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The effectiveness of non-pharmacological interventions using information and communication technologies for behavioral and psychological symptoms of dementia: A systematic review and meta-analysis

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ABSTRACT

Background: Although behavioral and psychological symptoms of dementia are a global public health challenge, non-pharmacological interventions using information and communication technologies can be an affordable, cost-effective, and innovative solution.
Objectives: This study aimed to examine the effectiveness of non-pharmacological interventions using information and communication technologies on the behavioral and psychological symptoms of dementia and identify potential moderators of intervention effects.
Design: Systematic review and meta-analysis of randomized controlled trials.
Methods: A systematic literature review was conducted using PubMed, CINAHL, PsycINFO, Embase, and the Cochrane Library from May 2022. Randomized controlled trials that examined the effects of non-pharmacological interventions using information and communication technologies on the behavioral and psychological symptoms of dementia were included. A meta-analysis using a random-effects model was performed to calculate the pooled standardized mean differences between overall symptoms and each type of symptom. For moderator analyses, subgroup and meta-regression analyses were performed.
Results: Sixteen trials (15 articles) met the eligibility criteria. The interventions were grouped into activity engagement interventions using digital health that provided music and reminiscence therapy, physical exercise, social interaction interventions using social robots, and telehealth-based care aid interventions that provided coaching or counseling programs. Pooled evidence demonstrated that non-pharmacological interventions using information and communication technologies exerted a large effect on depression (SMD = −1.088, 95% CI −1.983 to −0.193, $p = 0.017$), a moderate effect on overall behavioral and psychological symptoms of dementia (SMD = −0.664, 95% CI −0.990 to −0.338, $p < 0.001$), and agitation (SMD = −0.586, 95% CI -1.130 to −0.042, $p = 0.035$). No effects on neuropsychiatric symptoms (SMD = −0.251, 95% CI -0.579 to 0.077, $p = 0.133$), anxiety (SMD = −0.541, 95% CI −1.270 to 0.188, $p = 0.146$), and apathy (SMD = −0.830, 95% CI −1.835 to 0.176, $p = 0.106$) were reported. Moderator analyses identified the mean age of the participants as a potential moderator of intervention effects.
Conclusions: Evidence from this systematic review and meta-analysis suggests that non-pharmacological interventions, using information and communication technologies, were an applicable approach to managing behavioral and psychological symptoms among older adults with dementia, with moderate to large effect sizes. However, evidence on anxiety and apathy is inconclusive due to the limited number of existing randomized controlled trials. Future studies with subgroup analyses are warranted to conclude the most effective types of intervention using information and communication technologies for each type of symptom.
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What is already known

- Non-pharmacological interventions should be considered as the first-line management for the behavioral and psychological symptoms of dementia.
- Information and communication technology has great potential as an affordable and cost-effective intervention for dementia.

What this paper adds

- Non-pharmacological interventions using information and communication technologies have been effective in reducing the behavioral and psychological symptoms of dementia.
- Participants' mean age affected the effects of non-pharmacological interventions using information and communication technologies on the overall behavioral and psychological symptoms of dementia.

1. Introduction

Dementia, a group of disorders characterized by a progressive decline in functional abilities, poses a significant global challenge to health and social care (Prince et al., 2015). The estimated total number of dementia cases worldwide was approximately 50 million in 2020 and is expected to increase threefold by 2050 with the aging population worldwide (World Health Organization, 2021). Along with cognitive and functional decline, nearly all people living with dementia experience behavioral and psychological symptoms of dementia at a point in the illness trajectory (Lyketsos et al., 2011). This refers to distressing perceptions, thought content, mood, and behaviors, such as delusions, hallucinations, agitation, depression, anxiety, and apathy (Kales et al., 2014). Behavioral and psychological symptoms of dementia have a profound effect on individuals with dementia with accelerated functional decline and disease progression (Wancata et al., 2003); their caregivers have increased caregiving burden and depression (Ornstein and Gaugler, 2012), healthcare costs with greater risk for nursing home placement (Toot et al., 2017), and healthcare utilization (Herrmann et al., 2006).

While the use of pharmacological treatments for behavioral and psychological symptoms of dementia has shown substantial side effects in frail older adults with dementia, current evidence has demonstrated the effectiveness of non-pharmacological interventions as the first-line management for behavioral and psychological symptoms of dementia (Dyer et al., 2018). Moreover, managing behavioral and psychological symptoms of dementia via non-pharmacological interventions is critical for achieving well-being and quality of life among older adults with dementia (Sanders and Scott, 2020). The current evidence of acceptable and safe non-pharmacological interventions for behavioral and psychological symptoms of dementia includes sensory practices (e.g., aromatherapy, massage, and sensory stimulation), psychosocial practices (e.g., reminiscence therapy, music therapy, pet therapy, and meaningful activities), and structured protocols for personal care, such as bathing and mouth care (Scales et al., 2018).

"Global action plan on the public health response to dementia 2017–2025" endorsed by the World Health Organization (2017) highlights the potential of information and communication technology for affordable, cost-effective, sustainable, and high-quality interventions for dementia care by improving implementation, monitoring, reporting and surveillance systems, and dissemination of the programs. The previous studies have reported a positive perception and high motivation of older adults with dementia regarding the use of technology-based interventions (Jelcic et al., 2014; Lee et al., 2013). Interventions using information and communication technologies also significantly decrease the burden, depression, and anxiety among informal caregivers of older adults with dementia (Lucero et al., 2019).

In a few prior reviews that synthesized interventions for persons with dementia and their caregivers, a wide range of technology-based non-pharmacological interventions for symptom management has been introduced (Alves et al., 2020; Ghafurian et al., 2021; Leng et al., 2020). Conversely, traditional psychosocial interventions rely on human interaction. Thus, recent trials have adopted computer-based tools and digital media to deliver music and reminiscence therapy using rich audiovisual content. The approach enables the personalization of content and recounting of personal life stories (Kerssens et al., 2015). Another technology-based intervention is an Internet-based supportive program that meets the educational and psychosocial support needs of family caregivers who care for older adults with dementia (Van Mierlo et al., 2015). Social robot intervention is another evolution of the social interaction approach. It has been designed to be a companion for and increase the social engagement of persons with dementia (Ghafurian et al., 2021). Furthermore, social robot interventions have been tested for a reduction in behavioral and psychological symptoms (Lane et al., 2016; Shibata, 2012). Finally, monitoring systems that assess the symptoms and track the treatment responses using sensing technologies, such as wearable sensors, non-wearable motion sensors, and assistive and smart home technologies, have been developed as evidence-based solutions for symptom management (Husebo et al., 2020).

The expectations for a wide array of new technologies to bring solutions for the burdens that arise from dementia care and revolutionize personalized care for behavioral and psychological symptoms of dementia (Husebo et al., 2020) require further systematic investigation. Although the potential and feasibility of the technology-based approach have been well-established, the effectiveness of such interventions remains unclear. According to our review of relevant literature, no systematic review has evaluated the effectiveness of non-pharmacological interventions using information and communication technology on behavioral and psychological symptoms of dementia. Although current evidence suggests non-pharmacological interventions as the first-line management for the challenging symptoms of dementia, there is no clear evidence of whether the non-pharmacological interventions remain effective on the symptoms when the technologies are applied.

