09.009.
9. Alaiad A, Zhou L. Patients' adoption of WSN-based smart home healthcare systems: an integrated model of facilitators and barriers. IEEE Trans Prof Commun. 2017;60(1):4–23. https://doi.org/10.1109/TPC.2016.2632822.
10. Currie LM. Evaluation frameworks for nursing informatics. Int J Med Inform. 2005;74(11–12):908–16. https://doi.org/10.1016/j.ijmedinf.2005.07.007.
11. Fynn JF, Hardeman W, Milton K, Jones AP. A scoping review of evaluation frameworks and their applicability to real-world physical activity and dietary change programme evaluation. BMC Public Health. 2020;20(1):1000. https://doi.org/10.1186/s12889-020-09062-0.
12. Grant MJ, Booth A. A typology of reviews: an analysis of 14 review types and associated methodologies. Health Inf Libr J. 2009;26(2):91–108. https://doi.org/10.1111/j.1471-1842.2009.00848.x.
13. Boll S, Hein A, Heuten W, Wolf-Ostermann K: Grußwort der Organisatoren. In: *Zukunft der Pflege Tagungsband der 1 Clusterkonferenz* 2018 *"innovative Technologien für die Pflege"*. Edn. Edited by Boll S, Hein a, Heuten W, Wolf-Ostermann K. Oldenburg: OFFIS - Institut für Informatik; 2018: iii-iv.
14. Kowatsch T, Otto L, Harperink S, Cotti A, Schlieter H: A design and evaluation framework for digital health interventions. *it - Information Technology* 2019;61(5-6):253–63.
15. Vonville H: Screening titles/abstracts, reviewing full text, and reporting results. In: *142nd APHA Annual Meeting and Exposition* 2014. New Orleans; 2014.
16. Greenhalgh T, Peacock R. Effectiveness and efficiency of search methods in systematicreviews of complex evidence: audit of primary sources. BMJ. 2005;331(7524):1064–5. https://doi.org/10.1136/bmj.38636.593461.68.
17. Mandelblatt JS, Ramsey SD, Lieu TA, Phelps CE. Evaluating frameworks that provide value measures for health care interventions. Value Health. 2017;20(2):185–92. https://doi.org/10.1016/j.jval.2016.11.013.
18. Barnett-Page E, Thomas J. Methods for the synthesis of qualitative research: a critical review. BMC Med Res Methodol. 2009;9(1):59. https://doi.org/10.1186/1471-2288-9-59.
19. Coravos A, Doerr M, Goldsack J, Manta C, Shervey M, Woods B, et al. Modernizing and designing evaluation frameworks for connected sensor technologies in medicine. Npj Digital Medicine. 2020;3(1):37.
20. Haverinen J, Keränen N, Falkenbach P, Maijala A, Kolehmainen T, Reponen J: Digi-HTA: health technology assessment framework for digital healthcare services. Finnish Journal of eHealth and eWelfare. 2019;11(4):326–41.
21. Garcia-Smith D, Effken JA. Development and initial evaluation of the clinical information systems success model (CISSM). Int J Med Inform. 2013;82(6):539–52. https://doi.org/10.1016/j.ijmedinf.2013.01.011.
22. Khoja S, Durrani H, Scott RE, Sajwani A, Piryani U. Conceptual framework for development of comprehensive e-health evaluation tool. Telemed J E Health. 2013;19(1):48–53. https://doi.org/10.1089/tmj.2012.0073.
23. Broens T, Veld R, Vollenbroek - Hutten M, Hermens H, Halteren A, Nieuwenhuis B. Determinants of successful telemedicine implementations: a literature study. J Telemed Telecare. 2007;13(6):303–9. https://doi.org/10.1258/135763307781644951.

24. Chang H. Evaluation framework for telemedicine using the logical framework approach and a fishbone diagram. Healthcare informatics research. 2015;21(4):230–8. https://doi.org/10.4258/hir.2015.21.4.230.
25. Lau F, Hagens S, Muttitt S. A proposed benefits evaluation framework for health information systems in Canada. Healthcare Quarterly. 2007;10(1):112–6.
26. Sockolow PS, Crawford PR, Lehmann HP. Health services research evaluation principles. Broadening a general framework for evaluating health information technology. Methods Inf Med. 2012;51(2):122–30. https://doi.org/10.3414/ME10-01-0066.
27. Sadoughi F, Kimiafar K, Ahmadi M, Shakeri MT. Determining of factors influencing the success and failure of hospital information system and their evaluation methods: a systematic review. Iran Red Crescent Med J. 2013;15(12):e11716.
28. Stylianides A, Mantas J, Roupa Z, Yamasaki EN. Development of an evaluation framework for health information systems (DIPSA). Acta Inform Med. 2018;26(4):230–4. https://doi.org/10.5455/aim.2018.26.230-234.
29. Yusof MM. A socio-technical and lean approach towards a framework for health information systems-induced error. Stud Health Technol Inform. 2019;257:508–12.
30. Rouleau G, Gagnon MP, Côté J, Payne-Gagnon J, Hudson E, Dubois CA. Impact of information and communication technologies on nursing care: results of an overview of systematic reviews. J Med Internet Res. 2017;19(4):e122.
31. Kidholm K, Bowes A, Dyrehauge S, Ekeland AG, Flottorp SA, Jensen LK, Pedersen CD, Rasmussen J: The MAST Manual. MAST - Model for ASsessment of Telemedicine. In.: MethoTelemed team; 2010.
32. Mathews SC, McShea MJ, Hanley CL, Ravitz A, Labrique AB, Cohen AB. Digital health: a path to validation. NPJ Digit Med. 2019;2(1):38. https://doi.org/10.1038/s41746-019-0111-3.
33. Poulin P, Austen L, Scott CM, Waddell CD, Dixon E, Poulin M, et al. Multi-criteria development and incorporation into decision tools for health technology adoption. J Health Organ Manag. 2013;27(2):246–65. https://doi.org/10.1108/14777261311321806.
34. Greenhalgh T, Wherton J, Papoutsi C, Lynch J, Hughes G, A'Court C, et al. Beyond adoption: a new framework for theorizing and evaluating nonadoption, abandonment, and challenges to the scale-up, spread, and sustainability of health and care technologies. J Med Internet Res. 2017;19(11):e367. https://doi.org/10.2196/jmir.8775.
35. Bakken S, Ruland CM. Translating clinical informatics interventions into routine clinical care: how can the RE-AIM framework help? J Am Med Inform Assoc. 2009;16(6):889–97. https://doi.org/10.1197/jamia.M3085.
36. Van Der Meijden MJ, Tange HJ, Troost J, Hasman A. Determinants of success of inpatient clinical information systems: a literature review. J Am Med Inform Assoc. 2003;10(3):235–43. https://doi.org/10.1197/jamia.M1094.
37. Yusof MM, Papazafeiropoulou A, Paul RJ, Stergioulas LK. Investigating evaluation frameworks for health information systems. Int J Med Inform. 2008;77(6):377–85. https://doi.org/10.1016/j.ijmedinf.2007.08.004.
38. Vis C, Bührmann L, Riper H, Ossebaard HC. Health technology assessment frameworks for eHealth: a systematic review. Int J Technol Assess Health Care. 2020;36(3):204–16. https://doi.org/10.1017/S026646232000015X.
39. Bradford N, Chambers S, Hudson A, Jauncey-Cooke J, Penny R, Windsor C, et al. Evaluation frameworks in health services: an integrative review of use, attributes and elements. J Clin Nurs. 2019;28(13–14):2486–98. https://doi.org/10.1111/jocn.14842.
40. Nguyen H, Saranto K, Tapanainen T, Ishmatova D. A review of health information technology implementation success factors: importance of regulation and finance; 2014.
41. Lau F. Extending the infoway benefits evaluation framework for health information systems. Stud Health Technol Inform. 2009;143:406–13.
42. McNair J, Ammenwerth E, Nykänen P, Talmon J. Factors influencing success and failure of health informatics systems: a pilot Delphi study. Methods Inf Med. 2006;45:125–36.
43. Greenhalgh T, Maylor H, Shaw S, Wherton J, Papoutsi C, Betton V, Nelissen N, Gremyr A, Rushforth A, Koshkouei M, Taylor J. The NASSS-CAT Tools for Understanding, Guiding, Monitoring, and Researching Technology Implementation Projects in Health and Social Care: Protocol for an Evaluation Study in Real-World Settings. JMIR Res Protoc. 2020;9(5):e16861. https://doi.org/10.2196/16861.
44. Waffenschmidt S, Knelangen M, Sieben W, Bühn S, Pieper D. Single screening versus conventional double screening for study selection in systematic reviews: a methodological systematic review. BMC Med Res Methodol. 2019;19(1):132. https://doi.org/10.1186/s12874-019-0782-0.
45. Damschroder LJ, Aron DC, Keith RE, Kirsh SR, Alexander JA, Lowery JC. Fostering implementation of health services research findings into practice: a consolidated framework for advancing implementation science. Implement Sci. 2009;4(1):50. https://doi.org/10.1186/1748-5908-4-50.
46. Wahlster P, Brereton L, Burns J, Hofmann B, Mozygemba K, Oortwijn W, Pfadenhauer L, Polus S, Rehfuess E, Schilling I et al: Guidance on the integrated assessment of complex health technologies – the INTEGRATE-HTA model. 2016.

