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Review Article

The Effectiveness of e-Health Solutions for Aging With Cognitive Impairment: A Systematic Review

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Abstract

Background and Objectives: e-Health solutions are an innovative approach to support aging with cognitive impairment. Because technology is developing at a fast pace, the aim of this review was to present an overview of the research regarding the effectiveness of these solutions. Moreover, the availability of these solutions was examined.

Research Design and Methods: Systematic searches were conducted in 7 databases. Full texts of potentially relevant references were assessed by 2 reviewers, and discrepancies were solved through discussion. Data on study characteristics, technology type, application domain, availability, outcomes, and effects were extracted. A categorization exercise and narrative synthesis were conducted.

Results: In total, 72 studies describing 70 e-Health solutions were identified. The majority of solutions comprised cognitive training for older adults, followed by educational and supportive web platforms for caregivers. Outcomes included mainly measures of cognition, psychosocial functioning, caregiving processes, caregiver–care receiver relationship, and activities of daily living. Positive effects of cognitive training technologies were observed on cognitive functioning of older adults, as well as those of supportive web platforms on behavioral and psychological symptoms of dementia and caregiver self-efficacy. The effects of these solutions on depression in both target groups were inconclusive. The methodological quality of the studies was moderate to good. However, some important limitations were observed.

Discussion and Implications: The review identified cognitive training solutions and supportive web platforms as the most effective on a limited number of outcomes. Although other solutions seem promising, further research has to overcome methodological issues. Furthermore, solutions for leisure and reminiscence and outcomes specifically related to independent living deserve more attention.

Keywords: Technology, Digital, Outcomes, MCI, Dementia

Background and Objectives

Worldwide, the segment of older adults is growing at a fast pace (World Health Organization [WHO], 2018). Even the proportion of the oldest-old (85 and older) is growing exceedingly fast and this evolution is estimated to continue through the following decades (Eurostat, 2018). Advanced age is one of the most important risk factors for neurocognitive disorders such as mild cognitive impairment (MCI) and dementia (Alzheimer's Association, 2016; Artero et al., 2015). As a result of the associated functional decline and increased dependency, older adults with MCI or dementia have a four- to sixfold risk of institutionalization compared to cognitively healthy older adults (Löfqvist et al., 2013). However, older adults are often hesitant and reluctant toward relocation and prefer to age at home. This preference is defendable, even in older adults with dementia, because recent research shows the negative effects of relocation on well-being in this group (Ryman et al., 2018). Although it is clear that living at home as long as possible is desirable for many reasons, the implementation can be challenging. This is particularly the case for older adults with cognitive impairment, as the functional decline they face may gradually lead to loss of autonomy in major life domains (Lau, Parikh, Harvey, Huang, & Farias, 2015). Engagement in meaningful activities and memory support and social participation are important need domains (van der Roest et al., 2009). Furthermore, caregiver burden is also important to consider, as symptoms of distress and depression in caregivers are prevalent and interact negatively with the care receiver's ability to live independently (Afram et al., 2014).

To address these needs, many innovative approaches have been developed. Among them are those emerging from the research field of e-Health. The latter is an overarching term covering a multitude of information and communication technologies (ICTs) applied to health care and health promotion (WHO, 2019). In recent years, the development of e-Health solutions is more and more targeted toward older adults with cognitive impairment, with a focus on support of memory, social contact, daily activities, and safety (Kim, Gollamudi, & Steinhubl, 2017).

First, cognitive training applications and assistive technologies such as electronic memory aids are solutions that compensate for impaired cognitive function (Blackman et al., 2016; Kim et al., 2017; Meiland et al., 2017). These can be computer-based as well as based on mobile technologies such as tablets, hand-held devices, and wearables (Ienca et al., 2017). Video games combining cognitive gameplay with physical exercise have also been developed and are referred to as exergames (Chao, Scherer, & Montgomery, 2015). Another recent technology for cognitive training is virtual reality (VR). This uses a computer environment to simulate the sensation of a real physical world (Benoit et al., 2015). Lastly, cognitive training can be delivered through a brain–computer interface (BCI), which is a communication method solely based on neural activity (Vallabhaneni, Wang, & He, 2005). Adapted video- or telephone-based interventions can be used to engage in remote care and facilitate social connectedness. These are referred to as "telemedicine" or "telehealth" (Lauriks et al., 2007). To support activities of daily living (ADL) and safety in cognitively impaired older adults, monitoring technologies are developed (Blackman et al., 2016; Meiland et al., 2017). These detect changes in activities associated with cognitive deterioration and major safety incidents, for example, flooding or a house fire. Detection of wandering in older adults with dementia is possible with sensors or through geotracking with Global Positioning System-based systems (Blackman et al., 2016; Meiland et al., 2017). Moreover, mobile localization applications can support the autonomous spatial orientation in cognitively impaired older adults and subsequently the ability to live independently (Kim et al., 2017).

Development of e-Health solutions is also targeted at informal caregivers (ICs). The ones most frequently described are mobile applications, web-based portals, and telehealth solutions delivering education, support, and stress management training (Chi & Demiris, 2015; Kim et al., 2017). Moreover, multimedia solutions for art viewing or music experiencing targeted at the caregiver–care receiver dyad are reported to facilitate communication and enhance the relationship (Tyack & Camic, 2017). Furthermore, solutions targeting the psychological needs of caregivers, for example, technology-based equivalents of cognitive behavioral therapy, show promising results (Scott et al., 2015).

It appears that many different e-Health technologies are being developed to support cognitively impaired older adults and ICs. However, it is unclear how well developed these technologies are. Moreover, according to Schulz and colleagues (2015), these solutions are getting marketed despite the lack of convincing evidence regarding their effectiveness. Furthermore, the studies in which these solutions are tested are reported to have methodological limitations (Meiland et al., 2017). Considering the pace in which new innovative technologies are developed, the tenability of research findings is debatable. Therefore, the aim of the present review was to comprehensively review the current state-of-the-art of research on e-Health for community-dwelling older adults with cognitive impairment and ICs and to give an overview of the effectiveness and availability of e-Health solutions.

Research Design and Methods

This systematic review was conducted in accordance with the PRISMA guidelines (see Supplementary File S1).

Search Strategy

Seven electronic databases were searched, including PubMed, Web of Science, PsycINFO, CINAHL, the

Cochrane Library, Embase, and Sociological Abstracts (last search on September 30, 2018). The search strategies were developed by an information specialist and included keywords related to the target population (e.g., dementia and cognitive impairment) and to types of interventions or technologies (e.g., telehealth, assistive technology, and multimedia; see Supplementary Table S2). To guarantee compatibility with the different entry formats of the databases, adaptations to this search strategy were made. To minimize outdated publications (e.g., those published before the 5 years preceding the date of search), a publication date filter was set, excluding articles published before 2013.

Eligibility Criteria

Studies were included if (1) at least one e-Health solution was described and evaluated on its effectiveness; (2) the solution targeted (a) community-dwelling older adults at risk for cognitive impairment, older adults with MCI (i.e., persons with MCI [PwMCI]) or dementia (i.e., persons with dementia [PwD]), or (b) ICs; and (3) were written in English, Dutch, French, or Spanish (languages spoken by the authors). These publications were excluded: (1) nonempirical publications, editorials, letters to editors, comments to other publications, technical notes, and reviews; (2) studies based exclusively on qualitative designs; (3) studies exclusively describing telephone technology; (4) studies on solutions targeted at professional care providers; and (5) studies published before 2013. These eligibility criteria were established following multiple discussions among all authors.