Moreover, considering the wide range of heterogeneous symptoms targeted in individual trials and the varying intervention designs, it seems critical to evaluate for whom, on what specific symptoms, under what conditions, and what types of interventions worked. Moderator analyses, which account for heterogeneity by examining study-level variables that potentially exert a systematic influence on the intervention effects on outcome measures, can address this question (Viechtbauer, 2007). In this review, potential moderators may include subject characteristics such as age and proportion of women (Watt et al., 2019); study country and settings (e.g., community, residential care, or acute care settings) (Leng et al., 2019; Watt et al., 2019); intervention elements including intervention types, duration, intervention mode (Leng et al., 2019); and research design such as sample size and methodological characteristics including risk for bias (e.g., blinding of participants and/or experimenter with regard to the group assignment) (Viechtbauer, 2007). For example, while the individualized strategy has received attention as a critical element of non-pharmacological interventions for symptom management in dementia (Cai et al., 2020), the results on the effect of intervention mode (i.e., individualized vs. group) have been inconsistent (Leng et al., 2019).

To provide directions for future intervention efforts, this systematic review and meta-analysis aimed to 1) examine the effectiveness of non-pharmacological interventions using information and communication technologies in reducing behavioral and psychological symptoms of dementia and 2) explore the potential moderators of the intervention effects.

2. Methods

This systematic review and meta-analysis were conducted according to the updated Preferred Items for Systematic Reviews and Meta-

Analyses (PRISMA) guidelines (Page et al., 2021; Prince et al., 2013) and registered in the International Prospective Register of Systematic Reviews (PROSPERO protocol number: CRD42021258498). A protocol paper that outlines the approach for this systematic review and meta-analysis has been developed and published elsewhere (Seok et al., 2022).

2.1. Literature search

To identify relevant articles for review, a comprehensive search was conducted with the assistance of an experienced medical librarian using five databases: PubMed, CINAHL, PsycINFO, Embase, and the Cochrane Library. Based on a review of previous relevant articles, the search strategy used a combination of subject headings and keywords for the following concepts: 1) older adults, 2) dementia, 3) behavioral and psychological symptoms of dementia, 4) non-pharmacological intervention, and 5) technology. No restrictions were applied regarding publication status and date to retrieve all the relevant articles. The search was conducted from the inception of the database to May 29, 2022. The entire search strategy tailored for each database is available in the published protocol (Seok et al., 2022) and also updated in Appendix A (Supplementary Tables 1–5), which describes detailed search trails. An additional manual search through the bibliographies of the included articles and previously published relevant reviews was also conducted.

2.2. Inclusion and exclusion criteria

As described in the protocol (Seok et al., 2022), the core elements of inclusion criteria in the PICOS format were used as follows: 1) **Population:** older adults diagnosed with any type of dementia; 2) **Intervention:** non-pharmacological interventions using information and communication technologies for managing behavioral and psychological symptoms of dementia. A non-pharmacological intervention using information and communication technologies refers to one that employs information and communication technologies such as Internet-based mobile, tablet, video, sensor, and robot as one of the intervention delivery modes, which enhance collecting, processing, saving, and communicating information electronically (Lau et al., 2011); 3) **Comparison:** studies that assigned participants into either an experimental group or a control group including usual, routine, and conventional care, or waitlist as defined by the original studies; 4) **Outcomes:** effects of interventions in overall or at least one type of behavioral and psychological symptoms of dementia (e.g., depression, anxiety, agitation, and apathy); and 5) **Study Design:** randomized controlled trials.

As there are no reliable methods to retrieve information about all the possible unpublished studies, the identified unpublished studies are highly likely to be an unrepresentative subset of all the unpublished studies in existence (Higgins et al., 2019). Considering that the inclusion of unpublished studies itself may introduce bias (Higgins et al., 2019; Scherer and Saldanha, 2019), only peer-reviewed studies were included in this systematic review and meta-analysis. Additionally, a funnel plot and Egger's test were used to evaluate publication bias, with $p > 0.05$ indicating no publication bias (Egger et al., 1997).

Studies were excluded if they 1) were publications in languages other than English; 2) incomplete studies such as study protocols or ongoing studies; 3) included participants with only mild cognitive impairment or cognitive impairment without dementia; 4) did not have sufficient information about the measurement of the outcome of interest; and 5) did not include adequate statistical values (e.g., mean, standard deviation, and median with range) of the quantitative results, which are required to compute an effect size for the meta-analysis procedure.

2.3. Study selection and data extraction

First, the results of the literature search were exported from all the search databases to the EndNote 20 management software program (Clarivate Analytics, Philadelphia, PA, USA) to manage and delete duplicates. A two-phase strategy as described in the protocol (Seok et al., 2022 was employed to ensure a comprehensive search of English-written peer-reviewed studies that fulfilled the following inclusion criteria: 1) two independent reviewers (JS and JWS) screened the titles and abstracts of the identified articles according to the inclusion and exclusion criteria, and 2) after retrieving and uploading the full text of the potentially relevant articles to the Endnote software, the two reviewers conducted a full-text-level assessment to select the eligible articles to be included in this systematic review and meta-analysis. At each step, any disagreements and discrepancies were discussed with a third reviewer (BK) until a consensus was reached.

Following the matrix method (Garrard, 2020), one reviewer from three data extraction team members (BK, JS, and JWS) independently extracted information from five articles per person, and another reviewer verified the extracted information. The extracted data included author (s), year of publication, country, setting, sample size, sample characteristics, intervention type and characteristics (components, technology, delivery mode, duration, and frequency), comparison, and outcome measures. Any disagreements were resolved through discussion among all authors.

2.4. Risk of bias assessment

At least two reviewers independently assessed the risk of bias and quality of the included studies using the revised Cochrane risk-of-bias tool for randomized trials (RoB 2) (Sterne et al., 2019). The tool assesses five bias domains that could occur in randomized controlled trials: randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of reported results. Each domain consists of a set of questions with response options ("low," "some concerns," and "high") for categorizing risk-of-bias judgments. Studies were categorized as "low," "some concerns," or "high" in the overall risk of bias score. The overall risk of bias was considered "low risk of bias" if all five domains were judged as low risk, "Some concern of bias" if at least one domain was judged as having some concern of bias with no domains judged as high risk, and "high risk of bias" when at least one domain was judged as high risk (Sterne et al., 2019). Any discrepancies were resolved in the discussion with a third reviewer when necessary, and a consensus was reached.