Publisher's Note

Additional File 1: Framework Analysis

Framework	Top Category	Subcategories	Specification
Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS) [1]	Condition	• Nature of condition or illness	• What is the nature of the condition or illness?
		• Comorbidities, sociocultural influences	• What are the relevant sociocultural factors and comorbidities?
	Technology	• Material features	• What are the key features of the technology?
		• Type of data generated	• What kind of knowledge does the technology bring into play?
		• Knowledge needed to use	• What knowledge and/or support is required to use the technology?
		• Technology supply model	• What is the technology supply model?
	Value Proposition	• Supply-side value (to developer)	• What is the developer's business case for the technology (supply-side value)?
		• Demand-side value (to patient)	• What is its desirability, efficacy, safety, and cost effectiveness (demand-side value)?
	Adopters	• Staff (role, identity)	• What changes in staff roles, practices, and identities are implied?
		• Patient (simple vs complex input)	• What is expected of the patient (and/or immediate caregiver)—and is this achievable by, and acceptable to, them?
		• Carers (available nature of input)	• What is assumed about the ex- tended network of lay caregivers?
	Organisation	• Capacity to innovate (leadership etc.)	• What is the organisation's capacity to innovate?
		• Readiness for this technology (change)	• How ready is the organisation for this technology-supported change?
		• Nature of adoption/ Funding decision	• How easy will the adoption and funding decision be?
		• Extend of change needed to routines	• What changes will be needed in team interactions and routines?
		• Work needed to implement change	• What work is involved in implementation and who will do it?
	Wider System	• Political/ policy • Regulatory/ legal	• What is the political, economic, regulatory, professional (eg,

		• Professional • Socio-cultural	medicolegal), and sociocultural context for program rollout?
	Embedding and adaption over time	• Scope for adaption over time	• How much scope is there for adapting and coevolving the technology and the service over time?
		• Organisational resilience	• How resilient is the organisation to handling critical events and adapting to unforeseen eventualities?
Model for Assessment of Telemedicine (MAST Manual) [2]	Preceding consideration	• Purpose of the telemedicine application? • Relevant alternatives? • International, national, regional or local level of assessment? • Maturity of the application	
	Health problem and characteristics of the application	• Health problem	• Definition of target condition/disease • Symptoms, consequences • Number of patients (epidemiology) • Burden of disease, resource use • Current management of health condition • Existing quality standards • Relations to other conditions or treatments. (Does the service have implications for treatment of competing disease) • Change in patient segments (will the service increase or decrease the group of patients who can benefit from or will get the service offered)
		• Description of the application	• Features of the application • Tools required for using the application • Training and information needed for utilizing the application (staff and patients) • Maturity of the telemedicine application (life cycle) • Division of responsibility for the technical solution between involved organisations. • Regulatory status • Technical platform • Market situation
		• Technical characteristics	• Infrastructure requirements • Interoperability: Integration needs (EPR, devices, with current

		applications, technical standards etc.) • Technical support • Technical environment • Standard situation • User support • Back-up systems and procedures
Safety	• Clinical safety (patients and staff)	• What are the direct or indirect harms when using the telemedicine application? • What is the scope of the harms? • What are the types of harms? • Are there estimates of incidence of harms? • What is the timing of onset of harms? • What is the duration and severity of the harms? • What can be done to minimise the harms?
	• Technical safety (technical reliability)	• Is there a backup system and how does it work? • What do the Service Level Agreements cover? • Does the technology experience interference and what are the consequences? • How is the safety compared to alternative technologies? • How is security of data and the database (data privacy) and quality of data managed? - encryption/cryptography - data storage and ownership - data ownership
Clinical effectiveness	• Effects on mortality • Effects on morbidity • Physical health • Mental health • Effects on health related quality of life (HRQL) • Behavioural outcomes (e.g. exercise) • Utilization of health services	
Patient perspectives	• Satisfaction and acceptance • Understanding of information • Confidence (in the treatment) • Ability to use the application • Access and accessibility • Empowerment, self-efficacy	

Economic aspects	• Economic evaluation (societal perspective)	• Amounts of resources used when delivering the assessed telemedicine application and its comparators in the health care sector and other sectors (e.g.): - Investments in equipment - Training of staff - Maintenance • Unit costs or prices for each resource used • Related changes in use of health care resources (e.g.): - Primary care - Emergency unit
	• Business case (institutional level)	• Expenditures per year (including expenditures related to the resource use described in the cost estimation above) • Revenue per year: - Activity (number of patients or services) - Reimbursement (e.g. DRG-rate) per service or patient
	• Sensitivity analysis (Risk analysis)	
Organisational aspects	• Process	• Workflow • Staff, training and resources • Interaction and communication
	• Structure	• Spread of technology, centralization or decentralization • Economy (see domain on economic aspects)
	• Culture • Management	• Attitude and culture
Socio-cultural, ethical and legal aspects	• Ethical issues	• Overall questions: Does the application challenge religious, cultural or moral beliefs? • Potential ethical problems, e.g. giving the responsibility to the Patients • Autonomy: Is the patient's autonomy challenged or increased? • Equity
	• Legal issues	• Clinical accreditation • Information governance • Professional liability

		• Social issues	• Patient control – consent, access • Changes in the patients role in major life areas (e.g. social life, working life) • Patients' relatives and others' understanding of the technology • Societal, political context and changes. Will the service influences the general model for the delivery of healthcare service if deployed • Changes in responsibility. Are the patients and/or relatives capable of handling their responsibility? • Gender issues. Has the service any consequences on the position of gender?
	Transferability Assessment	• Cross-border • Scalability • Generalizability	
Infoway benefits evaluation Framework [3]	System Quality	• Functionality • Performance • Security	• Type of feature and level of decision support • Accessibility (distance and availability) reliability (down time, system response time) • Type of features
	Information Quality	• Content • Availability	• Completeness, accuracy, relevance, comprehension • Timeliness, reliability and consistency of information when and where needed
	Service Quality	• Responsiveness	• User training, ongoing technical support and availability of support
	Use	• Use/behaviour pattern • Self-reported use • Intention to use	• Frequency, duration, location, type or nature and flexibility of actual usage • Frequency, duration, location, type or nature and flexibility of perceived usage • Proportion of and factors for current non-user to become user
	User Satisfaction	• Competency • User Satisfaction • Ease of use	• Knowledge, skills and experience • Perceived expectations, value, information/system/service quality and use of the system (including provider – patient interaction, preference, comfort and experience) • User friendliness and learnability
	Net Benefits	• Quality	• Patient Safety

		• Access	• Appropriateness/effectiveness • Health outcomes
			• Ability of patient/provider to access service • Patient and caregiver participation
		• Productivity	• Efficiency • Care coordination • Net Cost
	Organisational Context Factors	• Strategy • Culture • Business Process	
Health Information Technology Evaluation Framework (HITREF) [4]	Structural Quality	• Organizational Support/ Capacity • Hardware • Software • Functionality	
	Quality of Information Logistics	• Completeness/ Correctness of data • Costs of information processing • User satisfaction • Patient privacy • Patient satisfaction with HIT • Diffusion	
	Unintended Consequences/ Benefits	• Unintended Consequences/ Benefits	
	Effects on Outcome Quality of Care	• Patient outcome • Costs of patient care • Patient satisfaction with care • Patient related knowledge	
	Effects on Quality Processes	• Efficiency • Appropriateness of patient care • Organizational or social Quality • Clinical involvement in HIT Selection, Implementation, Training	
	Barriers or Facilitators to Adoption	• Barriers or Facilitators to Adoption	
Evaluation Framework for Fit-For-Purpose Connected Sensor Technologies [5]	Verification, analytical validation, and clinical validation		• Does the tool measure what it claims to measure? • Is the measurement appropriate for the target population?
	Security practices		• Does the manufacturer build with safety by design? Is there a disclosure policy? Software bill of materials?
	Data rights and governance		• Who has access to the data and when? Is the privacy policy publicly accessible?
	Utility and usability		• How is the tool worn? Battery life? Available technical support?

	Economic feasibility		• What's the net benefit vs price? Is cost a one-time or a subscription model?
RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance.) (expanded to clinical informatics) [6]			
	Reach (individual level)	• Absolute number • proportion • representativeness of individuals who are willing to participate in a given initiative, intervention, or program	• What percentage of the target population came into contact with or began program? • Did program reach those most in need? • Were participants representative of your practice setting?
	Efficacy/effectiveness (individual level)	Impact of an intervention on: • Important outcomes • Potential negative effects • Quality of life • Economic outcomes	• Did program achieve key targeted outcomes? • Did it produce unintended adverse consequences? • How did it affect quality of life? • What did the program cost as implemented and what would it cost in your setting?
	Adoption (setting and/or organizational level)	• Absolute number • proportion, • representativeness of settings and intervention agents (people who deliver the program) who are willing to initiate a program	• Did low-resource organizations serving high-risk populations use it? • Did program help the organization address its primary mission? • Is program consistent with your values and priorities?
	Implementation (setting and/or organizational level)	Intervention agents' fidelity to the various elements of an intervention's protocol, including consistency of delivery as intended and the time and cost of the intervention; individual level—clients' use of the intervention strategies	• How many staff members delivered? • Did different levels of staff implement the program successfully? • Were different program components delivered as intended?
	Maintenance (individual and setting and/or organizational levels)	Extent to which a program or policy becomes institutionalized or part of the routine organizational practices and policies; individual level—long-term effects of a program on outcomes for 6 or more month after the most recent intervention contact	• Did program produce lasting effects at individual level? • Did organizations sustain the program over time? • How did the program evolve? • Did those persons and settings that showed maintenance include those most in need?
Adapted nursing care performance framework [7]	Acquiring, Deploying, and Maintaining Resources	• Time and Efficiency	• Time Management • Time Spent for Patient Care • Documentation Time
	Transforming Resources into Services	• Nurses' Practice Environment	• Knowledge Updating and Utilization • Information Quality and Access • Nurse Autonomy

			• Intra- and Interprofessional Collaboration
		• Nursing Processes	• Nurses’ Competencies and Skills • Quality of Documentation • Nurse-Patient Relationship • Assessment, Care Planning, and Evaluation • Teaching of Patients and Families • Communication and Care Coordination
		• Professional Satisfaction	• Nurses’ Perspectives of the Quality of Care Provided • Satisfaction or Dissatisfaction of Nurses Using ICTs
	Producing Changes in Patients’ Condition	• Nursing-Sensitive Outcomes	• Patient Comfort and Quality of Life Related to Care • Empowerment • Functional Status • Satisfaction or Dissatisfaction of Patients of Using ICTs
Design and Evaluation of DHI Framework)[8]	Ease of use		• The degree to which effort is required to take advantage of the DHI (e. g., using common interaction paradigms).
	Content Quality		• The degree to which the content of a DHI is accurate, timely, complete, relevant, and consistent (e. g., real-time location-based pollen warnings for asthmatics)
	Privacy & security		• The degree to which the DHI considers legal requirements and aspects with respect to privacy and security aspects (e. g., a DHI is compliant with the General Data Protection Regulation).
	Accountability		• The degree to which information about the DHI is made explicit for usage decisions (e. g., details of the intervention author of a DHI are accessible).
	Adherence		• The ratio of actual usage to intended usage

		of a DHI (e. g., 4 out of 5 exercises are conducted per week).
	Aesthetics	• The degree to which the DHI interface applies design elements, colors and fonts in a logical way (e. g., consistent use of colors, figures and fonts).
	Perceived benefit	• The degree to which a person believes that using a DHI improves his or her health behavior/health condition (e. g., a believe that a DHI helps to increase physical activity)
	Effectiveness	• The degree to which the DHI contributes to the enhancement of an individual's health behavior/condition (e. g., significant reduction of fat mass).
	Service Quality	• The extent to which support of a DHI is provided (e. g., a technical support line is made available).
	Personalization	• The degree to which the DHI adapts to the needs of an individual (e. g., the daily step goal of a DHI adapts to the capabilities of an individual).
	Perceived enjoyment	• The degree to which an individual believes that using a DHI is engaging (e. g., the use of game elements and level designs in a DHI).
	Ethics	• The degree to which the DHI addresses ethical aspects (e. g., the DHI was designed for individuals with various cultural backgrounds or disabilities).
	Safety	• The extent to which the usage of a DHI is safe with respect to side effects (e. g., interactions with a DHI are limited to account for addiction behavior
Health technology assessment framework for digital healthcare services (Digi HTA) [9]	Company information	• Contact information of company. • What is the company's business model?