Inclusion and exclusion criteria were applied independently by at least two reviewers (S. Dequanter and M.-A. Ndiaye) at each stage. Disagreements were resolved through discussion until consensus was reached. The study selection process followed a staged method in which title, abstract, and full text were consecutively screened (Mateen, Oh, Tergas, Bhayani, & Kamdar, 2013).

Data Extraction and Synthesis

Publications that met the eligibility criteria were selected for data extraction and analyses. Data extraction was conducted by the first author (S. Dequanter). Extracted data included publication year, country of the first author, journal type (healthcare oriented, technology oriented, or hybrid), technology type of the solution, application domain of the solution, name of the solution (if applicable), sample and sample size, outcome variables, and outcome effects. The categorization of technology types was conducted according to the intervention's underlying hardware or software architecture (i.e., web platform, mobile application, etc.). The categorization of solutions by application domain emphasized functionality and followed the taxonomy of van Bronswijk, Bouma, and Fozard (2002). To determine the availability of the solutions, systematic Google searches were conducted (last search on December 13, 2019). The strategies included the solution names retrieved from the publications as keywords combined with terms referring to the sample population (e.g., "dementia" or "mild cognitive impairment") and sometimes combined with meaningful terms from the publication title (e.g., "cognitive stimulation") to specify the search more. These searches are listed in Supplementary Table S3. Of the solutions for which one of the first 10 search results suggested commercialization, the commercial names were listed. Outcome variables were extracted and inductively categorized into outcome concepts. Outcome effects were labeled good if clinically or statistically significant intervention effects were reported or labeled as neutral or negative in case of no or adverse effects, respectively. Because a multitude of outcome variables were expected, we opted for a narrative synthesis of study findings instead of a meta-analysis with effect size calculations.

Methodological Assessment

The methodological quality of the publications was assessed with the Mixed Methods Appraisal Tool (MMAT; Hong et al., 2018). This validated tool can be used to assess the methodological quality of quantitative, qualitative, and mixed-methods studies according to five criteria that depend on the study design. Summative total scores were calculated by dividing the number of criteria met by 5 and could range between 0% (no quality), 20% (very low quality), 40% (low quality), 60% (moderate quality), 80% (considerable/good quality), and 100% (very high quality). By calculating a score for each methodological criterion, problematic methodological aspects were discovered. However, no minimal criteria were set for inclusion and no studies were excluded based on this quality assessment. All publications were independently assessed by teams of two authors and critically discussed until consensus was reached.

Results

Selection of Publications

Figure 1 depicts the PRISMA flow diagram of the study selection process. The systematic search identified 13,424 publications. After removing duplicates, 12,988 publications were eligible for screening. After first- and second-level screening of title and abstract, 143 publications were retained and consecutively assessed on eligibility based on their full text. Of these, 73 publications were included. One additional associated publication was identified through reference tracking (Cavallo, Hunter, van der Hiele, & Angilletta, 2016). In total, 74 publications were included in the data analysis and synthesis of this review. Two publications stemmed from the same study but focused

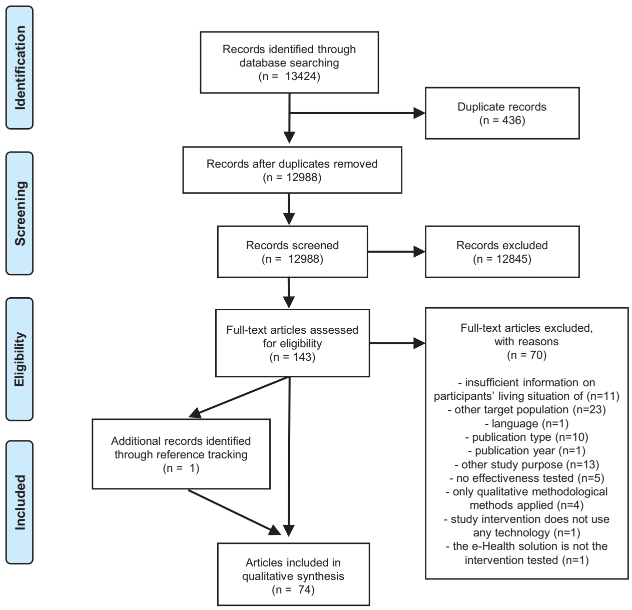

Figure 1. PRISMA flow diagram of the study selection process.

on separate participant samples and outcomes (Chandler et al., 2017; Cuc et al., 2017), and two publications were causally related because one was a follow-up study of the other (Cavallo & Angilletta, 2018; Cavallo et al., 2016). Thus, these 74 publications reflected 72 unique studies and comprised 70 unique e-Health interventions.

Study Characteristics

The characteristics of the 74 included publications are presented in Table 1. The majority of the articles were published in Europe (n = 35, 47%), followed by North America (n = 29, 39%) and East Asia (n = 6, 8%). Furthermore, a few (n = 4, 5%) studies were conducted in Australia. We observed an increase of total publications from 2013 (n = 8, 11%) up and until 2017 (n = 16, 22%). For the publication year 2018 (until September), we identified 12 publications (16%). Most articles were published in healthcare-oriented journals (n = 60, 81%), as opposed to technology-oriented (n = 1, 1%) and hybrid journals (n = 13, 18%).

Altogether, a total of 4,481 participants were recruited. After a dropout of 1,060 participants, a total of 3,421 were included in the descriptive analyses. The median sample size was n = 35, with the largest identified sample size being n = 245 (Blom, Zarit, Groot Zwaaftink, Cuijpers, & Pot, 2015) and the smallest being n = 1. The latter was the case in several case studies (El Haj, Gallouj, & Antoine, 2017; Foloppe, Richard, Yamaguchi, Etcharry-Bouyx, & Allain, 2015; White & Moussavi, 2016). Most studies included exclusively ICs (n = 27, 37%), PwMCI (n = 19, 26%), or PwD (n = 16, 22%). However, some studies included mixed samples consisting of PwD and ICs (n = 9, 12%), PwMCI and ICs (n = 1, 1%), and PwD and PwMCI (n = 1, 1%).

The applied study designs (n = 72) were mostly quantitative, including randomized controlled trials (RCTs; n = 31, 43%) and nonrandomized quantitative (NRQ) studies (n = 36, 50%). The latter consisted mainly of studies with a pre–post design (n = 33) with outcome variables measured at baseline (pretest) and after exposure to the intervention (posttest) within the same participant group. Three of the NRQ studies were nonrandomized controlled trials in which the e-Health solutions were compared to an alternative intervention. In the majority of RCTs (84%), the e-Health solutions were also compared to an alternative intervention (n = 17) or to usual care (n = 9). Only five RCTs compared results of the intervention group with a group that received no intervention, for example, a waitlist control group. No case studies (n = 1) or small sample studies (n < 10) were identified in the sample of RCTs. However, in the sample of NRQ studies, 3 case studies and 10 small sample studies were identified (n = 13, 36%). Furthermore, five studies (7%) had a mixed-methods study design. None of these were case studies or small sample studies. The majority of these mixed-methods studies (n = 4, 80%) combined qualitative research methods such as interviews and focus groups with an NRQ design. One study used a combination of qualitative methods and RCT (Duggleby et al., 2018). Of these mixed-methods studies, one had a sequential explanatory design in which the qualitative findings served to further explain the quantitative findings (Barbabella et al., 2016). All other mixed-methods studies had a concurrent design, in which the quantitative and qualitative data are gathered during the same time period and the findings are compared or analyzed together.

