Designing User Interface for People with Dementia: A Systematic Literature Review

Minmin Zhou[1], Kamal Sabran[2], Zuriawati Ahmad Zahari[3]
{min145051@gmail.com[1], kamalsabran@gmail.com[2], zuriawati@gmail.com[3]}

Universiti Sains Malaysia, 11800 Gelugor Penang [1], Universiti Sains Malaysia, 11800 Gelugor Penang[2], Universiti Sains Malaysia, 11800 Gelugor Penang[3]

Abstract. Dementia is a health challenge faced by people from all over the world. From the perspective of respecting the needs of people with dementia and the caregivers, user interface can improve the quality of life and the emotional needs of people with dementia besides supporting the humanized work needs of caregivers. This study selected user interfaces developed for people with dementia in the past five years. A systematic literature review explored the types of user interface that help people with dementia and looked at how these user interfaces can help improve their daily living abilities and nursing care surroundings. The main contribution of this study is in providing researchers with an understanding that the current focus on people with dementia has shifted from basic physiological needs to a meaningful and normal life. The development of a valuable user interface combined with non-pharmaceutical interventions can help people with dementia have a better quality of life.

Keywords: people with dementia, user interface, caregiver, healthcare, intervention.

1 Introduction

The rapid growth of the elderly population worldwide has caused increasingly serious social problems. Alzheimer's disease and other forms of dementia are among the top ten causes of death in the world [1]. Dementia is a complex disease that cannot be attributed to a fixed set of cognitive, social, or emotional defects [2]. In addition to the physical health problems experienced by people diagnosed with dementia, families and society also face nursing challenges. According to statistics, nearly 60% of people with dementia (PwD) live in low- and middle-income countries [3]. This phenomenon has led to an increase in the cost of the healthcare system and social care. Most care for dementia is at home or in long-term care facilities. At least one-third of caregivers have communication problems with PwD in some daily activities [4]. For people with dementia who want to live independently, intelligent environments and devices can improve their ability to stay in their own homes by providing environmental control and monitoring of medication to ensure their health and safety [5].

There are many problems in the current health care system for dementia. In addition to the inability to provide adequate essential healthcare services for PwD, there are also continuous and quality care challenges. These challenges can only be addressed by developing sustainable interventions for the future. Interactive training of human–environment interaction can be successfully used in the cognitive training of PwD who are in the early stages of dementia [6].

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Multimedia can also provide a valuable memory experience for PwD [7]. These user interfaces provide a certain level of healthcare services at low costs and specific qualities.

In this work, a systematic literature review was conducted to verify how various user interfaces are applied to PwD. Therefore, this research has defined the following research questions:

RQ1. What types of user interface can help PwD?

RQ2. How can these user interfaces help PwD?

2 Method

This research was conducted according to the guidelines of the systematic literature review. It is mainly divided into the following steps:

2.1 Search Process

The selected research must be related to user interface development for dementia between 2015 and 2021. The search was conducted in May 2021 in the databases of Scopus, ACM digital library, and IEEE Explore. Since the discussion includes a wide range of PwD, the search keyword used is "dementia". There were no separate searches for keywords such as Alzheimer's, vascular dementia, Pick's disease, frontal dementia, and Parkinson's dementia. Therefore, the primary form of the search string is:

"dementia" AND "user interface" OR "application"

2.2 Inclusion and Exclusion Criteria

A study is selected for the systematic review if it meets the following inclusion criteria:

- The target audience of the article is dementia-related
- The article is written in English
- The article is full text and can be used to answer the research questions

The exclusion criteria for this study are as follows:

- The article is a literature review
- The article is related to medical theory

2.3 Quality evaluation

After the search results generated studies that fulfilled the inclusion and exclusion criteria, in order to further improve the quality and ensure the authenticity of the results, the following questions based on quality standards were asked for each selected study:

EQ1. Does the article introduce user interfaces related to dementia?

EQ2. Does the article include the use of research methods?

EQ3. Did the article produce results on the healthcare or nursing setting of dementia?

2.4 Data Extraction and synthesis

After the above steps were performed, 33 papers were finally selected from Scopus, ACM Digital Library, and IEEE Explore databases for review. All the studies have been peer-reviewed. Two papers were published at different times on the same study [8] [9]. The data extraction and synthesis of the selected studies needed to answer the detailed elements listed in Table 1. Data extraction needed to answer three questions about user interface type, research methods, and current research results. Data synthesis was obtained through detailed reading and analysis of selected studies, including user interface classifications developed for dementia (Fig. 2) and user interface improvement areas developed for dementia (Fig. 3). Fig. 1 depicts the flow chart for the selection of studies to be included in this research.

Table 1. Elements of data extraction and synthesis.