	• Are quality management systems in use? Which ones?
Product information	• The name of the product. • Short description of the product. • What is the product's readiness level (TRL levels 1–9)? • Which platforms and platform versions of the product are available? • Does the product have CE and/or FDA approval? • Is the product a medical device, and what classification does it have? • Is the product classified according to MDD or MDR requirements? • Does the product meet the electrical safety requirements for medical devices (if applicable)? • Does the use of the product require registration or login? • Does the use of the product require strong identification? • Does the company have any plans for post-market surveillance of the product? • What kind of product support does the company offer? • What is the intended use of the product? • What are the intended user groups? • What problem in the healthcare system is the product trying to solve? • Is the aim of the product to replace any existing healthcare services? • Does the introduction of the product cause any changes to the premises, information systems, or care processes? • Is the product already in use elsewhere in Finland or worldwide? • Where, and for how long? • What kind of support does the end user need to use the product? • If users need training, who organizes it? When? What is the language of training? • Does the company have instructions (e.g., a project plan) for healthcare service

	providers to ensure fluent introduction of the product?
Technical stability	• What is the company's testing process? • What is the company's process for handling error messages? • Does the company have the capacity to roll back to previous versions of the product? • Does the company have a process to proactively monitor the running of systems and system components to automatically identify faults and technical issues? • Does the company have a plan for decommissioning the product? • Has there been any downtime or impairment time in the use of the product during the last six months?
Cost	• What are the costs of using the product for a healthcare customer? • If the use of the product is free, what is the source of the company's income? • What kind of initial costs (estimated minimum and maximum values in detail) does the introduction of the product impose on the organization, including changes to buildings or facilities, a need for new devices and software, as well as needed training? • What are the maintenance costs (estimated minimum and maximum values) to the organization for the use of the product? • How often must devices or software versions related to the product be renewed? • Which uncertainties apply to these cost estimates?
Effectiveness	• Does the product provide clinical benefits? What are they? • Does the product provide benefits to the end users by improving their behavior related to their own health? How so?

	• Does the product provide benefits to the organization (like improving care processes)? How so? • What kind of evidence is available for effectiveness (case studies, randomized controlled trials, Cochrane reviews, etc.)? • Are there any ongoing studies to investigate the product's effectiveness? • Does any institution like the Duodecim Current Care Guidelines recommend the use of the product?
Clinical Safety	• Are there any risks, possible side effects, or other undesirable effects associated with using the product? • Is there any research evidence available related to clinical safety? • Have any product-related adverse events been reported or identified? • What is the company's process to handle adverse events? • Has the product undergone a risk analysis? • Are there any undesirable effects associated with misuse of the product? • Are the error conditions of guidelines removed, or is their realization unlikely? • Is the company aware of the product register and Manufacturer Incident Report supervised by the National Supervisory Authority of Welfare and Health? • Who is the responsible person in the company for handling Manufacturer Incident Reports?
Data security and protection	• Data Security and Protection Preliminary Task • Information Security and Data Protection Requirements
Usability and accessibility	• Have all user groups been taken into account in product design, like people with visual or hearing impairments?

	• Has the product been tested with real user groups? • What kind of accessibility testing has been performed on the product? • Has the functionality of the product been tested with screen readers or other assistive technol-ogies? • How have the product's users been taken into account in the product's text (clear, concrete language; the avoidance of professional language)? • How have the product's users been taken into account in the design of its textual content (headings, lists, and images)? • How does the company continue to collect feedback from users and make changes to the product based on this feedback? • What changes have been made to the product based on user feedback? • How is the company going to continue to evaluate and develop accessibility? • Is the product compatible with the following ty guidelines (if applicable)? WCAG 2.0/ WCAG 2.1 Papunet Design Guide for Websites EN 301 549 section 11-Software Design guidelines for native application Design guidelines for progressive web application • Does the application support OS accessibility features?
Interoperabilty	• Does the product have interfaces into the website or other software? • Does the product have interfaces into the following healthcare services? Electronic patient records (which ones?) Finnish Kanta PHR Other (what?) • Are proprietary formats used to store and transfer data?

	• Are the definitions of the original proprietary formats openly available? • Does the product have interfaces for other companies' services? • Can the data contained in the product be exported in a commonly used or standard format? • Does the product use data from other systems via interfaces? If yes, can the data produced by others be separated in the system? • Does the product connect with health or wellness devices? If yes, is it compatible with ISO/IEEE 11073 Personal Health Data (PHD) Standards?
Artificial intelligence	• Exactly what defined problem is going to be solved by the AI? • What is the classification of AI? Visualization only, AI–assisted (e.g., diagnosis/classification/decision), or solely AI–controlled? • Could the problem be solved without the AI solution? • Is the solution based on machine learning or a neural network? • Do the staff have sufficient capacity to understand the operational logic of AI (e.g., do they need additional training)? • Are the conclusions and decisions of the AI solution transparent, i.e., can medical staff understand what the decisions are based on? • Is the AI solution validated in the environment in which it will be used? • What are the data sources for the AI solution? • Are the data sources used in the training of AI solutions relevant to a final use case (e.g. are the age and gender composition of training groups comparable to that of real user groups)? • Are the access rights required for the use of the data in order, and have data protection (e.g., GDPR) and security

			issues been taken into account? • When it comes to classifier teaching, are there enough data relative to the size of the smallest class? • Can the AI solution use incomplete data? Can the AI solution use noisy data? • Is retraining possible for the AI solution? What are the data sources for retraining? • How is it ensured that the system is not taught with irrelevant data? • How many tests or results are needed for the AI model? • Is the algorithm purchased software as a service (SaaS) or its own design? What performance criteria are used? • Does the AI solution change care processes? How? • When does the AI solution propose an action? • How, and who will actually implement it? • Is staff's approval needed for action proposed by the AI?
	Robotics		• Is there any possibility that using the robot could create safety risks for healthcare personnel or customers (e.g., forces that could be destructive or collision with people)? • How have those risks been avoided in the robot's design? • What kind of arrangements are needed to teach or program the robot to operate? • If the robot is battery-operated, what are the operating, idle, and charging times?
Clinical Information Systems Success Model (CISSM) [10]	System Performance (SP)	• Ease of Use	• The degree to which a person believes that using a particular system would be free of effort
		• Accessibility	• The ease or difficulty with which the user may act to utilize the capability of the computer system
		• Reliability	• The dependability and consistency of access and uptime of systems

	Information Quality (IQ)		
		• Perceived Usefulness	• The degree to which a person believes that using a particular system would enhance his or her job performance
		• Content Completeness	• The completeness and precision of the output information
		• Format	• The material design of the layout and display of the output contents
		• Accuracy	• The correctness of the output information
	Social Influence (SI)		
		• Service Support	• The degree to which clinicians perceive a helpful network of co-workers
		• Social Support	• User's expectations and perceptions of service performance levels provided by CIS staff
	Facilitating Conditions (FC)	• Perceived Behavioral Control	• Perceptions of internal and external constraints on behavior
		• Work Processes	
			• The clinician's perceptions of clinical activities as they relate to specific CIS applications
	CIS Use Dependency		• The extent to which the CIS is integrated into the clinician's work routine
	Nurse Satisfaction		• The level of overall clinician satisfaction with CIS
	Net Benefit		• The degree to which a clinician believes that using a particular CIS impacts job performance
Comprehensive evaluation framework for telemedicine implementation [11]	Human	• Service Provider	• Comfort with Work flow • Expertise on ICT • Education & Training • Comfort with Patient communication • Comfort with Provider interaction • Resistance to Change
		• Patient/clinic	• Location/ travel time • Disease characteristics • ICT skills & knowledge • Patient awareness • ICT equipment • User habit

			• Medical cost (out-of-pocket)
	System	• Organisation	• Leadership • Organizational culture • Change management • Hospital information systems • Budget • Training & support • Work flow reengineering
		• Technology	• Reliability of technology • Storage • System speed • User interface • Data quality • Transmission • Interoperability • Information security
	Environment	• Society	• Reimbursement • 3rd party payer • Insurance fee schedule • ICT infrastructure • Social norms & values
		• Rules/policy	• Governmental authority • Interface standards • Privacy certification & license • Privacy & security rule • Practice Medical liability
	Outcomes	• Cost effectiveness • Quality of care • Patient satisfaction	
Digital Health Score Card [12]	Technical	• Performance	• Assessment of performance when compared to technical gold standard
		• Security • Interoperability	• Testing of security • Testing of interoperability
	Clinical	• Evidence	• Critical appraisal of evidence supporting whether solution has impact on defined clinical outcome • Comparison to existing clinical gold standard • Real world testing or simulation performance intarget population
	Usability	• Usability (helpful, learnable, likable)	• Assessment using standardized usability framework that evaluates Performance across basic Characteristics (e.g. helpful; effective; learnable; likeable)
	Cost	• Purchasing price • Resources	• Purchase price • Resources including time required for training, set-up, implementation, and management