Methodological Quality of the Studies

The methodological quality assessment using the mixed-methods appraisal tool (MMAT) of the total of 72 studies is given in Table 1 and more details are depicted in Supplementary Tables S4 and S5. Overall, the majority of studies (n = 51, 70%) obtained MMAT scores ranging from moderate to excellent. Of the 31 RCTs, half were evaluated as moderate to excellent, as reflected by eight studies with a score of 60%, four with a score of 80% and four with a score of 100%. Of the poorer scoring RCTs (n = 15), seven scored 40% and eight scored 20%. The items most frequently scored negative in RCTs were those referring to adherence of participants to the assigned interventions (n = 18, 58%) and to the blinding of the outcome assessors in the studies (n = 18, 55%).

Compared to the RCTs, the NRQ studies (n = 36) and mixed-methods studies (n = 5) obtained better MMAT scores. Only 6 (17%) of the 36 NRQ studies scored less than 60% (moderate). However, on item level, the majority of these NRQ studies (n = 32, 89%) obtained a negative score for the consideration of confounding bias. Furthermore, 21 (58%) of these studies scored 60% and 8 (22%) scored 80%. One study (3%) obtained an excellent

Table 1. Data Extracted From the Selected Studies

First author, year, country	Journal type	Technological intervention, comparison (C)	Intervention name	Marketed; commercial name, if yes	Sample (subsample)[a]; sample size	Study design	MMAT score	Outcomes (effects)	Application domain[b]
Anderson-Hanley, 2018, USA	H	Exergame cognitive training, C1: exergaming alone C2: neurogaming alone	ACES	No	PwMCI (83); 46	RCT	1	Mobility (+)	HS
Astell, 2018, UK	H	AT multimedia device for reminiscence, C: —	CIRCA	No	PwD; 143	NRQ	4	Cognition (+), QoL (+), perceived health (±)	WL
Austrom, 2015, USA	H	Telehealth support, C: —	—	—	IC; 4	NRQ	2	Burden (±), depression (±), anxiety (+), QoL (+)	HS, CG
Bahar-Fuchs, 2017, Australia	H	Tailored computerized cognitive training, C: nontailored computerized training	—	—	PwMCI (34)+IC; 44	RCT	3	PwMCI: cognition (+), apathy (+), iADL (±); IC: burden (+)	HS
Barbabella, 2016, Italy	H + T	Web platform for support, C: —	InformCare Web	Yes; InformCare	IC; 94	MM	4	Burden (±), social support (−), perceptions on caregiving (−)	HS, CG
Blom, 2015, The Netherlands	H + T	Web platform for support, C: e-bulletin	Mastery over Dementia	No	IC; 245	RCT	3	Depression (+), anxiety (+)	HS, CG
Boots, 2018, The Netherlands	H + T	Web platform for support, C: waiting list	Partner in Balance	No	IC; 68	RCT	3	Stress (±), depression (±), anxiety (±), mastery (+), self-efficacy (+), QoL (+)	HS, CG
Boots, 2016, The Netherlands	H + T	See Boots, 2018, C: —	See Boots, 2018	See Boots, 2018	IC; 10	NRQ	3	Self-efficacy (+), goal attainment (+)	
Caffo, 2014, Italy	H	AT for orientation/navigation, C: backward chaining	—	—	PwD; 4	NRQ[c]	3	Task performance (indoor traveling) (+)	HDL, MT
Camateros, 2016, Canada	H	Web platform for support, C: —	—	—	IC; 31	NRQ	3	Emotion regulation (+), management of BPSD (+)	HS, CG
Cavallo, 2018, Italy	H	Computerized cognitive training, C: computer time	—	—	PwD; 72	RCT	5	Cognition (+)	HS

Table 1. Continued

First author, year, country	Journal type	Technological intervention, comparison (C)	Intervention name	Marketed; commercial name, if yes	Sample (subsample)[a]; sample size	Study design	MMAT score	Outcomes (effects)	Application domain[b]
Cavallo, 2016, Italy	H	See Cavallo, 2018							
Chandler, 2017, USA	H	Computerized training for activity reminding, C: calendar training	Brain Fitness	No	PwMCI; 77	RCT	2	Cognition (±), self-efficacy (±)	HS, HDL
Cristancho-Lacroix, 2015, France	H+T	Web platform for education, C: information (UC)	Diapason	No	IC; 49	RCT	2	Burden (±), stress (±), depression (±), self-efficacy (±), management of BPSD (±)	HS, CG
Cuc, 2017, USA	H	See Chandler, 2017			IC; 77			Burden (±), depression (+), anxiety (±), QoL (±)	
Czaja, 2013, USA	H	Telehealth support, C1: attention control C2: information only	—	—	IC; 99	RCT	4	Burden (+), depression (±), social support (+), perceptions on caregiving (+)	HS, CG
Damirchi, 2018, Iran	H	Computerized cognitive training, C1: physical training C2: mixed training C3: waiting list	—	—	PwMCI; 44	RCT	1	Cognition (+)	HS
Djabelkhir, 2017, France	H	Computerized cognitive training, C: cognitive engagement	—	—	PwMCI; 19	RCT	5	Cognition (±), anxiety (±), depression (±), QoL (±), self-esteem (±)	HS
Duggleby, 2018, Canada	H + T	Web platform for support, C: educational control (UC)	MT4C	No	IC; 154	MM	3	Self-efficacy (±), QoL (±), hope (+)	HS, CG
El Haj, 2017, France	H	Mobile application for personal organization, C: —	Google Calendar	Yes[d]; Google Calendar	PwD; 1	NRQ	3	Task performance (remembering tasks) (+)	HS, HDL
Finn, 2014, Australia	H	Computerized cognitive training, C: —	—	—	PwMCI; 2	NRQ	3	Cognition (±), anxiety (+), depression (+), perceived cognitive failures (+)	HS

Table 1. Continued

First author, year, country	Journal type	Technological intervention, comparison (C)	Intervention name	Marketed; commercial name, if yes	Sample (subsample)[a]; sample size	Study design	MMAT score	Outcomes (effects)	Application domain[b]
Foloppe, 2015, France	H	VR cooking training, C: —	—	—	PwD; 1	NRQ	3	Cognition (±), task performance (cooking) (+), QoL (±)	HS, HDL
Fowler, 2016, USA	H	Web platform for support, C: sleep actigraphy (UC)	Virtual Healthcare Network	No	IC; 28	RCT	2	Self-efficacy (+), sleep quality (±)	HS, CG
Gaitán, 2013, Spain	H	Computerized cognitive training, C: traditional training (UC)	—	—	PwD + PwMCI; 34	RCT	3	PwD/PwMCI: cognition (±), anxiety (+), depression (±), decision making (+)	HS
Gaugler, 2015, USA	H	Web platform for support, C: —	CARES for Families	Yes; CARES Dementia Care for Families	IC; 41	NRQ	3	Dementia care knowledge (+)	CG
Gigler, 2013, USA	H + T	Computerized cognitive training, C: —	Cognifit	Yes; Cognifit	PwMCI (7); 18	NRQ	4	Cognition (+), IADL (±), task performance (±)	HS
Gonzalez-Palau, 2014, Spain	H	Computerized cognitive training, C: —	Long Lasting Memories	No	PwMCI (11); 44	NRQ	4	Cognition (+), depression (+)	HS
Gooding, 2016, USA	H	Computerized cognitive training, C1: traditional training (UC) C2: nontested games and puzzles	—	—	PwMCI; 74	RCT	1	Cognition (+), depression (+)	HS
Griffiths, 2018, USA	H	Web platform for support, C: —	Tele-Savvy	No	IC; 30	NRQ	3	Burden (+), depression (+), mastery (+), observed BPSD in PwD/PwMCI (+)	HS, CG
Griffiths, 2016, USA	H	See Griffiths, 2018			20	NRQ	2		
Han, 2017, Korea	H	Mobile application cognitive training, C: UC	USMART	No	PwMCI; 57	RCT	5	Cognition (+), subjective memory complaints (±), depression (±)	HS
Hattink, 2015, The Netherlands	H + T	Web platform for education, C: Waiting list	STAR	No	IC (72); 43	RCT	1	Burden (±), QoL (±), dementia care knowledge (±), caregiver competence (+), attitude toward dementia (±), empathy (+), approaches toward dementia (+)	HS, CG