2.5. Data synthesis and analysis

A narrative synthesis was conducted to describe the characteristics of the included studies. Statistical analyses for the meta-analysis were performed using R version 4.0.3 (R Foundation for Statistical Computing, Vienna, Austria). As the studies used different measures for the outcomes of interest, the standardized mean difference was calculated (SMD) to determine the effects of the intervention in the experimental group compared to the control group. SMDs were computed by calculating Hedges' g (i.e., subtracting the mean outcome score of the comparison group from the mean outcome score of the intervention group and dividing by the pooled standard deviation) because of the small sample size in most of the included studies (Rosenthal, 1994). A negative SMD indicated that the symptoms decreased among participants in the intervention group compared to those in the control group. A conservative estimated value ($r = 0.5$) was applied to the studies in which the correlation coefficient (r) values between the baseline and post-intervention scores were not reported (Higgins et al., 2019; Saragih et al., 2021). Effect size magnitudes were interpreted as $0.2 \leq SMD < 0.5$ = small, $0.5 \leq SMD < 0.8$ = moderate, and $0.8 \leq SMD$ = large (Hedges and Olkin, 2014). When the studies measured outcomes at multiple follow-up time points, post-test outcome measures, conducted immediately after the intervention, were used.

A priori random-effects models were chosen to account for the extent of expected variations among the included studies (DerSimonian and Kacker, 2007; DerSimonian and Laird, 1986). The effect sizes of the individual studies were weighted using the inverse of the variance to calculate the overall pooled treatment effect estimates with 95%

confidence intervals (CIs). The effects of the treatment on overall behavioral and psychological symptoms of dementia were evaluated. Further, we stratified outcomes by symptom type as defined and measured in each study and conducted subgroup analyses to examine the effects of interventions on each type of symptom, and assessed the heterogeneity of effect sizes according to the differential outcomes (i.e., symptom type).

Between-study heterogeneity was assessed by inspecting the forest plots and calculating I^2 statistics, with which 75%, 50%, 25%, and 0% were denoted as high, moderate, low, and no heterogeneity, respectively (DerSimonian and Kacker, 2007; Higgins et al., 2019).

Given the foreseeable heterogeneity, random-effects moderator analyses were preplanned to explore whether any study-level moderators explained the heterogeneity of effect sizes calculated as SMDs in the present review (Higgins et al., 2019). Potential moderators were preselected based on methodological, clinical, and intervention features that could vary between studies and consist of the following variables: mean age of participants, proportion of women, sample size, country where studies were conducted, group vs. individualized intervention, intervention type, setting, duration of intervention, and risk of bias assessed by the RoB 2 (Sterne et al., 2019). Subgroup analyses (Q-test of homogeneity) with random-effects models were applied to categorical variables. However, univariate meta-regressions based on a random-effects model were conducted to examine the potential continuous moderators for the intervention effects. If a potential moderator yielded a statistically significant result, the variable was considered to influence the effect sizes of the interventions and a possible moderator variable (Deeks et al., 2019). In the present study, the criterion for statistical significance was set at $P < 0.05$.

3. Results

3.1. Study selection

The PRISMA flowchart in Fig. 1 summarizes the decision pathway for the final inclusion of the studies. The electronic search yielded a total of 2615 records, and two records were searched manually through the

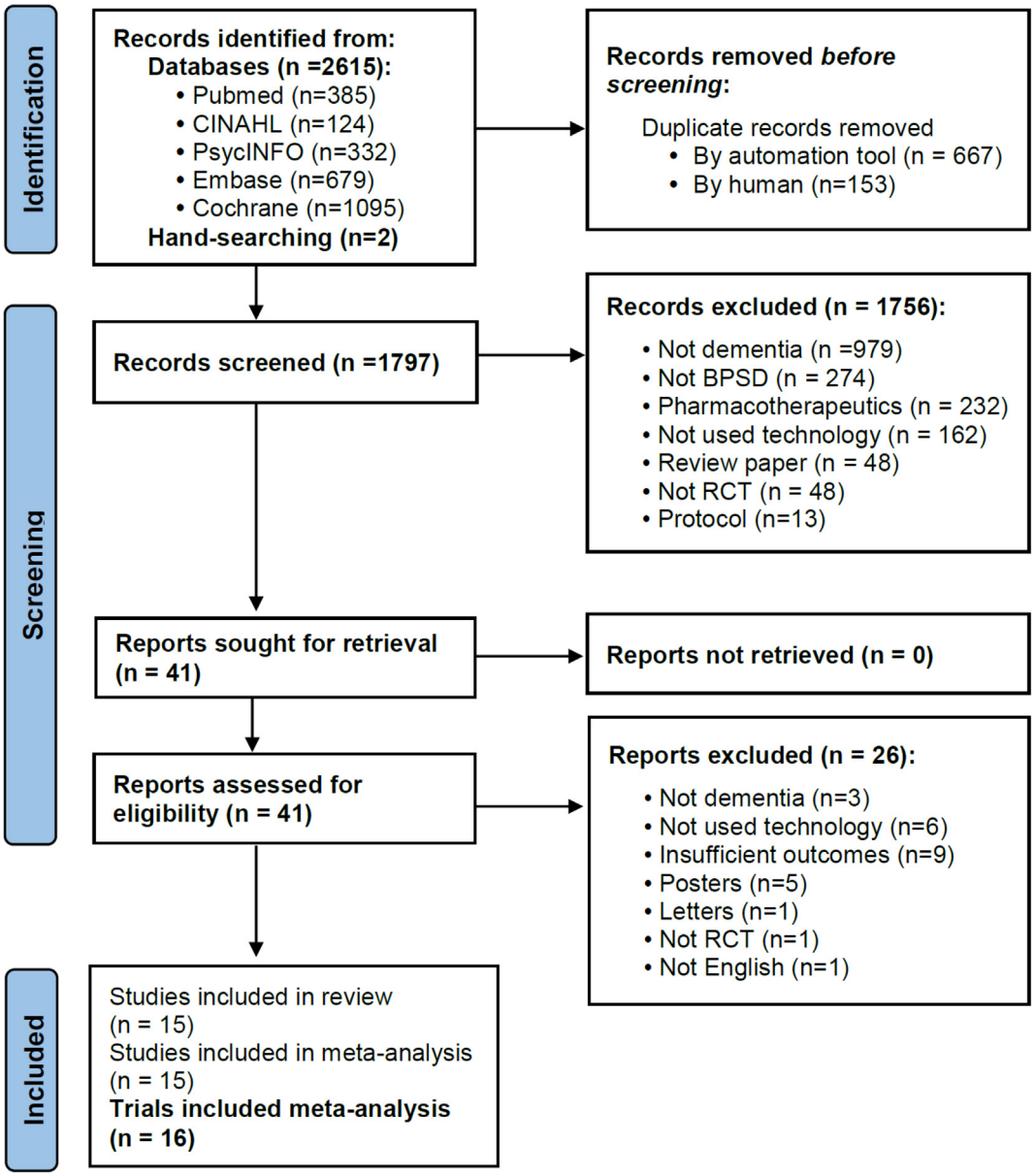

Fig. 1. PRISMA flowchart illustrating the study selection process.
Note. BPSD: behavioral and psychological symptoms of dementia; RCT: randomized controlled trial.

bibliographies of the included articles and previously published relevant reviews. After removing duplicates, 1797 articles remained. A total of 1756 articles were excluded after the title and abstract screening, leaving 41 for full-text assessment. Fifteen articles met the inclusion criteria and were included in the final analysis. Of the 15 articles, one study had two intervention arms that could not be collapsed (i.e., a three-arm trial comparing two different interventions to a control). Ultimately, 16 trials were included in the meta-analysis.