		• Anticipated costs	of solution • Anticipated cost impact on clinical outcome of interest
Development of an Evaluation Framework for Health Information Systems (DIPSA Framework) [13]	Technology	• System quality • Safety	
	Human Factor	• Collaboration • Satisfaction	
	Organization	• Procedures	
Health Technology Adoption Framework [14]	Health gain	• Efficacy (evidence based medicine, clinical outcomes and quality of life)	• Is there evidence that the technology will improve individual patient short-term (, 5 years) gain in health (clinical outcomes and/or quality of life) as compared with the current practice? • Is there evidence that the technology will improve individual patient long-term (5 years) gain in health or reduce the likelihood of further disease or complications as compared with the current practice? • Can the technology, including risk of adverse events, benefit cases with few alternatives?
		• Population health (burden of disease)	• Does the technology address a condition with significant incidence and/or prevalence (burden of disease)? • Is the incidence or prevalence projected to increase or decrease over the next 5 years?
		• Standard of care	• Has the technology become the Standard of Care in other health regions? • Will the technology establish a new Standard of Care?
	Service delivery	• Safety	• Is the technology at least as safe as current practice for the patients? • Is the technology at least as safe as current practice for the health care providers?
		• Training	• Will the technology require health care provider training? • What is the expected time frame for more health care providers to acquire the expertise to use the technology?
		• Access	• Will the technology improve accessibility (i.e.

		shift services closer to where patients reside; geographic equity)? • Will the technology provide services to under-served population(s)? • Will the technology improve the provision of services at the most appropriate time or decrease wait times? (Timeliness; service efficiency)?
	• Service coordination	• Will the technology improve coordination and collaboration with other clinical services or reduce or increase impact on other services (service coordination)? • Will the technology reduce load or positively impact other services?
	• Sustainability	• How many health care providers are demanding this technology? • Will the technology be well utilized? • How many health care providers have the expertise to use the technology upon acquisition? • Will additional human resources be required?
Strategic fit	• Strategic fit	• Is the technology aligned with internal (Department/Division) strategic goals?
Innovation	• Knowledge and research	• Will the technology improve the generation, transfer, and/or application of new knowledge to patient care services? (innovation characteristics)
Financial	• Cost (resources, infrastructure)	• Will the technology have Direct costs (purchase of technology)? • Will the technology have One Time and Start Up Costs? • Will the technology have Ongoing costs? • Will the technology impact Other Services Areas? • Will the technology have Alternative or Partial Funding Sources? • Will the technology have Environmental costs?
	• Economic analysis (cost-effectiveness, cost-benefit)	• Is there evidence to support the cost-

			effectiveness of the technology? • Is the cost-effectiveness threshold the same for all (e.g. children vs adults)? • Is there evidence to support the cost-benefit ratio of the technology? • Are any potential cost increases associated with the technology offset by significant improvements in quality of life or other patient outcomes?
Hospital Information SystemSuccess Framework [15]	Functional	• Preparation of the user requirements • Alignment of the role and design of the HIS (Task-technology adaption) • Flexibility towards dynamic changes and changes in the organizational context • Added functionality are provided by the HIS, enabling users to provide new or better services • Improve clinical performance and outcomes • In general	
	Organizational	• Collaboration and cooperation • Participation in decision-making • Work from the workflow • Support from higher level organizations • Make implementation a transparent process within the organization • Organizational stability • Rate of hospital independence and authority • Organizational capacity for changes • In general	
	Behavioral	• User involvement • User engagement and commitment • Resistance to changes • User knowledge and skills • Stakeholder, user and patient satisfaction • Motivational activities • User acceptance (perceived system ease of use, perceived system usefulness) • In general	
	Cultural	• Understand health care as a specific culture • Understand the local culture (such as attention to cultural differences between public and private hospitals as well as developing and developed countries)	

		• Preparedness and willingness towards cultural change (professional culture) • Expectations of users • In general
	Management	• Managers commitment • Formulation and expression of a clear vision for the enterprise showing the HIS as part of it • Setting clear goals and instructions • Flexible planning • Prospective and proactive control • Coping with the impact of change • Internal communication and clear feedback • Having a strategy • Handling the diversity within stakeholder goals • Using formal project management methodology • Dedicate, availability and prioritize of competitive hospital resources (human, financial and physical resources and time) • Identify and mitigate risk (risk management) • Consider IT implementation as a change process 1 • Understanding socio-technical nature of HIS • Regular evaluations and using their results at different stages of HIS life cycle • In general
	Technical (system quality, information quality and service quality)	• Integration with Legacy system • Interoperability and Interconnectivity • Usability • Balance between flexibility and stability of IT • Reliable technical infrastructure or network • Complexity of the system • Information quality (relevancy, usefulness, completeness, etc.) • Response time (system speed) • System security • Service quality (the support provided by the information department, the support provided by the maintenance company) • Quality of user documentation

		• Flexibility and adoptability, enabling future functional and technical changes • Using proper standards, coding and nomenclature • In general	
	Strategy	• National, regional, organizational • Accepted also at lower levels • Alignment between system strategies and hospital strategies • In general	
	Economy	• Return on investment (material or immaterial) • Justification of increase of costs • Sufficient funding • In general	
	Education	• Sufficient training to make the best out of the daily operation • Sufficient training to provide an understanding of its limitations and future potentials • In general	
	Legal	• Compliance with legal requirements • Know what the legal constraints/opportunities • In general	
	Ethical	• Compliance with existing ethical rules in affairs management • Privacy and confidentiality • In general	
	Political	• Political games/conflicts • Willingness towards investment on IT systems • Reliable external partners • In general	
Human, Organization, Process and Technology-fit (HOPT-FIT) [16]	Human	• System Design • System Implementation • System Use	
	Organisation	• Structure • Environment	
	Process	• Clinical Flow/Standard • Business Process Management • Lean Method	
	Technology	• System Quality • Information Quality • Service Quality	
Khoja–Durrani–Scott Evaluation Framework [17]	Health services outcomes	• Development	• Ongoing and periodic assessment of health status, existing services, needs, and opportunities
		• Implementation	• Improved diagnosis and treatment of disease conditions • Improved decision support and clinical

		care and health management • Improved access to care • Barriers and facilitators • Acceptability of e-health • Better clinical safety • Improved quality of care • Functional independence among staff • Equity of care • Stability of services • Effects on the delivery of medical care
	• Integration	• Health impact leading to change in disease status • Social impact due to improved access and quality of services • Stability of services • Improvement in quality of life
	• Sustained Operation	• Health impact showing change via indicators • Stability of services • Wide reach
Technology outcomes	• Development	• Development cost, availability, affordability • Interoperability and standardization • Well-designed software • Reliable hardware • Technical efficiency or fix • Timeliness • Cost • Robust and reliable networking • Easily adaptable to different settings (patenting) • Cultural acceptability • Environmental viability
	• Implementation	• Interoperability • User-friendliness/usability • Appropriate in a variety of conditions • Relevance to existing and growing needs • Flexible (can be modified to suit local cultural/social needs) • Efficiency/error rates • Accuracy • User acceptance
	• Integration	• Appropriate in a variety of conditions • Relevant to existing and growing needs • Broader interoperability
	• Sustained Operation	• Scalability • Cost benefit

		• Ability to be incorporated into policy
Economic outcomes	• Development • Implementation • Integration • Sustained Operation	• Affordability • Cost minimization • Cost-utility • Cost-benefit • Improved DALYs • Improved QALYs
Behavioral and sociotechnical outcomes	• Development • Implementation • Integration • Sustained Operation	• Human resource factors (management style, working relationship, communications flow, staff motivation) • Strategy for e-health implementation • User-friendliness • Human–computer interaction • Direct benefits to users in routine work • Benefits in learning • Penetration/diffusion of innovation (addressing the digital divide) • Trust • Beneficence/nonmaleficence (client, provider, organization) • Problem handling • Gender issue/gender divide • Penetration/diffusion of innovation (addressing the digital divide) • Strategy for broader e-health adoption • Adoption/adaptation of technology on a wider Scale
Ethical outcomes	• Development • Implementation	• Prioritizing e-health over other issues • Moral consideration • Autonomy (client based) • Justice and equity • Selection of study subjects/patients and population • Securing identity and maintaining confidentiality of patient information • Sensitive to sociocultural issues • Security • Liability • Licensure

			• Reimbursement
		• Integration	• All of the following in a broader perspective: • Sensitive to sociocultural issues • Security • Liability • Licensure • Reimbursement
		• Sustained Operation	• Security
	Readiness and change outcomes	• Development	• Plan for change management • Individual, organizational, and societal readiness to technology change • "Involvement" of end user in requirements elicitation phase, selection of vendor, solution, evaluation, features, etc.
		• Implementation	• Effective change management (preparation and action) • Training of all staff, including clinical and management staff
		• Integration	• Effective change management (maintenance)
		• Sustained Operation	• Modification • Improvement • Customization
	Policy outcomes	• Development	• Policies for change management • Scope for innovations • Funding support for research
		• Implementation	• Limited changes in organizational and national policies to facilitate e-health implementation
		• Integration	• Policy changes to facilitate broader adoption, implementation, and innovation in e-health
		• Sustained Operation	• Healthy public policy and organizational practice • Knowledge sharing with other organizations and countries
The layered telemedicine implementation model [18]	Technical	• Technology	• Support • Training • Usability

		• Quality
Behavioural	• Acceptance	• Attitude and usability • Evidence based medicine • Diffusion and dissemination
Economical Organizational	• Financial • Organization	• Provider and structure • Intramural and extramural work practices
	• Policy and Legislation	• Legislation and policy • Standardization • Security