Table 1. Continued

First author, year, country	Journal type	Technological intervention, comparison (C)	Intervention name	Marketed; commercial name, if yes	Sample (subsample)[a]; sample size	Study design	MMAT score	Outcomes (effects)	Application domain[b]
Hughes, 2014, USA	H	Exergame cognitive training, C: health education	—	—	PwMCI; 59	RCT	2	Cognition (±), IADL (±), mobility/gait speed (±), subjective social functioning (±), subjective cognitive ability (±)	HS
Hwang, 2017, Korea	H	VR cognitive training, C: traditional training (UC)	—	—	PwMCI; 20	RCT	1	Cognition (+), mobility/balance (+)	HS
Hyer, 2016, USA	H	Computerized cognitive training, C: nonadaptable training	Cogmed	Yes; Cogmed	PwMCI; 24	RCT	3	Cognition (+), IADL (+), perceived cognitive failures (+)	HS
Imbeault, 2016, Canada[e]	H	Mobile application personalized agenda, C: —	AP@LZ	No	PwD + IC; 2	NRQ	3	PwD: cognition (±), depression (±); IC: burden (±)	HS, HDL
Imbeault, 2016, Canada[f]	H	Mobile application calendar, C: —	—	—	PwD + IC; 68	NRQ	3	PwD: cognition (±), depression (±); IC: burden (±)	HS, HDL
Kajiyama, 2017, USA	H	Web platform for support, C: —	Webnovela Mirela	Yes; Webnovela Mirela	IC; 19	NRQ	3	Stress (+), depression (+), dementia care knowledge (+)	HS, CG
Kajiyama, 2013, USA	H	Web platform for support, C: education only	iCare	No	IC; 103	RCT	1	Stress (+), depression (±), QoL (±), caregiver bother (±)	HS, CG
Kim, 2015, Korea	H + T	Telehealth support and psychotherapy, C: clinic visits (UC)	—	—	PwD; 188	NRQ[c]	3	Cognition (+)	HS
Knoefel, 2018, Canada	H	Computerized cognitive training, C: word/number puzzles	BrainHQ	Yes; BrainHQ	MCI; 17	RCT	2	Cognition (±), task performance (cognitive training games performance) (±)	HS
Kwok, 2014, China	H	Web platform for support with CBT, C: —	—	—	IC; 26	NRQ	4	Burden (+), self-efficacy (+), observed BPSD in DEM/MCI (+)	HS, CG
Laird, 2018, UK	H + T	Mobile application for reminiscence, C: —	InspireD	No	PwD + IC; 58	NRQ	4	PwD: mutuality (+), quality of PwD–IC receiver relationship (+), well-being (+); IC: mutuality (±), quality of PwD–IC relationship (±), well-being (±)	WL

Table 1. Continued

First author, year, country	Journal type	Technological intervention, comparison (C)	Intervention name	Marketed; commercial name, if yes	Sample (subsample)[a]; sample size	Study design	MMAT score	Outcomes (effects)	Application domain[b]
Lancioni, 2017, Italy	T	Mobile application with activity reminders, C: —	—	—	PwD; 8	NRQ	3	Task performance (performing independent activities) (+)	HS, HDL
Lanza, 2014, Germany	H	AT for orientation/ navigation, C: —	—	—	PwD; 14	NRQ	3	Task performance (navigation) (±)	HDL, MT
Lee, 2013, China	H	Computerized cognitive training, C1: traditional training (UC) C2: waiting list	—	—	PwD; 19	RCT	4	Cognition (+), depression (+), IADL (±)	HS
Leng, 2014, Australia	H	Mobile applications for leisure, C: —	—	—	PwD; 6	NRQ	3	Well-being (+)	WL
Mansbach, 2017, USA	H	Computerized cognitive training, C: no intervention	Memory Match	Yes; Memory Match	PwMCI; 38	RCT	5	Cognition (+), subjective cognitive ability (+)	HS
Maseda, 2013, Spain	H	Computerized cognitive training, C: —	—	—	MCI (9); 101	NRQ	3	Cognition (+)	HS
McKechnie, 2014, UK	H + T	Web platform for support, C: —	—	—	IC; 61	MM	3	Depression (±), anxiety (±), quality of PwD–IC relationship (±)	HS, CG
Megges, 2017, Germany	H	Mobile application for locating/ tracking, C: —	—	—	PwD + IC; 34	NRQ	4	Burden (±), self-efficacy (±)	MT, CG
Mendoza Laiz, 2018, Spain	H	BCI cognitive training, C: —	NeuronUp	Yes; NeuronUp	PwMCI; 32	NRQ	2	Cognition (+)	HS
Navarro, 2016, Mexico	H + T	AT with activity reminders and games, C: —	Answerboard	No	PwD + IC; 4	NRQ	3	PwD: apathy (+); IC: burden (+), self-efficacy (+), observed BPSD in DEM (+)	HS, HDL, CG, WL
Nunez-Naveira, 2016, Spain	H	Mobile application and platform for support, C: no intervention	UnderstAID	No	IC; 61	RCT	3	Depression (+), caregiver competence (±), caregiving satisfaction (+)	HS, CG
O'Connor, 2014, USA	H	Web platform (virtual environment) for support, C: —	—	—	IC; 7	NRQ	3	Stress (+), depression (±), loneliness (±)	HS, CG
Olsson, 2015, Sweden	H	AT for locating/ tracking, C: —	—	—	PwD + IC; 6	NRQ	1	PwD: task performance (number outdoor activities) (+), well-being (±); IC: stress (±), well-being (±)	HS, HDL, MT, CG

Table 1. Continued

First author, year, country	Journal type	Technological intervention, comparison (C)	Intervention name	Marketed; commercial name, if yes	Sample (subsample)[a]; sample size	Study design	MMAT score	Outcomes (effects)	Application domain[b]
Pagan-Ortiz, 2014, USA	H	Web platform for support, C: printed education	Cuidate Cuidador	No	IC; 23	NRQ[c]	2	Burden (±), mastery (±), social support (±)	HS, CG
Pleasant, 2017, USA	H	Web platform for education, C: —	CARES	Yes; CARES Dementia Basics	IC (14); 51	NRQ	3	Dementia care knowledge (+), caregiver competence (+), person-centered attitude (±)	HS, CG
Rogalski, 2016, USA	H	Telehealth aphasia support, C: —	—	—	PwD + IC; 62	NRQ	2	PwD: communication skills (+), self-efficacy (+)	HS, CG
Savulich, 2017, UK	H	Mobile application cognitive training, C: clinic visits (UC)	Game Show	No	PwMCI; 42	RCT	3	Cognition (+), apathy (+)	HS
Schaller, 2016, Germany	H + T	Web platform for education/support, C: —	eHealthMonitor	No	IC; 25	MM	5	Burden (±), QoL (±)	HS, CG
Serino, 2017, Italy	H	VR cognitive training, C: traditional training (UC)	—	—	PwD (20); 26	RCT	1	Cognition (+)	HS
Steffen, 2016, USA	H	Telehealth support, C: basic education	—	—	IC; 66	RCT	4	Depression (±), anxiety (+), self-efficacy (+), caregiver bother by BPSD (+), negative affect (+)	HS, CG
Tchalla, 2013, France	H	AT for fall prevention, C: fall program	—	—	PwD; 96	RCT	3	Mobility (indoor falls) (+)	HS, HDL, MT
Torkamani, 2014, UK	H	Web platform for support, C: no intervention	ALADDIN	No	PwD + IC; 60	RCT	1	PwD: cognition (±), depression (±), IADL (±); IC: burden (±), stress (±), depression (±), QoL (+), observed BPSD in DEM (±)	HS, CG
Tyack, 2015, UK	H	Mobile application for art-viewing, C: —	—	—	PwD + IC; 24	MM	5	PwD: well-being (±), happiness (±), interestedness (±); IC: well-being (±)	WL
Van Mierlo, 2015, The Netherlands	H	Web platform for support, C: brochures (UC)	DEM-DISC	No	IC; 73	RCT	2	PwD: QoL (±)[g]; IC: stress (±), QoL (±), observed BPSD in DEM (+), caregiver competence (±)	HS, CG
Wall, 2018, USA	H	Exergame cognitive training, C: —	iPACES/Memory Lane	No	PwMCI; 14	NRQ	3	Cognition (+)	HS