3.2. Characteristics of the included studies

Table 1 presents the characteristics of the included studies. With the publication years ranging from 2015 to 2021, over 37.5% of the included studies were published after 2020. The studies were conducted in Europe (n = 8), Oceania (n = 4), the United States (n = 2), and Asia (n = 2). The trials were implemented in both residential long-term care settings (n = 12) and community settings, including daycare centers (n = 1), meeting centers (n = 1), homes (n = 1), and both daycare centers and homes (n = 1). The mean age of study participants ranged from 74.1 years (İnel Manav and Simsek, 2019) to 90.0 years (Sautter et al., 2021). The percentage of female participants ranged from 39.7% (Laver et al., 2020) to 100% (Moon and Park, 2020).

Either overall behavioral and psychological symptoms of dementia or a single type of behavioral and psychological symptoms of dementia were measured as target outcomes in the included trials: neuropsychiatric symptoms (n = 8), depression (n = 9), agitation (n = 5), apathy (n = 3), and anxiety (n = 2). Previous studies have measured the aforementioned outcomes using various symptom-measuring instruments. Most studies used the Neuropsychiatric Inventory (NPI) to measure neuropsychiatric symptoms (Chen et al., 2020; D'Aniello et al., 2021; Dröes et al., 2019; Liang et al., 2017; Moon and Park, 2020; Swinnen et al., 2021; Valentí Soler et al., 2015). Additionally, they have used the Cornell Scale for Depression in Dementia (CSDD; Davison et al., 2016; Jøranson et al., 2015; Liang et al., 2017; Moon and Park, 2020; Petersen et al., 2017; Swinnen et al., 2021) and Geriatric Depression Scale (GDS; Chen et al., 2020; Pérez-Ros et al., 2019; Sautter et al., 2021). Agitation was measured using the Cohen-Mansfield Agitation Inventory (CMAI; Davison et al., 2016; Liang et al., 2017; Moyle et al., 2017), Caregiver Behavioral Occurrence and Upset Scale (Laver et al., 2020), and Brief Agitation Rating Scale (BARS; Jøranson et al., 2015). Apathy was measured using the Apathy Rating Scale (ARS; İnel Manav and Simsek, 2019) and the Apathy Scale for Institutionalized Patients with Dementia Nursing Home (APADEM-NH; Valentí Soler et al., 2015). Anxiety was measured using the Rating for Anxiety in Dementia (RAD; Davison et al., 2016; Petersen et al., 2017).

3.3. Intervention characteristics

Nonpharmacological interventions for managing behavioral and psychological symptoms of dementia vary widely (Table 2). The interventions were classified into three categories based on the intervention contents: 1) "activity engagement" interventions that provided music therapy (n = 2), reminiscence (n = 2), personalized multimedia devices (n = 2), and physical exercise (n = 1); 2) "social interaction" interventions that promoted participants to socially interact with companions (n = 7); and 3) "care-aid" interventions that provided educational and counseling programs for people with dementia and their caregivers (n = 2). While five studies provided group interventions, 11 provided individualized interventions tailored to each participant's preferences and functional abilities. The interventions were delivered by different personnel, including researchers and staff working in care settings. The intervention frequency for the experimental groups ranged from once every two weeks to daily, with the length of intervention for one dosage of the intervention ranging from 15 min to one hour. One study did not limit the length of one dosage of intervention, indicating an average of 2.6 h (Davison et al., 2016). The duration of the intervention ranged from 4 to 24 weeks.

Control conditions varied depending on the intervention type. Most studies maintained usual care (n = 14). However, a few studies have employed parallel control conditions. For example, Moon and Park (2020) used storytelling with no digital materials instead of digital reminiscence therapy.

3.4. Information and communication technologies

Various information and communication technologies have been adopted as intervention delivery modes (Table 2). Web-based music players have been used for music therapy in activity engagement

Table 1
Characteristics of the included studies.

Author (year), country	Setting	Sample size (n)		Mean age (SD)		Female (%)
		Intervention group	Control group	Intervention group	Control group	
Activity engagement						
D'Aniello et al. (2021), Italy	Residential LTC	30	30	89.5 (7.0)[a]	89.5 (7.0)[a]	58.3
Davison et al. (2016), Australia	Residential LTC	11	11	86.0 (5.2)[a]	86.0 (5.2)[a]	NR
İnel Manav and Simsek (2019), Turkey	Residential LTC	16	16	74.1 (4.5)	74.8 (4.5)	39.7
Moon and Park (2020), South Korea	Day care center	22	19	84.1 (6.2)	83.0 (6.0)	100.0
Pérez-Ros et al. (2019), Spain	Residential LTC	47	72	80.1 (7.6)	80.8 (7.4)	51.3
Sautter et al. (2021), USA	Residential LTC	12[b]	16[b]	90.0[a] (NR)	90.0[a] (NR)	85.7
Swinnen et al. (2021), Belgium	Residential LTC	23	22	84.7 (5.6)	85.3 (6.5)	77.8
Care-aid						
Dröes et al. (2019), Netherland	Meeting center	65	54	79.1 (7.5)	80.7 (7.0)	64.7
Laver et al. (2020), Australia	Home	31	32	79.5 (6.5)	80.5 (7.2)	39.7
Social interaction						
Chen et al. (2020), China	Residential LTC	52	51	87.0 (8.2)	87.3 (6.6)	79.6
Jøranson et al. (2015), Norway	Residential LTC	27	26	83.9 (7.2)	84.1 (6.7)	66.7
Liang et al. (2017), New Zealand	Day care center & home	13	11	83.8 (7.9)	NR	64.0
Moyle et al. (2017), Australia	Residential LTC	138	137	84.0 (8.4)	85.0 (7.1)	72.7
Petersen et al. (2017), USA	Residential LTC	35	26	83.5 (5.8)	83.3 (6.0)	77.1
Valentí Soler et al. (2015),[b] Spain	Residential LTC	30	38	84.7[a]	84.7[a]	88.0
Valentí Soler et al. (2015),[c] Spain	Residential LTC	33	38	84.7[a]	84.7[a]	88.0

Note. SD, Standard Deviation; LTC, long-term care; NR, Not reported.
[a] Mean age was provided for all participants in both intervention and control groups.
[b] Randomized clinical trial of humanoid robots included in Valentí Soler et al.'s (2015) study.
[c] Randomized clinical trial of a robotic pet in Valentí Soler et al.'s (2015) study.

Table 2
Characteristics of non-pharmacological interventions using information and communication technologies for behavioral and psychological symptoms of dementia.