1. Greenhalgh T, Wherton J, Papoutsi C, et al. (2017) Beyond Adoption: A New Framework for Theorizing and Evaluating Nonadoption, Abandonment, and Challenges to the Scale-Up, Spread, and Sustainability of Health and Care Technologies. J Med Internet Res 19:e367
2. Kidhom K, Bowes A, Dyrehauge S, et al. (2010) The MAST Manual. MAST - Model for ASsessment of Telemedicine. In:MethoTelemed team
3. Francis Lau F, Hagens S, Muttitt S (2007) A Proposed Benefits Evaluation Framework for Health Information Systems in Canada. Healthcare Quarterly 10
4. Sockolow PS, Crawford PR, Lehmann HP (2012) Health services research evaluation principles. Broadening a general framework for evaluating health information technology. Methods Inf Med 51:122-130
5. Coravos A, Doerr M, Goldsack J, et al. (2020) Modernizing and designing evaluation frameworks for connected sensor technologies in medicine. npj Digital Medicine 3:37
6. Bakken S, Ruland CM (2009) Translating clinical informatics interventions into routine clinical care: how can the RE-AIM framework help? Journal of the American Medical Informatics Association : JAMIA 16:889-897
7. Rouleau G, Gagnon MP, Côté J, Payne-Gagnon J, Hudson E, Dubois CA (2017) Impact of information and communication technologies on nursing care: Results of an overview of systematic reviews. Journal of Medical Internet Research 19
8. Kowatsch T, Otto L, Harperink S, Cotti A, Schlieter H (2019) A design and evaluation framework for digital health interventions. it - Information Technology
9. Jari H, Niina K, Petra F, Anna M, Timo K, Jarmo R (2019) Digi-HTA: Health technology assessment framework for digital healthcare services. Finnish Journal of eHealth and eWelfare 11
10. Garcia-Smith D, Effken JA (2013) Development and initial evaluation of the Clinical Information Systems Success Model (CISSM). Int J Med Inform 82:539-552
11. Chang H (2015) Evaluation Framework for Telemedicine Using the Logical Framework Approach and a Fishbone Diagram. Healthcare informatics research 21:230-238
12. Mathews SC, McShea MJ, Hanley CL, Ravitz A, Labrique AB, Cohen AB (2019) Digital health: a path to validation. NPJ Digit Med 2:38
13. Stylianides A, Mantas J, Roupa Z, Yamasaki EN (2018) Development of an Evaluation Framework for Health Information Systems (DIPSA). Acta informatica medica : AIM : journal of the Society for Medical Informatics of Bosnia & Herzegovina : casopis Drustva za medicinsku informatiku BiH 26:230-234
14. Poulin P, Austen L, Scott CM, et al. (2013) Multi-criteria development and incorporation into decision tools for health technology adoption. Journal of health organization and management 27:246-265
15. Sadoughi F, Kimiafar K, Ahmadi M, Shakeri MT (2013) Determining of factors influencing the success and failure of hospital information system and their evaluation methods: A systematic review. Iranian Red Crescent Medical Journal 15

16. Yusof MM (2019) A Socio-Technical and Lean Approach Towards a Framework for Health Information Systems-Induced Error. Stud Health Technol Inform 257:508-512
17. Khoja S, Durrani H, Scott RE, Sajwani A, Piryani U (2013) Conceptual framework for development of comprehensive e-health evaluation tool. Telemed J E Health 19:48-53
18. Broens T, Veld R, Vollenbroek - Hutten M, Hermens H, Halteren A, Nieuwenhuis B (2007) Determinants of successful telemedicine implementations: A literature study. Journal of telemedicine and telecare 13:303-309

Additional File 2: Evaluation Areas

Canvas Category	Framework Category	Related Framework
Focus	Nature of condition or illness	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
	Health problem	Model for Assessment of Telemedicine (Mast Manual)
	Disease characteristics	Comprehensive evaluation framework for telemedicine implementation
	Comorbidities	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
	Purpose of the telemedicine application	Model for Assessment of Telemedicine (Mast Manual)
	Relevance to existing and growing needs	Khoja–Durrani–Scott Evaluation Framework
Product/ Technology	Material features	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
	Aesthetics	Design and Evaluation of DHI Framework
	User interface	Comprehensive evaluation framework for telemedicine implementation
	System Design	Human, Organization, Process and Technology-fit (HOPT-FIT)
	Well-designed software	Khoja–Durrani–Scott Evaluation Framework
	Format (material design of the layout and display)	Clinical Information Systems Success Model (CISSM)
	Alignment of the role and design of the HIS (Task-technology adaption)	Hospital Information System Success Framework
	Technology supply model	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
	Maturity of the application	Model for Assessment of Telemedicine (Mast Manual)
	Functionality	Infoway benefits evaluation Framework
	Performance	Infoway benefits evaluation Framework
	Ease of use	Infoway benefits evaluation Framework
	Responsiveness	Infoway benefits evaluation Framework
	Software (Usability)	Health Information Technology Evaluation Framework (HITREF)
	Functionality	Health Information Technology Evaluation Framework (HITREF)
	Usability	Evaluation Framework for Fit-For-Purpose Connected Sensor Technologies
	Ease of use	Design and Evaluation of DHI Framework
	Technical stability	Health technology assessment framework for digital healthcare services (Digi HTA)
	Usability	Health technology assessment framework for digital healthcare services (Digi HTA)
	Ease of Use	Clinical Information Systems Success Model (CISSM)
	Reliability	Clinical Information Systems Success Model (CISSM)
	Accuracy	Clinical Information Systems Success Model (CISSM)
	Reliability of technology	Comprehensive evaluation framework for telemedicine implementation
	Storage	Comprehensive evaluation framework for telemedicine implementation
	System speed	Comprehensive evaluation framework for telemedicine implementation

Transmission	Comprehensive evaluation framework for telemedicine implementation
Performance	Digital Health Score Card
Usability (helpful, learnable, likable)	Digital Health Score Card
System quality	Development of an Evaluation Framework for Health Information Systems (DIPSA Framework
Preparation of the user requirements	Hospital Information System Success Framework
Usability	Hospital Information System Success Framework
Balance between flexibility and stability of IT	Hospital Information System Success Framework
Reliable technical infrastructure or network	Hospital Information System Success Framework
Complexity of the system	Hospital Information System Success Framework
Response time (system speed)	Hospital Information System Success Framework
Flexibility and adoptability, enabling future functional and technical changes	Hospital Information System Success Framework
System Quality (measures of the information processing system itself)	Human, Organization, Process and Technology-fit (HOPT-FIT)
Reliable hardware	Khoja–Durrani–Scott Evaluation Framework
Technical efficiency or fix	Khoja–Durrani–Scott Evaluation Framework
Robust and reliable networking	Khoja–Durrani–Scott Evaluation Framework
User-friendliness/usability	Khoja–Durrani–Scott Evaluation Framework
Usability	The layered telemedicine implementation model
Quality	The layered telemedicine implementation model
Type of data generated Data	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
Description of the application	Model for Assessment of Telemedicine (Mast Manual)
Content	Infoway benefits evaluation Framework
Completeness/Correctness of data	Health Information Technology Evaluation Framework (HITREF)
Content quality (accurate, timely, complete, relevant, and consistent)	Design and Evaluation of DHI Framework
Personalization	Design and Evaluation of DHI Framework
Content Completeness	Clinical Information Systems Success Model (CISSM)
Data quality	Comprehensive evaluation framework for telemedicine implementation
Information quality (relevancy, usefulness, completeness, etc.)	Hospital Information System Success Framework
Quality of user documentation	Hospital Information System Success Framework
Information Quality (measures of IS output)	Human, Organization, Process and Technology-fit (HOPT-FIT)
Timeliness	Khoja–Durrani–Scott Evaluation Framework
Accuracy	Khoja–Durrani–Scott Evaluation Framework
Efficiency/error rates	Khoja–Durrani–Scott Evaluation Framework
Technical safety (technical reliability)	Model for Assessment of Telemedicine (Mast Manual)

Clinical safety (patients and staff)	Model for Assessment of Telemedicine (Mast Manual)
Security	Infoway benefits evaluation Framework
Security	Evaluation Framework for Fit-For-Purpose Connected Sensor Technologies
Safety	Design and Evaluation of DHI Framework
Clinical safety	Health technology assessment framework for digital healthcare services (Digi HTA)
Security	Digital Health Score Card
Safety	Development of an Evaluation Framework for Health Information Systems (DIPSA Framework
Safety	Health Technology Adoption Framework
System security	Hospital Information System Success Framework
Clinical Safety	Khoja–Durrani–Scott Evaluation Framework
Security	Khoja–Durrani–Scott Evaluation Framework
Security	The layered telemedicine implementation model
Technical characteristics (eg.) Infrastructure requirements; Interoperability: Integration needs	Model for Assessment of Telemedicine (Mast Manual)
Interoperability	Health technology assessment framework for digital healthcare services (Digi HTA)
Interoperability	Comprehensive evaluation framework for telemedicine implementation
Integration with Legacy system	Hospital Information System Success Framework
Interoperability and Interconnectivity	Hospital Information System Success Framework
Using proper standards, coding and nomenclature	Hospital Information System Success Framework
Interoperability and standardization	Khoja–Durrani–Scott Evaluation Framework
Interoperability	Digital Health Score Card
Knowledge needed to use	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
Availability	Infoway benefits evaluation Framework
Product information (detailed information about the product e.g. name, technology readiness or intended use)	Health technology assessment framework for digital healthcare services (Digi HTA)
Accessibility	Health technology assessment framework for digital healthcare services (Digi HTA)
Accessibility	Clinical Information Systems Success Model (CISSM)
Access	Health Technology Adoption Framework
Sustainability	Health Technology Adoption Framework
Flexibility towards dynamic changes and changes in the organizational context	Hospital Information System Success Framework
Flexible (can be modified to suit local cultural/social needs)	Khoja–Durrani–Scott Evaluation Framework
Easily adaptable to different settings (patenting)	Khoja–Durrani–Scott Evaluation Framework
Appropriate in a variety of conditions	Khoja–Durrani–Scott Evaluation Framework
Ability to be incorporated into policy	Khoja–Durrani–Scott Evaluation Framework