Table 1. Continued

First author, year, country	Journal type	Technological intervention, comparison (C)	Intervention name	Marketed; commercial name, if yes	Sample (subsample)[a]; sample size	Study design	MMAT score	Outcomes (effects)	Application domain[b]
Werner, 2018, Greece	H	Robotic rollator, C: nonassisted rollator	MOBOT Rollator	No	PwMCI (20); 42	RCT	2	Task performance (navigation) (+)	HS, MT
White, 2016, Canada	H	VR navigational training, C: —	—	—	PwD; 1	NRQ	3	Task performance (navigation) (+)	HDL, MT
Wijma, 2018, The Netherlands	H	VR dementia experience simulation tool, C: —	Through the D'mentia Lens	Yes; Dementiebril	IC; 35	NRQ	4	Burden (±), caregiver competence (+), empathy (+), quality of DEM–IC relationship (+), person-centered attitude (±)	HS, CG
Wiloth, 2018, Germany	H	Exergame cognitive training, C: nonspecific exercises	Physiomat	No	PwD; 99	RCT	4	Cognition (+)	HS
Yasuda, 2013, Japan	H	Telehealth reminiscence and support through activity reminding, C: —	—	—	PwD; 4	NRQ	4	Task performance (completion rate of tasks as cooking and medicine taking) (±), psychological stability (±)	HS, HDL, CG, WL
Yi, 2015, Australia	H	AT for orientation/ navigation, C: —	—	—	PwD; 28	NRQ	5	Task performance (navigation while driving) (+)	HS, MT

Note: H = healthcare-oriented journal; T = technologically oriented journal; H + T = hybrid journal integrating healthcare and technological aspects; AT = assistive technology; VR = virtual reality; RCT = randomized controlled trial; NRQ = nonrandomized quantitative study; MM = mixed methods; PwD = people with dementia; PwMCI = people with MCI; IC = informal caregiver(s); MMAT = Mixed Methods Appraisal Tool; MMAT score 1 = 20% (very low quality), 2 = 40% (low quality), 3 = 60% (moderate quality), 4 = 80% (good quality), 5 = 100% (very high quality); +: positive effect, ±: neutral effect, –: negative effect; UC = usual care; CBT = cognitive behavioral therapy; BCI = brain–computer interface; BPSD = behavioral and psychological symptoms of dementia; QoL = quality of life; iADL = instrumental activities of daily living.

[a]Number of participants of the sample that were involved as a subsample combined with other participants (e.g., healthy older adults for PwMCI and PwD or ICs of older adults with a chronic disease other than dementia).

[b]As proposed by van Bronswijk and colleagues (2002), HS = health and self-esteem; HDL = housing and daily living; MT = mobility and transport; CG = communication and governance; WL = work and leisure.

[c]These NRQ studies were based on nonrandomized trials. All other (nonindexed) NRQ studies were based on pre–post designs.

[d]This solution was marketed and commercialized before the start of the study.

[e]See Imbeault et al., 2016.

[f]See Imbeault, Langlois, Bocti, Gagnon, & Bier, 2016.

[g]Proxy rated by informal caregivers.

score (Yi, Lee, Parsons, & Falkmer, 2015). All of the mixed-methods studies (*n* = 5) scored moderate to excellent on methodological quality.

e-Health Solutions

Seventy (*n* = 70) unique e-Health solutions were identified. The Venn diagram in Figure 2 shows the categorization of the solutions by application domain according to van Bronswijk and colleagues (2002). All application domains were represented in our sample; however, considerable overlap between the domains was observed. In total, 61 (87%) solutions were developed to enhance health and self-esteem in the target groups. One third (*n* = 23) of them focused on cognitive training. The main targeted population of these cognitive training solutions were PwMCI (*n* = 18), PwD (*n* = 4), or both (*n* = 1). Another solution in this domain reported a telehealth application for delivering education and support to PwD (Kim, Jhoo, & Jang, 2015). A total of 13 solutions (19%) were identified in the domain of housing and daily living which mainly focused on PwD (*n* = 11, 85%). These consisted of solutions for personal organization (*n* = 3) and solutions for training and support of ADL (*n* = 3; e.g., cooking, medication management, and daily chores). All of these were identified at the intersection with the domain of health and self-esteem. A smaller number of solutions (*n* = 8, 11%) were identified in the mobility and transport domain. Most of these solutions were also identified in the previous domains and focus on the support of spatial orientation and autonomous navigation (*n* = 6). Locating and tracking solutions (*n* = 2) were also identified in this domain. The majority of these solutions were, again, mainly targeted at PwD (*n* = 7, 88%) as only one solution (*n* = 1, 12%) was tested with PwMCI. Solutions situated in the domain of work and leisure were in the minority (*n* = 6, 9%). These were mainly focused on PwD and dyads of PwD and ICs and comprise solutions for leisure activities such as music listening and art viewing, as well as for reminiscence activities. A great number of solutions were identified in the domain of communication and governance (*n* = 30, 43%). With the exception of a therapeutic speech-language web platform for cognitively impaired persons with aphasia (Rogalski et al., 2016), most of these (*n* = 26) consisted of solutions targeted at education and support of ICs (including web platforms, video-based telehealth interventions, a mobile application, and a VR tool that simulates the dementia experience). Furthermore, all but one (Gaugler, Hobday, Robbins, & Barclay, 2015) of these solutions were situated at the intersection with the domain of health and self-esteem.