Author, (year)	Intervention (individualized or group)	Technology	Control group	Intervention provider	[a]Duration/ Length [b](frequency)	Outcomes (instrument)
Activity engagement						
D'Aniello et al. (2021)	Music therapy with participants' preferred song selection (Individualized)	Web-based music player (MP3)	Usual care	Researcher (Psychologist)	8/30 (2)	Neuropsychiatric symptoms (NPI)
Davison et al. (2016)	Operating multimedia device loaded with participants' preferred materials such as favorite music tracks, movies, video messages, and photos (Individualized)	Personalized multimedia device (Memory Box)	Weekly 30-min visits	Researcher	4/2.6 (average) (Daily)	Depression (CSDD), Anxiety (RAID), Agitation (CMAI)
İnel Manav and Simsek (2019)	Reminiscence therapy with participants' photos, pictures, and YouTube videos (Individualized)	Internet-based video (YouTube)	Casual talk	Researcher (Nurse)	12/60 (1)	Apathy (ARS)
Moon and Park (2020)	Digital reminiscence therapy using smartphone application with participants' favorite music, photos, and YouTube or stored videos (Individualized)	Smartphone application + Internet-based video (YouTube)	Telling story with no digital materials	Researcher (Nurse)	4/30–40 (2)	Neuropsychiatric symptoms (NPI), Depression (CSDD)
Pérez-Ros et al. (2019)	Music therapy with participants' preferred song (Group)	Web-based music player (MP3)	Occupational therapy with no music	Researcher	8/60 (5)	Depression (GDS)
Sautter et al. (2021)	Using multimedia device for accessing meaningful content and entertainment via games, movies, audiobooks, and more (Individualized)	Personalized multimedia device (iN2L tablet)	Usual care (Group computer activity as part of facility's standard of care)	Staff (Therapeutic Recreation intern and medical student)	9/60 (5)	Depression (GDS)
Swinnen et al. (2021)	Step-based medical training platform with the game interface to engage users in physical training for increasing gait stability (Individualized)	Motion-based input exergame device (Dividat Senso)	Listening & Watching music video	Researcher (Physical therapist)	8/15 (3)	Neuropsychiatric symptoms (NPI), Depression (CSDD)
Care-aid						
Dröes et al. (2019)	Telephone support and Internet-based courses for caregivers of persons with dementia (Individualized)	Telephone (Dementelcoach) + e-Learning (STAR)	Regular Meeting Centers Support Program (MCSP)	Researcher	24/45 (average 8.2)	Neuropsychiatric symptoms (NPI)
Laver et al. (2020)	Online consultation using telehealth technologies related to the care of persons with dementia (Individualized)	Online meeting program (Cisco Webex software)	Same care program using face-to-face home visit	Researcher (Occupational therapist)	16/60 (8 during 16 weeks)	Agitation (Caregiver Behavioral Occurrence and Upset Scale)
Social interaction						
Chen et al. (2020)	Interact with Kabochan such as talking, singing, and response with head nodding (Individualized)	Humanoid robot which looks like a 3-year-old boy (Kabochan)	Usual care	Researcher	7/NR (7 during 7 weeks)	Neuropsychiatric symptoms (NPI), Depression (GDS)
Jøranson et al. (2015)	Interact with PARO such as talking, smiling, and singing (Group)	Robotic pet which looks like baby harp seal with artificial intelligence software (PARO)	Usual care	Staff	12/30 (2)	Depression (CSDD), Agitation (BARS)
Liang et al. (2017)	Interact with PARO such as stroking its flippers (Individualized)	Robotic pet (PARO)	Usual care	Researcher	6/30 (2–3)	Neuropsychiatric symptoms (NPI), Depression (CSDD), Agitation (CMAI)
Moyle et al. (2017)	Interact with PARO as participants' preferred way (Individualized)	Robotic pet (PARO)	Usual care	Researcher	10/15 (3)	Agitation (CMAI)
Petersen et al. (2017)	Interact with PARO on the table surrounded by participants (Group)	Robotic pet (PARO)	Usual care	Staff (Facility nurse and staff)	12/20 (3)	Depression (CSDD), Anxiety (RAID)
Valentí Soler et al. (2015)	Interact with NAO, which acts out a script in cognitive or physical therapy (Group)	Humanoid robot which can move or dance with motion and sound sensing sensors (NAO)	Usual care	Researcher (Occupational and physical therapist, neuropsychologist)	12/30–40 (2)	Neuropsychiatric symptoms (NPI), Apathy (APADEM-NH)
Valentí Soler et al. (2015)	Interact with PARO in the cognitive or physical therapy (Group)	Robotic pet (PARO)	Usual care	Researcher (Occupational and physical therapist, neuropsychologist)	12/30–40 (2)	Neuropsychiatric symptoms (NPI), Apathy (APADEM-NH)

Note. SD, standard deviation; NR, not reported; NPI, neuropsychiatric inventory; CSDD, Cornell Scale for Depression in Dementia; RAID, Rating for Anxiety in Dementia; CMAI, Cohen-Mansfield Agitation Inventory; ARS, Apathy Rating Scale; GDS, Geriatric Depression Scale; BARS, Brief Agitation Rating Scale; APADEM-NH, Apathy Scale for Institutionalized Patients with Dementia Nursing Home version.

[a] Length refers to the total number of weeks during which the intervention was provided, and duration refers to the number of minutes per session.

[b] Frequency refers to the number of sessions per week.

interventions (D'Aniello et al., 2021; Pérez-Ros et al., 2019). Reminiscence interventions have been implemented using the smartphone application (Moon and Park, 2020) and internet-based video (İnel Manav and Simsek, 2019; Moon and Park, 2020). A few studies provided activity programs using personalized multimedia devices (Davison et al., 2016; Sautter et al., 2021). Training games with motion-based input devices have been used to motivate participants' engagement in physical exercise activities (Swinnen et al., 2021). For care-aid programs, a telephone support program, an internet-based e-learning course, and a real-time consultation program using an online meeting program have been implemented to aid informal caregivers of older adults with dementia (Dröes et al., 2019; Laver et al., 2020). For social interaction interventions, most studies have used a companion pet robot to encourage social interaction through behaviors such as petting, talking, and smiling (Jøranson et al., 2015; Liang et al., 2017; Moyle et al., 2017; Petersen et al., 2017; Valentí Soler et al., 2015). Humanoid robots have been utilized to increase social interactions via talking and singing (Chen et al., 2020; Valentí Soler et al., 2015).

3.5. Risk of bias

The risk of bias assessment for the 15 studies is summarized in Supplementary Table 6 and demonstrated in Supplementary Fig. 1. The quality of the included studies varied. Four studies were rated as having "low risk." Six studies were judged as having "some concerns," primarily in terms of the randomization process or deviations from intended intervention, or both, or in measurement of the outcome. The remaining studies were rated as having "high risk" due to an inadequate randomization process, deviations from intended interventions, measurement of the outcome, or selection of the reported result. All included studies had a low risk of bias in missing outcome data, and all but one had a low risk of bias in the selection of reported results.

Publication bias was evaluated based on a visual inspection of the funnel plot asymmetry and Egger's test (Egger et al., 1997). Egger's test failed to detect a statistically significant asymmetry in the study distribution ($p = 0.331$). However, the funnel plot in Supplementary Fig. 2 is broadly symmetrical, indicating no publication bias in behavioral and psychological symptoms of dementia.