	Acceptability of e-health	Khoja–Durrani–Scott Evaluation Framework
Objective Value/Effect	Supply-side value (to developer)	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
	Demand-side value (desirability, efficacy, effectiveness)	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
	Clinical Effectiveness:	Model for Assessment of Telemedicine (Mast Manual)
	Effects on mortality	Model for Assessment of Telemedicine (Mast Manual)
	Effects on morbidity	Model for Assessment of Telemedicine (Mast Manual)
	Physical health	Model for Assessment of Telemedicine (Mast Manual)
	Mental health	Model for Assessment of Telemedicine (Mast Manual)
	Effects on health related quality of life (HRQL)	Model for Assessment of Telemedicine (Mast Manual)
	Behavioural outcomes (e.g. exercise)	Model for Assessment of Telemedicine (Mast Manual)
	Utilization of health services	Model for Assessment of Telemedicine (Mast Manual)
	Quality	Infoway benefits evaluation Framework
	Access	Infoway benefits evaluation Framework
	Productivity	Infoway benefits evaluation Framework
	Patient outcome	Health Information Technology Evaluation Framework (HITREF)
	Patient related knowledge	Health Information Technology Evaluation Framework (HITREF)
	Efficiency	Health Information Technology Evaluation Framework (HITREF)
	Appropriateness of patient care	Health Information Technology Evaluation Framework (HITREF)
	Organizational or social quality	Health Information Technology Evaluation Framework (HITREF)
	Evidence based medicine	The layered telemedicine implementation model
	Utility	Evaluation Framework for Fit-For-Purpose Connected Sensor Technologies
	Important outcomes	RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) (expanded to clinical informatics)
	Quality of life	RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) (expanded to clinical informatics)
	Long-term effects of a program on outcomes	RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) (expanded to clinical informatics)
	Time and Efficiency	Adapted nursing care performance framework
	Nurses' Practice Environment	Adapted nursing care performance framework
	Nursing Processes	Adapted nursing care performance framework
	Nursing-Sensitive Outcomes	Adapted nursing care performance framework
	Effectiveness	Design and Evaluation of DHI Framework
	Effectiveness	Health technology assessment framework for digital healthcare services (Digi HTA)
	Net Benefits	Clinical Information Systems Success Model (CISSM)
	Quality of care	Comprehensive evaluation framework for telemedicine implementation
	Efficacy (evidence based medicine, clinical outcomes and quality of life)	Health Technology Adoption Framework

	Population health (burden of disease)	Health Technology Adoption Framework
	Standard of care	Health Technology Adoption Framework
	Improved DALYs	Khoja–Durrani–Scott Evaluation Framework
	Improved QALYs	Khoja–Durrani–Scott Evaluation Framework
	Direct benefits to users in routine work	Khoja–Durrani–Scott Evaluation Framework
	Benefits in learning	Khoja–Durrani–Scott Evaluation Framework
	Beneficence/nonmaleficence (client, provider, organization)	Khoja–Durrani–Scott Evaluation Framework
	Improved diagnosis and treatment of disease conditions	Khoja–Durrani–Scott Evaluation Framework
	Improved decision support and clinical	Khoja–Durrani–Scott Evaluation Framework
	care and health management	Khoja–Durrani–Scott Evaluation Framework
	Improved access to care	Khoja–Durrani–Scott Evaluation Framework
	Improved quality of care	Khoja–Durrani–Scott Evaluation Framework
	Functional independence among staff	Khoja–Durrani–Scott Evaluation Framework
	Equity of care	Khoja–Durrani–Scott Evaluation Framework
	Stability of services	Khoja–Durrani–Scott Evaluation Framework
	Effects on the delivery of medical care	Khoja–Durrani–Scott Evaluation Framework
	Health impact leading to	Khoja–Durrani–Scott Evaluation Framework
	change in disease status	Khoja–Durrani–Scott Evaluation Framework
	Social impact due to improved access and quality of services	Khoja–Durrani–Scott Evaluation Framework
	Improvement in quality of life	Khoja–Durrani–Scott Evaluation Framework
	Health impact showing change via indicators	Khoja–Durrani–Scott Evaluation Framework
	Unintended Consequences/Benefits	Health Information Technology Evaluation Framework (HITREF)
	Potential negative effects	RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) (expanded to clinical informatics)
	Evidence	Digital Health Score Card
	Added functionality are provided by the HIS, enabling users to provide new or better services	Hospital Information System Success Framework
	Verification, analytical validation, and clinical validation	Evaluation Framework for Fit-For-Purpose Connected Sensor Technologies
Individual	Satisfaction and acceptance	Model for Assessment of Telemedicine (Mast Manual)
	User Satisfaction	Infoway benefits evaluation Framework
	Attitude (towards technology)	The layered telemedicine implementation model
	User satisfaction	Health Information Technology Evaluation Framework (HITREF)
	Patient satisfaction with EHR	Health Information Technology Evaluation Framework (HITREF)
	Patient satisfaction with care	Health Information Technology Evaluation Framework (HITREF)
	Professional Satisfaction	Adapted nursing care performance framework

Nurse Satisfaction	Clinical Information Systems Success Model (CISSM)
Comfort with Patient communication (provider)	Comprehensive evaluation framework for telemedicine implementation
Comfort with Provider interaction (provider)	Comprehensive evaluation framework for telemedicine implementation
Stakeholder, user and patient satisfaction	Hospital Information System Success Framework
Intention to use	Infoway benefits evaluation Framework
Individuals who are willing to participate	RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) (expanded to clinical informatics))
Resistance to Change (provider)	Comprehensive evaluation framework for telemedicine implementation
User acceptance (perceived system ease of use, perceived system usefulness)	Hospital Information System Success Framework
User acceptance	Khoja–Durrani–Scott Evaluation Framework
Staff (change of role or identity)	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
Patient (simple vs complex input - expectation)	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
Carers (available nature of input - assumptions about them)	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
User habit (patient)	Comprehensive evaluation framework for telemedicine implementation
User involvement	Hospital Information System Success Framework
User engagement and commitment	Hospital Information System Success Framework
Resistance to changes	Hospital Information System Success Framework
Motivational activities	Hospital Information System Success Framework
"Involvement" of end user in requirements elicitation phase, selection of vendor, solution, evaluation, features, etc.	Khoja–Durrani–Scott Evaluation Framework
Clinical involvement in HIT Selection, Implementation, Training	Health Information Technology Evaluation Framework (HITREF)
Use/behaviour pattern	Infoway benefits evaluation Framework
Self-reported use	Infoway benefits evaluation Framework
Clients use	RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) (expanded to clinical informatics))
Adherence	Design and Evaluation of DHI Framework
System Use	Human, Organization, Process and Technology-fit (HOPT-FIT)
Adoption/adaptation of technology on a wider Scale	Khoja–Durrani–Scott Evaluation Framework
Wide reach	Khoja–Durrani–Scott Evaluation Framework
Patients Confidence (in the treatment)	Model for Assessment of Telemedicine (Mast Manual)
Perceived benefit	Design and Evaluation of DHI Framework
Perceived enjoyment	Design and Evaluation of DHI Framework
Perceived Usefulness	Clinical Information Systems Success Model (CISSM)
Comfort with Work flow	Comprehensive evaluation framework for telemedicine implementation
Location/ travel time (patient)	Comprehensive evaluation framework for telemedicine implementation
Patient awareness (patient)	Comprehensive evaluation framework for telemedicine implementation

	Understanding of information	Model for Assessment of Telemedicine (Mast Manual)
	Ability to use the application	Model for Assessment of Telemedicine (Mast Manual)
	Empowerment, self-efficacy	Model for Assessment of Telemedicine (Mast Manual)
	Competency	Infoway benefits evaluation Framework
	Perceived Behavioural Control	Clinical Information Systems Success Model (CISSM)
	CIS Use Dependency	
	User knowledge and skills	Hospital Information System Success Framework
	Autonomy (client based)	Khoja–Durrani–Scott Evaluation Framework
	Degree of adolescent control (autonomy)	
	Individual readiness to change	Khoja–Durrani–Scott Evaluation Framework
	Expertise on ICT (provider)	Comprehensive evaluation framework for telemedicine implementation
	ICT skills & knowledge (patient)	Comprehensive evaluation framework for telemedicine implementation
Organisation	Work needed to implement change	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
	Organisational Strategy	Infoway benefits evaluation Framework
	Diffusion	Health Information Technology Evaluation Framework (HITREF)
	Consistency of delivery as intended and the time of the intervention	RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) (expanded to clinical informatics))
	Extent to which a program or policy becomes institutionalized or part of the routine organizational practices and policies	RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) (expanded to clinical informatics)
	Make implementation a transparent process within the organization	Hospital Information System Success Framework
	Consider IT implementation as a change process	Hospital Information System Success Framework
	System Implementation	Human, Organization, Process and Technology-fit (HOPT-FIT)
	Penetration/diffusion of innovation (addressing the digital divide)	Khoja–Durrani–Scott Evaluation Framework
	Modification	Khoja–Durrani–Scott Evaluation Framework
	Improvement	Khoja–Durrani–Scott Evaluation Framework
	Customization	Khoja–Durrani–Scott Evaluation Framework
	Policy changes to facilitate broader adoption, implementation, and innovation in e-health	Khoja–Durrani–Scott Evaluation Framework
	Strategy for e-health implementation	Khoja–Durrani–Scott Evaluation Framework
	Capacity to innovate	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
	Readiness for this technology (change)	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
	Nature of adoption (how easy will it be?)	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
	Scope for adaption over time	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
	Organisational resilience	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
	Structure	Model for Assessment of Telemedicine (Mast Manual)Model for Assessment of Telemedicine (Mast Manual)

Culture	Model for Assessment of Telemedicine (Mast Manual)Model for Assessment of Telemedicine (Mast Manual)
Culture	Infoway benefits evaluation Framework
Hardware (availability in the organisation)	Health Information Technology Evaluation Framework (HITREF)
Organizational culture	Comprehensive evaluation framework for telemedicine implementation
ICT infrastructure	Comprehensive evaluation framework for telemedicine implementation
ICT equipment (patient)	Comprehensive evaluation framework for telemedicine implementation
Resources (e.g. time for training, set-up, implementation, and management)	Comprehensive evaluation framework for telemedicine implementation
Knowledge and research	Health Technology Adoption Framework
Organizational stability	Hospital Information System Success Framework
Rate of hospital independence and authority	Hospital Information System Success Framework
Organizational capacity for changes	Hospital Information System Success Framework
Coping with the impact of change	Hospital Information System Success Framework
resources (human, financial and physical resources and time)	Hospital Information System Success Framework
Structure	Human, Organization, Process and Technology-fit (HOPT-FIT)
Environment	Human, Organization, Process and Technology-fit (HOPT-FIT)
Organisational readiness to change	Khoja–Durrani–Scott Evaluation Framework
Scope for innovations	Khoja–Durrani–Scott Evaluation Framework
Human resource factors (management style, working relationship, communications flow, staff motivation)	Khoja–Durrani–Scott Evaluation Framework
Organizational Support/ Capacity	Health Information Technology Evaluation Framework (HITREF)
Settings and intervention agents (people who deliver the program) who are willing to initiate a program	RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) (expanded to clinical informatics)
Social Support (to use CIS)	Clinical Information Systems Success Model (CISSM)
Service Support	Clinical Information Systems Success Model (CISSM)
Education & Training & Support	Comprehensive evaluation framework for telemedicine implementation
Training	Health Technology Adoption Framework
Sufficient training to make the best out of the daily operation	Hospital Information System Success Framework
Sufficient training to provide an understanding of its limitations and future potentials	Hospital Information System Success Framework
Training of all staff, including clinical and management staff	Khoja–Durrani–Scott Evaluation Framework
Support	The layered telemedicine implementation model
Training	The layered telemedicine implementation model
(leadership etc.)	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
Management	Model for Assessment of Telemedicine (Mast Manual)Model for Assessment of Telemedicine (Mast Manual)
Leadership	Comprehensive evaluation framework for telemedicine implementation