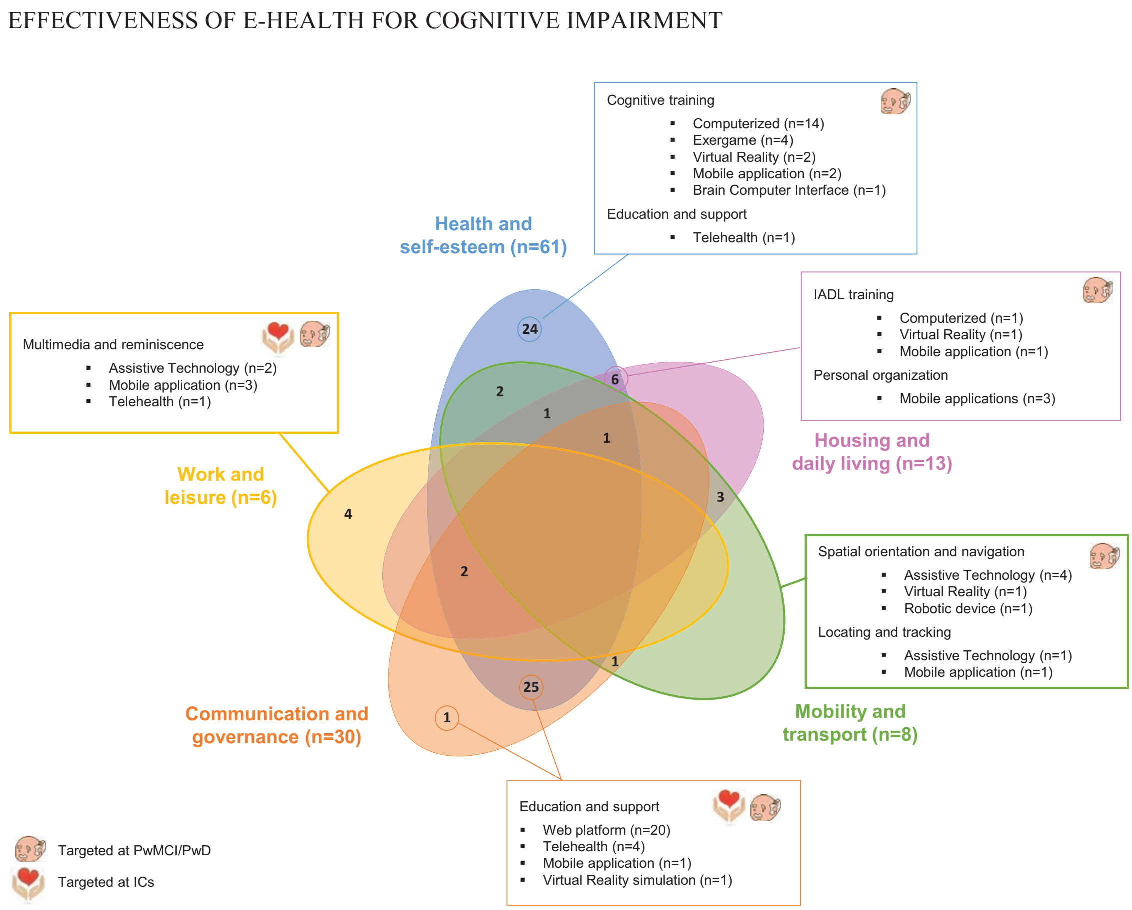

Figure 2. Categorization of the e-Health interventions by application domain.

Outcomes

In total, 57 publications (77%) reported at least one positive outcome effect. These were observed in 29 NRQ studies, 27 RCTs, and 1 mixed-method study. These had reasonably high methodological quality, as reflected by 79% moderate to high MMAT scores in NRQ studies, 62% in RCTs, and the good quality of the mixed-method study. Moreover, sufficiently large sample sizes were observed: with the mixed method, all of the RCTs and 62% of the NRQ studies having sample sizes greater than 10. NRQ studies with samples less than 10 had good methodological quality. Aspects related to psychosocial functioning were the most often studied outcomes in all target groups.

Outcomes in Cognitively Impaired Older Adults

A total of 98 outcome variables reflecting 23 unique outcome concepts focusing on cognitively impaired older adults were identified (Table 2). The most prevalent outcomes were those on psychosocial functioning (*n* = 36, 37%) and cognition (*n* = 35, 36%). With regard to psychosocial functioning, symptoms of depression (*n* = 10), caregiver-rated behavioral and psychological symptoms of dementia (BPSD; *n* = 6), quality of life (QoL), and well-being (both *n* = 4) were the most prevalent. In total, half of the findings with regard to effects on psychosocial functioning were positive (*n* = 18, 50%). The majority of these positive effects were reported for BPSD (*n* = 5, 14%), which resulted mainly from supportive web platforms targeted at IC (*n* = 4) and from an assistive cognition system (*n* = 1).

Table 2. Outcome Measures and the Associated Intervention Effects in Cognitively Impaired Older Adults and Informal Caregivers

	PwMCI/PwD				ICs		
Outcome variables	+	±	−	Outcome variables	+	±	−
Psychosocial functioning	18	18	0	Psychosocial functioning	27	31	1
Depression	4	6	0	Depression	6	9	0
BPSD[a]	5	1	0	Negative affect	1	0	0
QOL	1	3	0	Self-efficacy	6	3	0
Well-being	2	2	0	QOL	3	6	0
Apathy	3	0	0	Stress	3	5	0
Anxiety	2	1	0	Anxiety	4	3	0
Self-efficacy	1	1	0	Well-being	0	3	0
Self-esteem	0	1	0	Perceived social support	1	1	1
Happiness	0	1	0	Hope	1	0	0
Interestedness	0	1	0	Loneliness	0	1	0
Psychological stability	0	1	0	Emotion regulation/coping	1	0	0
Cognition	22	13	0	Goal attainment	1	0	0
Objective measures	19	11	0	Caregiving	22	21	1
Subjective measures				Caregiver burden	6	12	0
Perceived cognitive failures	2	0	0	Caregiver competence	4	2	0
Subjective cognitive ability	1	1	0	Dementia (care) knowledge	3	1	0
Subjective memory complaints	0	1	0	Caregiver bother by BPSD	2	1	0
Task performance	8	4	0	Mastery	2	1	0
IADL	1	5	0	Person-centered attitude	0	2	0
Mobility	3	1	0	Perceptions on caregiving	1	0	1
Social functioning	1	1	0	Management of BPSD	1	1	0
Subjective social functioning	0	1	0	Caregiving satisfaction	1	0	0
Communication skills	1	0	0	Approaches toward dementia	1	0	0
Carer–caregiver relationship	2	0	0	Attitude toward dementia	0	1	0
Quality of the relationship	1	0	0	Carer–caregiver relationship	3	3	0
Mutuality	1	0	0	Quality of the relationship	1	2	0
Perceived health	0	1	0	Empathy	2	0	0
				Mutuality	0	1	0
				Health (sleep quality)	0	1	0
Total (*n* = 98)	55	43	0	Total (*n* = 109)	51	56	2

Note: PwMCI = people with MCI; PwD = people with dementia; ICs, informal caregivers; +, positive intervention effect; ±, neutral intervention effect; −, negative intervention effect; IADL = instrumental activities of daily living; BPSD = behavioral and psychological symptoms of dementia; QOL = quality of life.

[a]BPSD proxy rated by informal caregivers.

One web platform was not able to improve BPSD. A reasonable number of positive effects were also reported on depressive symptoms (*n* = 4, 11%). These were all the result of cognitive training applications (*n* = 4). However, a higher number of interventions (*n* = 6) were not able to improve depression in this target group, including also cognitive training solutions (*n* = 3), as well as mobile applications (*n* = 2) and a web platform.

Concerning cognitive outcomes, the majority of these were objective measures represented by neuropsychological test results (*n* = 30) measuring memory, attention, reaction speed, and decision making, among others. Most studies reported positive effects on these objective cognitive outcome variables (*n* = 19, 63%), which were mainly the result of cognitive training technologies (*n* = 18). Other types of technologies, such as two mobile apps, a telehealth system, and a web platform, were not effective in improving objective cognitive functioning. Subjective cognitive measures like memory complaints and perceived cognitive ability were also described, however to a lesser extent (*n* = 5), but with similar positive results (*n* = 3, 60%) and also resulting from interaction with cognitive training technologies (*n* = 3). However, for two cognitive training technologies, no positive results were observed.