3.6. Intervention effects

A meta-analysis was conducted on 16 trials of non-pharmacological interventions using information and communication technologies for behavioral and psychological symptoms of dementia, using their first measurement immediately after the endpoint of an intervention. The pooled overall effect of the interventions on reduction in behavioral and psychological symptoms of dementia, which encompassed various types of symptoms, was statistically significant, with a moderate effect size (SMD $= -0.664$, 95% CI -0.990 to -0.338, $p < 0.001$; see Fig. 2). The heterogeneity test revealed a large level of heterogeneity across studies ($I^2 = 89\%$, $p < 0.001$).

Additionally, subgroup analyses were performed to examine the intervention effects on each type of behavioral and psychological symptoms of dementia that was the target symptom in the trials and to assess whether the effect sizes were heterogeneous between different types of target symptoms (see Fig. 2). For depression, a meta-analysis was conducted on nine trials with 496 participants based on their first measurements after the intervention. The intervention effects were statistically significant, with a large effect size (SMD $= -1.088$, 95% CI -1.983 to -0.193, $p = 0.017$). The heterogeneity test revealed a large level of heterogeneity across studies ($I^2 = 95\%$, $p < 0.001$). For neuropsychiatric symptoms measured by the NPI, a meta-analysis was conducted on eight trials involving 483 participants. The intervention effects on NPS were not statistically significant (SMD $= -0.251$, 95% CI $= -0.579$ to 0.077, $p = 0.133$). Moderate but significant heterogeneity was observed among the studies ($I^2 = 68\%$, $p = 0.003$). For agitation, five trials involving 301 participants were pooled. The pooled effects of interventions on the reduction of the level of agitation were statistically significant, with a moderate effect size (SMD $= -0.586$, 95% CI -1.130 to -0.042, $p = 0.035$). Moderate but significant heterogeneity was observed among the studies ($I^2 = 77\%$, $p = 0.001$). For anxiety, only two trials tested the effects of the interventions on anxiety levels. The pooled effects of the interventions on the reduction of anxiety were not statistically significant (SMD $= -0.541$, 95% CI -1.270 to 0.188, $p = 0.146$). There was no heterogeneity among studies ($I^2 = 55\%$, $p = 0.134$). For apathy, only three trials tested the effect of interventions on the apathy level. The pooled effects of the interventions on the reduction of apathy were not statistically significant (SMD $= -0.830$, 95% CI -1.835 to 0.176, $p = 0.106$). Moderate but significant heterogeneity was observed among the studies ($I^2 = 89\%$, $p < 0.001$).

When comparing the relative effects of interventions between subgroups that differed in terms of specific target symptoms, it was found that the effects of interventions on depression (SMD $= -1.088$) were larger than for agitation (SMD $= -0.586$). However, the subgroup analysis yielded no significant heterogeneous effect sizes between different target symptoms ($p = 0.378$).

3.7. Moderator analysis

Univariate meta-regressions for continuous moderators based on the random-effects model were performed to examine whether the effect sizes on reduction in behavioral and psychological symptoms of dementia were significantly correlated with the mean age of participants, the proportion of women, and sample size. As shown in Table 3, the results revealed that the intervention effect was significantly moderated by age ($\beta = 0.129$, SE $= 0.058$, $p = 0.026$) but not by proportion of women ($p = 0.064$) and sample size ($p = 0.109$). Subgroup analyses were performed to assess pre-selected potential categorical moderators such as country, setting, intervention type, intervention mode (group vs. individualized), intervention duration, and risk of bias. As a result, none of the preselected categorical variables were moderators that caused heterogeneity in effect sizes between trials. For example, activity engagement interventions applying music, reminiscence, and exercise activities showed the highest effect on reducing behavioral and psychological symptoms of dementia (Hedges's $g = -1.174$) compared to care-aid interventions (Hedges's $g = -0.874$) and social interaction interventions (Hedges's $g = -0.284$). However, the differences were not statistically significant ($p = 0.082$). The risk of bias (methodological quality) assessed using the RoB 2 (Sterne et al., 2019) was not significantly correlated with intervention effects on the symptoms in a systematic way.

4. Discussion

4.1. Summary and interpretation of findings

This systematic review and meta-analysis identified and evaluated existing non-pharmacological interventions using information and communication technologies for the management of behavioral and psychological symptoms of dementia through 16 randomized controlled trials from 15 articles. Despite the significant variations across the 16 trials, the meta-analysis revealed that existing information and communication technology-based non-pharmacological interventions significantly reduced behavioral and psychological symptoms of dementia. Through moderation analyses using subgroup analysis and meta-regression, the mean age of the participants was identified as a potential moderator for the intervention effects.

Wide variability across studies was noted in intervention design, assessment instruments, and measures and reporting of dementia diagnosis and severity. The non-pharmacological interventions using information and communication technologies varied widely in terms of content, duration, frequency, professional background of the intervention provider,