Change management	Comprehensive evaluation framework for telemedicine implementation
Participation in decision-making	Hospital Information System Success Framework
Support from higher level organizations	Hospital Information System Success Framework
Managers commitment	Hospital Information System Success Framework
Formulation and expression of a clear vision for the enterprise	Hospital Information System Success Framework
showing the HIS as part of it	Hospital Information System Success Framework
Setting clear goals and instructions	Hospital Information System Success Framework
Flexible planning	Hospital Information System Success Framework
Prospective and proactive control	Hospital Information System Success Framework
Having a strategy	Hospital Information System Success Framework
Handling the diversity within stakeholder goals	Hospital Information System Success Framework
Using formal project management methodology	Hospital Information System Success Framework
Dedicate, availability and prioritize of competitive hospital	Hospital Information System Success Framework
Identify and mitigate risk (risk management)	Hospital Information System Success Framework
Understanding socio-technical nature of HIS	Hospital Information System Success Framework
Business Process Management	Human, Organization, Process and Technology-fit (HOPT-FIT)
Lean Method	Human, Organization, Process and Technology-fit (HOPT-FIT)
Prioritizing e-health over other issues	Khoja–Durrani–Scott Evaluation Framework
Plan for change management	Khoja–Durrani–Scott Evaluation Framework
Effective change management (preparation and action)	Khoja–Durrani–Scott Evaluation Framework
Effective change management (maintenance)	Khoja–Durrani–Scott Evaluation Framework
Policies for change management	Khoja–Durrani–Scott Evaluation Framework
Limited changes in organizational and national policies to facilitate e-health implementation	Khoja–Durrani–Scott Evaluation Framework
Healthy public policy and organizational practice	Khoja–Durrani–Scott Evaluation Framework
Collaboration	Development of an Evaluation Framework for Health Information Systems (DIPSA Framework
Collaboration and cooperation	Hospital Information System Success Framework
Internal communication and clear feedback	Hospital Information System Success Framework
Service quality (the support provided by the information department, the support provided by the maintenance company)	Hospital Information System Success Framework
Knowledge sharing with other organizations and countries	Khoja–Durrani–Scott Evaluation Framework
Extend of change needed to routines	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
Process	Model for Assessment of Telemedicine (Mast Manual)Model for Assessment of Telemedicine (Mast Manual)
Business Process	Infoway benefits evaluation Framework

	Work flow reengineering	Comprehensive evaluation framework for telemedicine implementation
	Procedures	Development of an Evaluation Framework for Health Information Systems (DIPSA Framework
	Service coordination	Health Technology Adoption Framework
	Work from the workflow	Hospital Information System Success Framework
	Regular evaluations and using their results at different stages of HIS life cycle	Hospital Information System Success Framework
	Clinical Flow/Standard	Human, Organization, Process and Technology-fit (HOPT-FIT)
	Service Quality	Human, Organization, Process and Technology-fit (HOPT-FIT)
	Intramural and extramural work practices	The layered telemedicine implementation model
Societal	Political/ policy	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
	Rules/policy	Comprehensive evaluation framework for telemedicine implementation
	Governmental authority	Comprehensive evaluation framework for telemedicine implementation
	Political games/conflicts	Hospital Information System Success Framework
	(political) Willingness towards investment on IT systems	Hospital Information System Success Framework
	Legislation and Policy	The layered telemedicine implementation model
	security (patient information) (Legislation)	The layered telemedicine implementation model
	Patient privacy	Health Information Technology Evaluation Framework (HITREF)
	Privacy & security	Design and Evaluation of DHI Framework
	Data security and protection	Health technology assessment framework for digital healthcare services (Digi HTA)
	Information security	Comprehensive evaluation framework for telemedicine implementation
	Regulatory/ legal	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
	Legal issues	Model for Assessment of Telemedicine (Mast Manual)
	Data rights and governance	Evaluation Framework for Fit-For-Purpose Connected Sensor Technologies
	Privacy certification & license	Comprehensive evaluation framework for telemedicine implementation
	Privacy & security rule	Comprehensive evaluation framework for telemedicine implementation
	Interface standards	Comprehensive evaluation framework for telemedicine implementation
	Practice Medical liability	Comprehensive evaluation framework for telemedicine implementation
	Compliance with legal requirements	Hospital Information System Success Framework
	Know what the legal constraints/opportunities	Hospital Information System Success Framework
	Justice and equity	Khoja–Durrani–Scott Evaluation Framework
	Liability	Khoja–Durrani–Scott Evaluation Framework
	Licesure	Khoja–Durrani–Scott Evaluation Framework
	Standardisation	The layered telemedicine implementation model
	Professional	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)

	Socio-cultural	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
	Social issues	Model for Assessment of Telemedicine (Mast Manual)
	Society	Comprehensive evaluation framework for telemedicine implementation
	Social norms & values	Comprehensive evaluation framework for telemedicine implementation
	Understand health care as a specific culture	Hospital Information System Success Framework
	Understand the local culture (such as attention to cultural differences between public and private hospitals as well as developing and developed countries)	Hospital Information System Success Framework
	Preparedness and willingness towards cultural change (professional culture)	Hospital Information System Success Framework
	(Cultural) Expectations of users	Hospital Information System Success Framework
	Cultural acceptability	Khoja–Durrani–Scott Evaluation Framework
	Environmental viability	Khoja–Durrani–Scott Evaluation Framework
	Gender issue/gender divide	Khoja–Durrani–Scott Evaluation Framework
	Sensitive to sociocultural issues	Khoja–Durrani–Scott Evaluation Framework
	Societal readiness to technology change	Khoja–Durrani–Scott Evaluation Framework
Ethics	Ethical issues	Model for Assessment of Telemedicine (Mast Manual)
	Ethics	Design and Evaluation of DHI Framework
	Compliance with existing ethical rules in affairs management	Hospital Information System Success Framework
	Privacy and confidentiality	
	Moral consideration	Khoja–Durrani–Scott Evaluation Framework
	Autonomy (client based)	
	Scalability	Khoja–Durrani–Scott Evaluation Framework
Economics	Supply-side value (business case)	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
	Business case (institutional level)	Model for Assessment of Telemedicine (Mast Manual)
	Company information	Health technology assessment framework for digital healthcare services (Digi HTA)
	Return on investment (material or immaterial)	Hospital Information System Success Framework
	Budget (Hospital)	Comprehensive evaluation framework for telemedicine implementation
	Reimbursement	Comprehensive evaluation framework for telemedicine implementation
	3rd party payer	Comprehensive evaluation framework for telemedicine implementation
	Sufficient funding	Hospital Information System Success Framework
	Reimbursement	Khoja–Durrani–Scott Evaluation Framework
	Funding support for research	Khoja–Durrani–Scott Evaluation Framework
	Funding decision (organisation)	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
	Costs of information processing	Health Information Technology Evaluation Framework (HITREF)

	Cost of the intervention	RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) (expanded to clinical informatics)
	Cost	Health technology assessment framework for digital healthcare services (Digi HTA)
	Productivity (net costs/efficiency)	Infoway benefits evaluation Framework
	Medical costs (out of pocket)	Comprehensive evaluation framework for telemedicine implementation
	Purchasing price	Digital Health Score Card
	Anticipated costs	Digital Health Score Card
	Cost (resources, infrastructure)	Health Technology Adoption Framework
	Development cost, availability, affordability	Khoja–Durrani–Scott Evaluation Framework
	Cost	Khoja–Durrani–Scott Evaluation Framework
	Affordability	Khoja–Durrani–Scott Evaluation Framework
	Cost	The layered telemedicine implementation model
	Demand-side value (cost-effectiveness)	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS)
	Economic evaluation (societal perspective)	Model for Assessment of Telemedicine (Mast Manual)
	Sensitivity analysis (Risk analysis)	Model for Assessment of Telemedicine (Mast Manual)
	Relevant alternatives	Model for Assessment of Telemedicine (Mast Manual)
	Costs of patient care	Health Information Technology Evaluation Framework (HITREF)
	Economic feasibility	Evaluation Framework for Fit-For-Purpose Connected Sensor Technologies
	Economic outcomes	RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) (expanded to clinical informatics)
	Cost effectiveness	Comprehensive evaluation framework for telemedicine implementation
	Economic analysis (cost-effectiveness, cost-benefit)	Health Technology Adoption Framework
	Justification of increase of costs	Hospital Information System Success Framework
	Cost benefit	Khoja–Durrani–Scott Evaluation Framework
	Cost minimization	Khoja–Durrani–Scott Evaluation Framework
	Cost-utility	Khoja–Durrani–Scott Evaluation Framework
	Cost-benefit	Khoja–Durrani–Scott Evaluation Framework
	(Financial) Provider and structure/cost effectiveness	The layered telemedicine implementation model
Strategic	Strategic fit	Health Technology Adoption Framework
	National, regional, organizational (Strategy)	Hospital Information System Success Framework
	Accepted also at lower levels	Hospital Information System Success Framework
	Alignment between system strategies and hospital strategies	Hospital Information System Success Framework
	Reliable external partners	Hospital Information System Success Framework
	Strategy for e-health implementation	Khoja–Durrani–Scott Evaluation Framework
	Problem handling	Khoja–Durrani–Scott Evaluation Framework

Trust	Khoja–Durrani–Scott Evaluation Framework
Cross-border (transferability)	Model for Assessment of Telemedicine (Mast Manual)
Scalability (of results)	Model for Assessment of Telemedicine (Mast Manual)
Generalizability (of results)	Model for Assessment of Telemedicine (Mast Manual)
Barriers or Facilitators to Adoption	Health Information Technology Evaluation Framework (HITREF)
Barriers and facilitators	Khoja–Durrani–Scott Evaluation Framework