A smaller number of outcome variables (*n* = 12, 12%) was related to task performance on tasks such as cooking (Foloppe et al., 2015), medication management (Gigler, Blomeke, Shatil, Weintraub, & Reber, 2013; Yasuda, Kuwahara, Kuwabara, Morimoto, & Tetsutani, 2013), using the telephone (Gigler et al., 2013), navigating (Caffo et al., 2014; Lancioni et al., 2017; Lanza, Knörzer, Weber, & Riepe, 2014; Olsson, Engström, Asenlöf, Skovdahl, & Lampic, 2015; Werner, Moustris, Tzafestas, & Hauer, 2018; White & Moussavi, 2016), and driving (Yi et al., 2015). A few studies measured performance for remembering and completing activities and calendar events (El Haj et al., 2017; Lancioni et al., 2017). The majority of these studies (*n* = 8, 67%) reported positive effects on these outcomes. These were mainly the result of assistive technologies for support of orientation and navigation (*n* = 3) and mobile applications for activity management (*n* = 2), but also a VR cooking training, a VR navigation task, and a robotic rollator with navigation assistance. Another identified outcome concept related to functional ability was instrumental (I) ADL, as measured with IADL scales informed by the proxy report. This outcome was identified in six studies (*n* = 6, 6%). However, only one study reported positive intervention effects on IADL (Hyer et al., 2016). In this study, the positive effect consisted of the stabilization of IADL in PwMCI who completed computerized cognitive training when compared with the decline in IADL observed in the older adults of the control group.

Four studies (*n* = 4, 4%) focused on mobility as an outcome variable. These reported mainly positive effects of exergame (Anderson-Hanley et al., 2018), VR training (Hwang & Lee, 2017), and a sensor-based assistive nightlight path (Tchalla et al., 2013) on gait, balance, and fall risk, respectively. Furthermore, two studies (*n* = 2, 2%) focused on social functioning and reported mixed results (Hughes et al., 2014; Rogalski et al., 2016). With regard to the caregiver–care receiver relationship, one study (Laird et al., 2018) investigated the effects of a reminiscence tablet application on mutuality and quality of the relationship (from the perspective of PwD and PwMCI) and reported positive results. Lastly, one study used perceived general health status as a study outcome and reported moderate effects of an assistive multimedia reminiscence device (Astell, Smith, Potter, & Preston-Janes, 2018).

Outcomes in ICs

From the selected studies, a total of 109 outcome variables reflecting 27 unique outcome concepts focused on ICs were extracted (Table 2). The majority of these variables were related to psychosocial functioning (*n* = 59, 54%) with most of the interventions evaluated against symptoms of depression or negative affect (*n* = 16), self-efficacy (*n* = 9), stress (*n* = 8), and anxiety (*n* = 7). Other prevalent outcome variables were QoL (*n* = 9), well-being (*n* = 3), and perceived social support and loneliness (*n* = 4). Less than half of the studies reporting on psychosocial functioning showed positive results (*n* = 27, 46%), with the most frequently positive results observed for depression (*n* = 6) and self-efficacy (*n* = 6). These resulted mainly from interacting with supportive web platforms (*n* = 5 for depression and *n* = 4 for self-efficacy) or mobile apps (*n* = 1 for depression). Other technologies responsible for the positive effects in self-efficacy were a telehealth behavioral coaching intervention and an assistive cognition system targeted at PwD–IC dyads. However, two web platforms and one mobile application were not able to improve self-efficacy. For depression, just as in PwD and PwMCI, the beneficial effects of web platforms are shadowed by a high number of nonpositive results that, in this case, result from evaluating web platforms (*n* = 6) and telehealth interventions (*n* = 3). Most psychosocial outcomes showed only moderate intervention effects (*n* = 31, 53%). One study (Barbabella et al., 2016) even reported negative effects of a web-based psychosocial intervention on perceived social support.

The second largest outcome category (*n* = 43, 39%) comprised variables related to caregiving competencies and the caregiving process itself. These mainly referred to caregiver burden (*n* = 18) and bother (*n* = 3) and caregiver capacities described as competence (*n* = 6), mastery (*n* = 3), and BPSD management (*n* = 2). Half of the study findings (*n* = 21, 49%) reporting on these outcomes described positive intervention effects and half described moderate effects (*n* = 21, 49%). Furthermore, Barbabella and colleagues (2016) identified negative intervention effects of a web-based psychosocial intervention on caregiving perceptions. Studies that observed aspects of the caregiver–care receiver relationship (from the caregiver perspective; *n* = 6, 5%)

reported on the quality of the relationship (n = 3), as well as elements such as empathy (n = 2) and mutuality (n = 1). Of these, statistically significant positive results were only reported for empathy. Lastly, sleep quality was studied by Fowler, Kott, Wicks, and Rutledge (2016) who found moderate effects of a caregiver supportive web platform.

Availability of e-Health Solutions

Although this was not the main focus of this systematic review, we also considered the availability of e-Health solutions (Table 1). Half (n = 36, 51%) of the total identified solutions were given a name in the publications. According to the Google search results, only 10 of these (28%) were already marketed at the time of the search. One was already a marketed product (i.e., Google Calendar mobile application) at the start of the study (El Haj et al., 2017). Half of the marketed solutions were cognitive training solutions for cognitively impaired older adults (n = 5), including four computerized solutions and one based on BCI. The other half of the marketed solutions (n = 5) included web platforms for IC support (n = 4) and a VR simulation tool for ICs (n = 1). Of these 10 marketed solutions, the vast majority stemmed from moderate- to high-quality studies and all stemmed from studies with sufficiently large sample sizes.

Discussion and Implications

This systematic review provided an overview of the existing body of evidence regarding the effectiveness of e-Health solutions in older adults with cognitive impairment and ICs. Although it was to be expected considering the growing interest in the field (Schulz et al., 2015), an increase in total publications over the years was observed. This potentially reflects the increasing need to expand or complement existing dementia care services with other approaches. A considerable number (n = 70) of distinct e-Health solutions were identified. All relevant need domains (Afram et al., 2014; van der Roest et al., 2009) were identified in this review, however not in the same amount. Thereby, the most prevalent solutions were those offering cognitive training to PwMCI and PwD and solutions focused on education and support of ICs. These solutions were mainly presented as computer programs and online web platforms, respectively. This is in line with Schulz and colleagues (2015) who referred to solutions for optimizing physical and mental health as the major life domain for which the majority of e-Health technologies are being developed. As expected, solutions specifically targeted at supporting task performance and IADL in PwD were also adequately represented. As in previous research, these included solutions for personal organization, medication management, and household activities (D'onofrio et al., 2017). However, solutions for mobility and transport, such as locating and navigation support, made up a minority in our sample. This finding is surprising considering the fact that issues related to safety and wandering of PwD have been related to nursing home admission (Afram et al., 2014; Thoma-Lürken, Bleijlevens, Lexis, de Witte, & Hamers, 2018). Furthermore, solutions facilitating leisure and reminiscence in PwD were almost completely lacking in our sample. Yet research shows that reminiscence activities are important for improving affective symptoms and QoL in PwD (Lök, Bademli, & Selcuk-Tosun, 2019) and can be delivered through ICT (Lazar, Thompson, & Demiris, 2014). A possible explanation for this finding is that research in this field has mainly been focused on PwD residing in long-term care facilities, instead of on community-dwelling PwD. This might have led to the limited identification of e-Health solutions in this field.