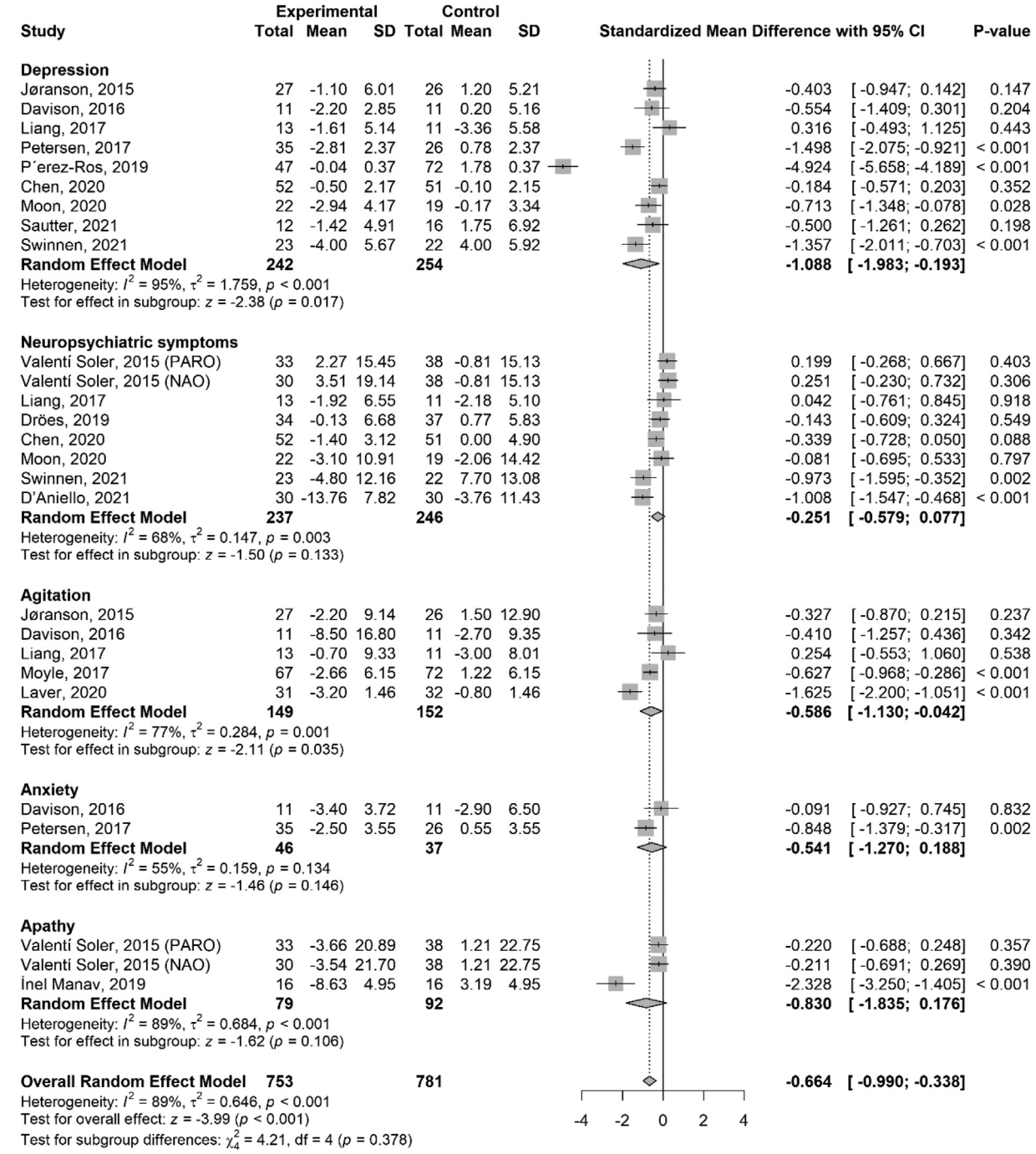

Fig. 2. Forest plot showing the effect of non-pharmacological interventions using information and communication technologies on behavioral and psychological symptoms of dementia (Studies are stratified by the symptom subgroup).

and delivery mode. While a reduction was observed in overall behavioral and psychological symptoms of dementia across the studies, results on the specific types of symptoms must be interpreted with caution because the different components of interventions may have varying impacts on the intervention effects for the different types of symptoms.

Consistent with the proliferation of technologies in social and healthcare interventions for older adults in recent years, every randomized controlled trial included in this review was published after 2015. Different technologies were applied depending on the intervention type, grouped into three categories (i.e., activity engagement, care-aid, and social interaction). For activity engagement interventions, digital technologies such as mobile and tablet applications, web-based programs, and multimedia devices have been applied. They ensure the provision of continuous access to rich images and other types of media and personally meaningful materials (Goodall et al., 2021; Lazar et al., 2014). For care-aid interventions, electronic communication technologies instead of traditional face-to-face coaching and counseling were employed to provide easier access and save time (Şahin et al., 2021). Social interaction interventions have implemented robotic pets or humanoid robots in diverse countries and settings to facilitate social and emotional engagement and social connection with others (Hung et al., 2021).

Consistent with a previous review (Goodall et al., 2021), control of the technology ranged between (a) intervention providers having complete control of the technology (D'Aniello et al., 2021; İnel Manav and Simsek, 2019; Jøranson et al., 2015; Moon and Park, 2020; Pérez-Ros

Table 3
Moderator analyses for the intervention effects on the overall behavioral and psychological symptoms of dementia.

Continuous moderators[a]	k	Slope	SE	Tau^2	$Q_{(model)}$	$P\text{-value}_{(slope)}$
Age	27	0.129	0.058	0.840	4.970	0.026
Women (%)[b]	24	0.026	0.014	0.985	3.425	0.064
Sample size	27	−0.010	0.006	0.925	2.574	0.109

Categorical moderators[c]	k	Effect size (Hedges' g)	95% CI	$Q_{between}$	*p*-value
Country				1.380	0.240
Europe	12	−0.921	−1.557, −0.264		
Non-Europe	15	−0.495	−0.767, −0.222		
Setting				2.060	0.151
Community-dwelling	7	−0.309	−0.833, 0.216		
Residential care setting	20	−0.791	−1.190, −0393		
Intervention				5.000	0.082
Social interaction	14	−0.284	−0.521, −0.048		
Care-aid	2	−0.874	−2.327, 0.579		
Music, reminiscence, exercise activity	11	−1.174	−1.958, −0.389		
Group				0.450	0.500
Group	9	−0.864	−1.677, −0.050		
Individualized	18	−0.570	−0.836, −0.303		
Duration				1.720	0.424
≤4 weeks	5	−0.369	−0.697, −0.042		
4–8 weeks	9	−0.907	−1.771, −0.042		
>8 weeks	13	−0.588	−0.927, −0.247		
Risk of bias[d]				2.030	0.363
High	6	−0.649	−1.181, −0.118		
Some concerns	13	−0.888	−1.602, −0.173		
Low	8	−0.324	−0.757, −0.109		

Note. K: number of studies; SE: standardized error; CI: confidence interval.
[a] Univariate (unadjusted) meta-regression was conducted for each continuous potential moderator.
[b] Results were obtained from 14 studies after excluding one study that had no information on the proportion of women.
[c] Subgroup analysis was conducted for each categorical potential moderator.
[d] Risk of bias (methodological quality) was assessed using the revised Cochrane risk-of-bias tool for randomized trials (RoB 2) and categorized into "low risk of bias," "some concern of bias," and "high risk of bias."

et al., 2019; Petersen et al., 2017; Swinnen et al., 2021; Valentí Soler et al., 2015), (b) collaborative use among individuals with dementia, their informal or formal caregivers, and researchers (Davison et al., 2016; Dröes et al., 2019; Laver et al., 2020; Liang et al., 2017; Moyle et al., 2017; Sautter et al., 2021), and (c) greater independent use by the person with dementia (Chen et al., 2020). A prior qualitative study found that a sense of lack of control over the device, a feeling of uncertainty, and a lack of adequate support for technical issues were perceived barriers to using sensor-based technology among people with dementia and their families (Malmgren Fänge et al., 2020). Due to the lack of information in the included studies, this review was unable to investigate whether the training on the use of technology was adequately provided before the intervention and whether the complexity of device operation corresponded to the participant's cognitive and functional abilities. Future systematic reviews should explore the usability and acceptability perceived by persons with dementia and their family caregivers, as well as their influence on outcomes related to symptom management.

Overall, this meta-analysis added evidence to support that non-pharmacological interventions using information and communication technologies are effective in reducing behavioral and psychological symptoms of dementia; however, the effects varied between target symptoms and measures. While non-pharmacological interventions using information and communication technologies exert a large effect on depression and a moderate effect on the overall behavioral and psychological symptoms of dementia and agitation, pooled evidence suggests no effect on neuropsychiatric symptoms, anxiety, and apathy. The lack of effect on anxiety and apathy might be due to the small sample sizes (two and three trials, respectively) and the heterogeneity of interventions. This is consistent with a prior review, which pointed out that current evidence on the effect of non-pharmacological interventions on apathy is not persuasive because of the low quality of the methodology and the small number of studies (Cai et al., 2020). Therefore, further rigorous trials on anxiety and apathy are warranted to draw highly robust conclusions.