Additional file 3. Detailed strength and weakness analysis

Framework	Assessment: Strengths	Assessment: Weaknesses
Infoway benefits evaluation Framework [19]	- Clear description of the purpose and addressed question (to evaluate benefits for investments) - Generalistic Health (business) settings described as a setting - Applicable for different health information technologies - Very well illustrated presentation of the model - Visualization of connections and relationships within the framework is given - Clear definition of terms with examples - Full transparency of the development process - Transferable (allows comparison of evaluation findings)	- No clear focus on a specific technology type - No specific application settings described - No application strategy for the framework - No guidance on interpretation of results - No discussion of weaknesses and limitations
Health Information Technology Evaluation Framework (HITREF)[20]	- Clear description of the purpose and the addressed question - Clear description of specific technology (health information technologies (EHR)) - Universal approach by referring to different possible settings (hospital, ambulatory, community-based, public health) - Well-illustrated presentation of the model - Visualization of connections and relationships within the framework is given - Clear definition of key concepts and terms - Exemplary explanation for the application - Full transparency of the development process - Transferable to different settings	- No specific application settings described - No guidance on interpretation of results - Insufficient discussion of weaknesses and limitations
Hospital Information System Success Framework [7]	- Clear description of the purpose and the addressed question - Clear description of the setting (hospital) - Clear description of the technology (hospital information systems) - Description of key concepts by presenting information on related sub factors and evaluation methods	- No visualization of the framework (table only) - No visualization of connections or relationships within the framework - No guidance on interpretation of results

		- Presentation of recommended methods and example studies for individual evaluation factors - Full transparency of the development process - Limitations/weaknesses are sufficiently described - Transferability in the hospital setting is given	
	Development of an Evaluation Framework for Health Information Systems (DIPSA Framework) [21]	- Clear description of the purpose and the addressed question - Clear description of the setting (hospital) - Clear description of the technology (integrated Health Information Systems) - Description and definition of key concepts and terms with related questions (questions are not easily accessible) - Application strategy exists - Description of the development process is given - Transferable to other hospital settings	- No visualization of the framework (table only) - No visualization of connections or relationships within the framework - Application of the framework only possible if the questions are available - No concrete instruction on how the results can be interpreted - Insufficient description of the limitations
	Human, Organization, Process and Technology-fit (HOPT-FIT) [22]	- Clear description of the purpose and addressed question - Applicable for different types of health organisations (setting) - Clear description of the technology (health information systems) - Well-illustrated presentation of the model - Visualization of connections and relationships within the framework is given	- Setting unspecified (health organisation) - Insufficient explanation of the individual terms - No concrete application strategy and instructions for use. The framework is still to be tested in clinical settings - No instruction on how the results can be interpreted - Methodology of the development process not sufficiently described - Insufficient discussion of weaknesses and limitations - Unclear transferability due to weaknesses in the development methodology
	Clinical Information Systems	- Clear description of the purpose and the addressed question - Clear description of the setting (hospital) - Clear description of the technology (clinical information systems) - Very well illustrated presentation of the model	- Discussion of weaknesses and limitations very short - Limited transferability of the framework to other settings

	Success Model (CISSM) [4]	- Visualization of connections and (statistically validated) relationships within the framework is given - Clear definition of key concepts and terms - Procedure, instruments, and evaluation matrix are given. A validation study has been carried out - Examples are provided to aid interpretation - Full transparency of the development process - Transferable to other hospital settings	
	Adapted nursing care performance framework [23]	- Clear description of the purpose and the addressed question - Clear description of technology (information and communication technologies for nurses) - Broad (healthcare) setting related to nursing care - Well-illustrated presentation of the model - Visualization of connections and relationships within the framework is given - Detailed definition and explanation of terms and concepts based on the studies examined - Description of the analysis process is given - Discussion of the weaknesses, biases, and limitations - Transferability to different nursing contexts given	- No clear focus on a specific on a setting - Framework as an overview with no application strategy - Indirect explanation how results can be interpreted (by referring to analysed studies) - Development process: No independent framework - rather the examination of the transferability of indicators of a framework to ICTs in the field of nursing
	Model for Assessment of Telemedicine (MAST Manual) [24]	- Clear description of the purpose and the addressed question - Universal setting approach (all telemedicine settings) - Clear description on specific technology (telemedicine technologies -application to other contexts still conceivable) - Clear definition of included domains (e.g. safety) with examples - Concrete application strategy and instructions for use is given including possible methods - High transparency of the development process - Limitations/weaknesses are sufficiently described - Transferability of the framework is described	- Setting undefined (telemedicine) - Moderate clarity of illustration - No visualization of connections or relationships within the framework - No guidance on interpretation of results

	Comprehensive evaluation framework for telemedicine implementation [18]	- Clear description of the purpose and the addressed question - Universal setting approach (all telemedicine settings) - Clear description of the technology (telemedicine systems) - Vivid illustration	- Setting undefined (telemedicine) - Lack of clarity of connections or relationships within the framework - Insufficient definition of terms in the framework - No concrete application strategy and instructions for use - No instruction on how the results can be interpreted - Methodology of the development process not sufficiently described - Insufficient description of the limitations - Unclear transferability
	The layered telemedicine implementation model [17]	- Clear description of the purpose and the addressed question - Universal setting approach (all telemedicine settings) - Clear description of the technology (telemedicine interventions) - Well-illustrated presentation of the model - Visualization of connections and relationships within the framework is given - Clear definition of key concepts and terms - Instruction to choose a layered approach along the development life cycle. Different determinants should gain focus during the maturity of the telemedicine implementation - Explanation of the development process is given - Limitations/weaknesses are sufficiently described	- Setting undefined (telemedicine) - No concrete application strategy and instructions for use - only example studies and the advice to involve multiple stakeholders in the analysis. - No instruction on how the results can be interpreted - Unclear transferability (study provides only an overview of the determinants described in the literature)
	Evaluation Framework for Fit-For-Purpose Connected Sensor Technologies [15]	- Clear description of the purpose, clear description of the addressed question (risk evaluation) - Applicable for clinical or research settings - Clear description of specific technology area (connected sensors) - Clear illustration - Clear definition of key concepts and terms - Exemplary explanation for the application - Sample threshold criteria for the interpretation of the results	- No specific application settings described - No visualization of connections or relationships within the framework - No discussion of weaknesses and limitations

		- Sufficient explanation of the development process - Transferable to different settings	
	Design and Evaluation of DHI Framework [11]	- Clear description of the purpose and wide variety of questions to be addressed to - Applicable for different care settings - Applicable for different digital health interventions (universal) - Clear definition of key concepts and terms - Description of the application based on different digital health intervention phases - Full transparency of the development process - Limitations/weaknesses are sufficiently described - Transferable to different settings and technologies	- No clear focus on a specific a technology area - No clear focus on a specific setting - No visualization of the framework (table only) - No visualization of connections or relationships within the framework - No instruction on how the results can be interpreted
	Health technology assessment framework for digital healthcare services (Digi HTA) [6]	- Clear description of the purpose and the addressed question - Applicable for different care settings - Applicable for different digital healthcare services (mHealth, AI, and robotics) - Evaluation categories (key concepts) are specified by means of questions - Application procedure is described - Grid for the interpretation of the results is presented (guidance on decision) - Full transparency of the development process - Transferable to different settings	- Unspecified setting - No visualization of the framework (table only) - No visualization of connections or relationships within the framework - Insufficient description of the limitations
	Digital Health Score Card [10]	- Clear description of the purpose and the addressed question - Applicable for different care settings - Applicable for different digital health technologies - Very well illustrated presentation of the model - Visualization of connections within the framework is given - Clear definition of key concepts and terms	- No clear focus on a specific setting - No clear focus on a specific technology type - No concrete application strategy and instructions for use. The framework is still in the early stages of development and iteration is ongoing - No instruction on how the results can be interpreted - Development process not sufficiently described - Insufficient description of the limitations

			- Unclear transferability
	Khoja–Durrani–Scott Framework for e-Health Evaluation [16]	- Clear description of the purpose and the addressed question - Universal setting approach (e-health) - Broad spectrum of possible technologies to be evaluated (e-health) - Table illustrates the relationships in the framework based on the e-health life cycle - Important terms and concepts are defined - but not every term is sufficiently defined in the framework - Sufficient explanation of the development process - Transferable to different settings and technologies	- Setting undefined (e-health) - No clear focus on technology area (e-health) - No visualization of the framework (table only) - No concrete application strategy and instructions for use (Specific evaluation tools were developed, but were not publicly available at the time of the review) - No instruction on how the results can be interpreted - No discussion of weaknesses and limitations
	RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) (expanded to clinical informatics) [25]	- Clear description of the purpose and research question (how research can be translated into practice) - Universal approach (applicable for "clinical informatics") - Clear description of the framework concepts and terms - Examples for the application given - Example advice for interpretation – (not very concrete) - Development: Framework based on the original article and validated by clinical information case studies - Meta Framework (very transferable)	- No clear focus on a specific technology area - No clear focus on a specific on a setting ("clinical informatics") - Illustration is a table - No visualization of connections or relationships within the framework - Insufficient discussion of weaknesses and limitations
	Health Technology Adoption Framework [8]	- Clear description of the purpose and the addressed question - Clear description of the setting (surgical context) - Clear description of the technology area is given (health technologies in the surgical context) - Vivid illustration with evaluation tool - Definitions of the domains, criteria and sub criteria provided (related questions provided) - Concrete application strategy and instructions for use is given by presenting an evaluation tool	- No visualization of connections or relationships within the framework - Transferability limited (limited to surgical context)

		- Instruction on how the results can be interpreted is included in the evaluation tool - Detailed description of the development process is given - Limitations/weaknesses are sufficiently described - Transferable to other surgical settings	
	Nonadoption, abandonment, scale-up, spread, and sustainability Framework (NASSS Framework) [9]	- Clear description of the purpose and the addressed question - Applicable for different care settings - Broad spectrum of possible technologies to be evaluated (Health and care technologies) - Well-illustrated presentation of the model - Visualization of connections and relationships within the framework is given - Clear definition of terms and associated question within the framework - Detailed examples of usage possibilities - Classification system to interpret the results (simple, complicated, complex) - Sound science-based framework development - Limitations are sufficiently described - High transferability to a wide variety of settings through generalistic structure	- No clear focus on a specific technology type - No clear focus on a specific setting - The individual application strategy of the framework must always be reflected, as it is not a directly applicable or a formulaic instrument