Overall, aspects related to psychosocial functioning were the most often studied outcomes in all target groups, with depression as the most prevalent outcome. For PwMCI and PwD, QoL and well-being were also important outcome variables. This finding is particularly favorable, because recent research has pointed out the relevance and importance of these outcome variables for PwD (Øksnebjerg et al., 2018). Outcomes related to objective and subjective cognition of PwD and PwMCI were also represented. For these, mainly positive effects were reported, with the vast majority of them generated by cognitive training solutions. This is in line with recent findings of Ge, Zhu, Wu, and McConnell (2018) who described the positive effects of technology-based cognitive training, in particular on memory. Promising effects in PwMCI and PwD were also reported on BPSD and depression. These resulted from web-based IC support and cognitive training, respectively. In line with findings of Rozzini and colleagues (2007), the latter suggests additional beneficial effects of cognitive training on mood in cognitively impaired older adults. However, because these positive findings for depression are shadowed by a reasonable number of nonpositive findings, the evidence is inconclusive. This was also the case for outcomes related to functional ability (i.e., task performance and proxy-rated IADL). Moreover, no specific e-Health solutions could differentiate between positive and nonpositive results. Therefore, no conclusions with regard to improvement in these domains can be drawn yet. Future research could further investigate these effects and additionally examine the generalizability of positive effects caused by cognitive training on functional ability. Furthermore, no outcomes were directly related to living longer independently (e.g., time to institutionalization).

In ICs, depression, stress, anxiety, and self-efficacy were frequently studied psychosocial outcomes. These outcomes are particularly relevant because depression, stress, and anxiety are well-known symptoms among ICs (Joling et al., 2015). Moreover, self-efficacy is known to be a resilience factor acting as a buffer for the exposure to these symptoms (Harmell, Chattillion, Roepke, & Mausbach, 2011). Web-based caregiver support showed positive effects on self-efficacy and depression, although the evidence for the latter was inconclusive in the presence of multiple studies reporting nonpositive findings. Overall, only in half of the cases were positive effects on psychosocial outcomes observed. Possibly, improvement in highly dimensional outcomes such as QoL (Trigg, Skevington, & Jones, 2007) is too difficult to detect in studies targeting specific outcomes. These mixed findings were also reported for aspects associated with caregiving, including most frequently competence and mastery, which are particularly relevant considering their relationship with incident depression and anxiety in caregivers (Joling et al., 2015). Although the importance of supporting ICs is clear, the present review showed mixed results with regard to effects on psychosocial and caregiving related outcomes. This is comparable to previous research in which results of technology-based caregiver support were inconclusive (Godwin, Mills, Anderson, & Kunik, 2013; Jackson, Roberts, Wu, Ford, & Doyle, 2016). A possible explanation could be that the selected studies did not include sufficiently long follow-up periods to determine effects on psychosocial and caregiving outcomes (Jackson et al., 2016). Furthermore, one study reported the adverse effects of supportive intervention for ICs on caregiving perceptions and perceived social support (Barbabella et al., 2016). The authors argued that the intervention could have stimulated a new appraisal of the caregiving situation, potentially leading to the caregivers' recognition of hidden needs of support.

With regard to the identified methodological aspects, the present review identified roughly half of the studies as RCTs and half as NRQ pre–post studies. Despite the identification of a few case and small sample studies, the vast majority of studies had acceptable sample sizes. Overall, the methodological quality of the studies was good, with a few exceptions in the group of RCTs. This was mainly the result of underreporting of allocation concealment and the adherence of participants to the assigned intervention. Yet adequate implementation and documentation of these conditions are necessary to provide a true assessment of causality (Hariton & Locascio, 2018). Therefore, these are important areas of improvement for future RCTs. NRQ studies performed overall good on the MMAT. However, the majority made insufficient efforts to avoid confounding bias, thereby causing issues of validity of the results. To explain effectiveness more adequately and compete with the gold standard of RCTs, the consideration of confounding variables is an important area of improvement for NRQ studies (Hariton & Locascio, 2018). Including age, educational level, digital literacy, and level of informal care as potential confounding factors in NRQ analyses can be a good starting point. Overall, this systematic review found good quality studies with adequate samples and comparators in support of the effectiveness of e-Health interventions. These include a good amount of RCTs, which are still considered the gold standard for effectiveness research (Hariton & Locascio, 2018). However, in order to make recommendations for their use in practice, other factors, such as their cost and acceptability, need to be considered.

The present review was also interested in the extent of the commercialization of the identified solutions. Only a small minority of the identified solutions are available on the market, which contrasts with the high availability of technological solutions developed and marketed by industry (Orlov, 2020). This could be explained by the fact that empirical research in this field often stems from academic projects that do not target commercialization. Furthermore, well-designed empirical studies such as RCTs are usually large-scaled and time consuming (Schulz et al., 2015). This can explain why the more recent studies in our selection could not have been marketed by the time of the search. Moreover, this can be a barrier for developers who want to bring new solutions to the market while they are still relevant. Although using an NRQ in development is not the most ideal choice from a methodological standpoint, it is an imaginable choice when considering the limitations associated with using RCTs in practice.

To the best of the authors' knowledge, this review was the first to generate an overview of studies evaluating the effects of a broad range of e-Health solutions in PwD, PwMCI, and ICs. This particularly wide scope allowed for the most comprehensive overview of research findings in this field. However, this also inherently involved limitations for the depth of the analysis. Moreover, the generated variety of target groups, solution types, study designs, outcome measures, and measurement instruments prevented the pooling of the results into a meta-analysis. Furthermore, the present review has potentially underestimated the number of marketed solutions, because the searches were only conducted for the solutions that were already referred to with a name. This way, solutions without a name could have been potentially overlooked.

The methodological quality of the studies was assessed with the MMAT. Although this is a validated and practical tool for the appraisal of empirical studies, this appraisal process does not start with an evaluation of sample size nor of the applied methodological design. Instead, the MMAT overlooks this and appraises studies based on the applied study designs. This could have led to an overestimation of the methodological quality of case studies and could potentially have contributed to the inconclusiveness of most study findings. Furthermore, according to the MMAT, the methodological quality of a given study has to be considered with respect to its own design, making comparisons between studies difficult. The present review identified relatively more methodologically good NRQ studies and mixed-methods studies than RCTs. However, this finding does not imply that the identified RCTs are less adequate, because other dimensions are considered for judging their methodological quality (Hong et al., 2019). Furthermore, given the trend of increased publishing in this area, our decision to set the end date of the search on September 30, 2018 in order to move forward with the analyses is a limitation. Lastly, given the fast pace in which the field of e-Health research is evolving, it is important to note that some of this review's findings will become obsolete in time. Nevertheless, we believe that the identified solutions and projects with a solid empirical base can be of value for current and future research and development.

Conclusions

This systematic review identified the occurrence of e-Health solutions and outcomes in the research field of e-Health for aging with cognitive impairment. The most prevalent solutions were also those providing the most promising results. These are cognitive training solutions for PwMCI and PwD and supportive and educational web platforms for ICs. While cognitive training solutions show clear positive effects on objective and subjective cognitive functioning, they also show promising effects on depression in PwMCI and PwD. Supportive web platforms for ICs are indirectly beneficial for BPSD in PwD and are successful in increasing self-efficacy in ICs. Their effect on depressive symptoms in ICs is, however, still ambivalent. Although e-Health solutions seem promising for outcomes related to psychosocial functioning, caregiving, caregiver–care receiver relationship, functional ability, and mobility, making conclusions on their effectiveness remains difficult due to methodological diversity across studies. Future research in this field should focus on developing more e-Health solutions for leisure and reminiscence activities and should further evaluate the effectiveness of outcomes other than cognition, including outcomes related to depression and living longer independently. Lastly, the generalizability of cognitive training effects to improvements in functional ability is an interesting area for future research.

Supplementary Material

Supplementary data are available at *The Gerontologist* online.

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Conflict of Interest

None reported.

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