Additionally, although the effects of the overall information and communication technology-based non-pharmacological interventions on reduction in behavioral and psychological symptoms of dementia were examined owing to the limited number of trials for each intervention category (i.e., activity engagement, care-aid, and social interaction), each intervention type might have different underlying mechanisms for influencing symptom reduction. Moreover, the varying mechanisms might exert intervention effects on each type of symptom, but not in the same way or to varying extents. Therefore, a greater number of elaborate reviews with sufficient trials are needed to reveal which type of non-pharmacological intervention using information and communication technologies is most effective for each type of symptom.

Moderator analyses using subgroup analyses and univariate meta-regressions revealed the types of interventions that worked with the elements and for whom the interventions worked. It is important to note that non-pharmacological interventions using information and communication technologies were highly effective in reducing behavioral and psychological symptoms of dementia in younger participants than in older participants living with dementia. Given that sensory, cognitive, and mobility-related capabilities decline not only due to the illness trajectory but also due to age, the remaining capabilities of older participants with dementia might not have matched certain capability requirements for achieving the interventional goals (Wang et al., 2019). In future trials, functional capabilities should be accounted for when designing interventions, and a profile of participants' capabilities should be assessed not only at baseline but also on a regular basis during the experiment (Wang et al., 2019). Additionally, although dementia severity was not included due to the lack of data and different measures used in the included studies, age might be associated with dementia severity. Furthermore, older

participants with advanced dementia might not have responded to the interventions in the same manner that efficiently worked for those with mild to moderate stages of dementia (Kverno et al., 2009).

4.2. Implication for practice and research

This meta-analysis provides a quantitative synthesis of the effects of non-pharmacological interventions using information and communication technologies on behavioral and psychological symptoms of dementia. The findings suggest that the implementation of appropriate non-pharmacological interventions using information and communication technologies can be suitable for managing behavioral and psychological symptoms of dementia and should be considered a useful strategy in clinical practice. The breadth of study designs included in this review allows for establishing an overall understanding of the proliferated technology-based interventions. Moreover, despite the heterogeneity across studies, synthesis of results across the range of interventions and on the differential outcomes will be valuable evidence for healthcare providers and researchers to know which differential outcomes the technology-based non-pharmacological interventions can exert effects among the heterogeneous range of behavioral and psychological symptoms of dementia. Although further research is needed to confirm the results, this technology-based approach is particularly recommended for managing depression and agitation as target outcomes.

While the ongoing COVID-19 pandemic has a considerable impact on people with dementia (Onder et al., 2020), the challenges imposed by the global pandemic highlight the pivotal and indispensable role of the information and communication technology-supported or mediated interventions for older adults living with dementia and their caregivers. Along with the restrictive measures implemented to prevent the spread of the virus, regular support systems for older adults living with dementia and their family caregivers and most non-pharmacological interventions for managing behavioral and psychological symptoms of dementia have been tentatively suspended worldwide (Canevelli et al., 2020). Echoing a previous study on the analysis of the lived experiences of people with dementia and their family caregivers (Tam et al., 2021), scalable information and communication technology-supported interventions are innovative solutions to restore the quality of life and well-being of vulnerable populations, particularly in resource-limited care settings, such as nursing homes or home care settings.

Several issues require attention to advance research on the non-pharmacological interventions using information and communication technologies for the challenging symptoms in dementia care. Future research should consider the potential moderating role of dementia severity, dementia diagnosis type, and whether standardized criteria were used to diagnose dementia. Additionally, future interventions should design the level of complexity of the intervention programs and technology operations, which correspond to the age, dementia severity, and functional capacity of the target populations. When designing randomized controlled trials, researchers also need to specify the target population for whom the interventions would work the best without adverse outcomes. Given that our moderator analyses revealed that this technology-based approach was highly effective in reducing the symptoms in younger than in older participants, applicability and effectiveness might vary from person to person. Thus, we suggest that healthcare providers develop an intervention protocol tailored to an individual and relevant target outcome in the individual context. Furthermore, because there was an insufficient number of studies, this study was unable to conclude which types of interventions were superior in reducing specific symptoms. With sufficient studies available for network meta-analysis, future studies can compare and rank the efficacy of different non-pharmacological interventions using information and communication technologies in the management of each type of symptom.

4.3. Limitations

This study had several limitations. First, the major limitation of this review is the moderate to large heterogeneity between studies. Although the underlying sources of the variation were explored and detected by conducting moderator analyses, results must be interpreted with caution because uncontrolled or unmeasured factors, which were not included in the moderator analyses due to unavailable information, potentially produce bias. Second, although blinding interventionists is challenging in care settings for the dementia population, there were risks of bias caused by the absence of blinding for study participants and interventionists in most of the included studies. Third, the results regarding the effectiveness of non-pharmacological interventions using information and communication technologies on anxiety and apathy are inconclusive because of the small number of studies. Thus, interpretations regarding the results from the subgroup analyses for anxiety and apathy should be made with caution. Furthermore, although this study was unable to conduct multivariate meta-regression due to the insufficient number of studies concerning the non-significant results of the subgroup analyses for potential moderators, future moderator analyses using multivariate meta-regression with a larger sample size are warranted to confirm the potential moderating effects after adjusting for covariates. Fourth, the vast majority of the selected trials were conducted in developed countries. This may be due to the limited availability of technology and the low feasibility of technology-based interventions in low-income countries. Fifth, as articles published in languages other than English were not included, findings from non-English articles are unknown, which limits the global generalizability of the findings. Lastly, of the studies identified from the electronic and manual search without restriction on publication status, none of the studies was excluded due to the publication status (e.g., dissertation study, conference abstracts, or preprints), which means that no unpublished studies were eligible. While controversies remain on whether to include gray literature in systematic reviews and meta-analyses (Scherer and Saldanha, 2019), the results should be interpreted with caution as only published data present in this review may produce publication bias (Higgins et al., 2019).

4.4. Conclusions

The present review has shown that non-pharmacological interventions using information and communication technologies were a functional approach to managing behavioral and psychological symptoms among older adults with dementia, with several trials reporting moderate to large effect sizes. Pooled evidence has demonstrated that non-pharmacological interventions using information and communication technologies exert a significant effect on depression and a moderate effect on agitation and overall behavioral and psychological symptoms of dementia. However, given that insufficient evidence is currently available to assess whether this intervention approach can effectively manage anxiety and apathy, results on anxiety and apathy remain inconclusive. Effect sizes varied between target symptoms, and the moderator analyses suggested that this intervention approach was more effective in younger participants than older participants. Thus, clinicians and healthcare providers should adopt the most effective type of technology-supported non-pharmacological interventions for the target population in a person-centered manner. Future subgroup analyses will also be useful for providing highly detailed information in developing optimal person-centered strategies for the target population and the specific challenging symptoms.

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CRediT authorship contribution statement

EC and BK contributed to the study concept and design; all authors contributed to the analysis and interpretation of data; all authors drafted the manuscript; participated in the interpretation of results and revision of the manuscript; and read and approved the final manuscript.

Declaration of Competing Interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijnurstu.2022.104392.

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