Description	Detail
Bibliographic information	Author(s), publication year, title etc.
Data extraction	User interface type
	Research method used
	Findings of the study
Data synthesis	User interface classification developed for dementia (Fig. 2)
	Areas of user interface improvement developed for dementia (Fig. 3)

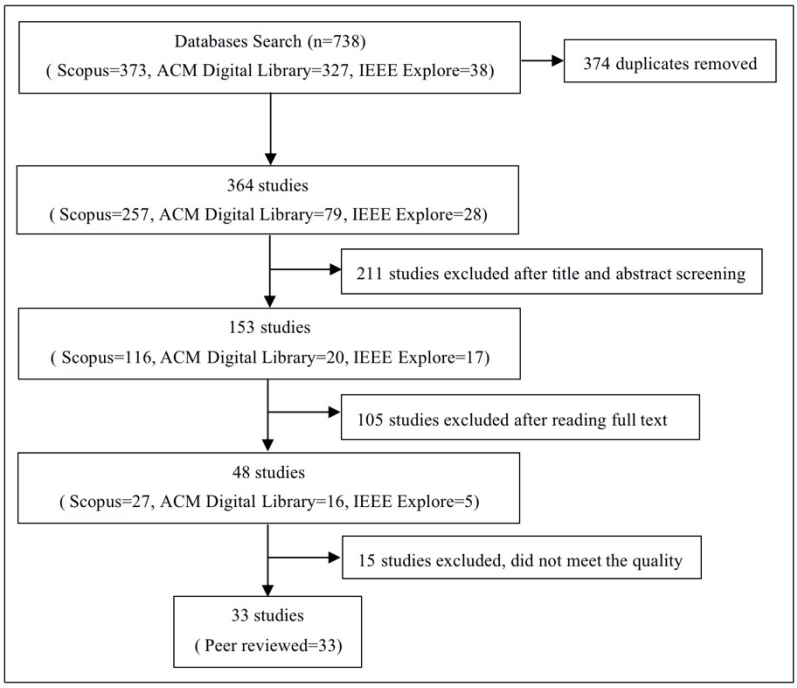

Fig. 1. Flow chart for the selction of previous studies

3 Result

3.1 RQ1: What types of user interface can help PwD?

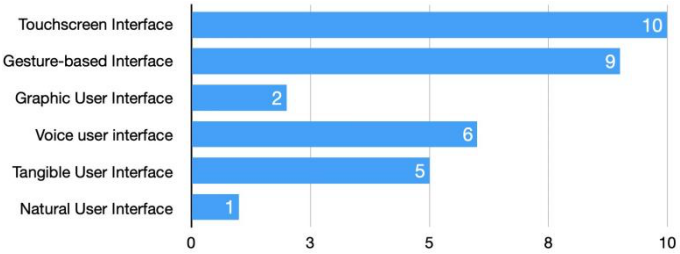

Fig. 2. Types of user interface

Touchscreen Interface

Fig. 2 shows several types of user interface for PwD. The most reviewed by the studies are the touchscreen user interface. A well-designed touch screen can be used with only a little training, and it can even be used as an intervention strategy to improve the quality of life of PwD [10]. As Table 2 shows, ten studies emphasized the usability of touchscreens on mobile devices for PwD or caregivers. The touchscreen is usually operated using fingers and a stylus for easy input. The studies reviewed explained that easy-to-understand and easy-for-intuitive interactions are the advantages of touchscreen interfaces [11][12][13].

The study of McAllister proposed a "memory guardian" application based on Apple's iPad to improve the happiness of PwD by supporting the interaction between nursing staff and PwD [14]. Another application, SMART4MD developed by Quintana et al. based on Android tablets, supports people with mild cognitive impairment to use it at home while optimizing the screen features of Android mobile phone devices and tablets [15]. Mobile applications support user-friendly use in any environment and at any time. Some studies have provided quantitative results and proven that mobile applications can benefit users by triggering their memory [16][17][18]. The intelligent environment assisted living system iCarus is a client application designed for standard mobile devices [19]. In addition to the user interfaces mentioned above based on mobile and tablet touch screens, Davison et al. developed a memory box interface for the surface computer [20]. The study found that residents, families, and employees had higher utilization rates of the memory boxes. During the intervention, the symptoms of depression and anxiety were significantly reduced. The system detects the cognitively impaired elderly and restless behavior to help family and nursing home staff improve their health.

Table 2. Touchscreen interface reviewed.

Authors(s)	Study Design	Participants	Interface Type	Findings
McAllister et al. [14]	Field notes, focus groups, and individual interviews	3 PwD	Prototype digital application: Memory Keeper	Memory Keeper helps caregivers improve the health of PwD by providing personalized reminders to stimulate memories

Lin et al. [16]	Semi-structured interviews, participatory design methods	8 caregivers of PwD	Social exergame: Go&Grow	Caregivers use Go&Grow to focus on their wellbeing, increase physical activity, and reduce stress
Quintana et al. [15]	Feasibility–usability testing, user evaluation	19 people with cognitive impairment and their informal caregivers	Tablet application: SMART4MD	SMART4MD is shared among family members and informal caregivers to provide reminders, cognitive support activities, and optional status and health information
Cunningham et al. [17]	Questionnaire, semi-structured interviews	11 persons diagnosed with vascular dementia or Alzheimer's	Musical mobile app: Memory Tracks	The use of musical mobile apps has produced positive changes in the behaviour, abilities, and daily life of PwD
Yilmaz [19]	Questionnaire, statistically analyzed and reported	44 users between the ages of 19 and 64	Intelligent ambient assisted living system: iCarus	The system can contribute to the safety of PwD and more extended independent living of the patient
Hattink et al. [18]	Pretest–posttest	42 people with cognitive impairment or dementia, and 32 of their informal carers	Multifunctional system: Rosetta	Rosetta system is a device that can provide good care for PwD
Davison et al. [20]	Randomized, single-blinded, cross-over trial	11 nursing home residents with dementia	Personalized multimedia device: Memory Box	The system helps nursing home workers improve their anxiety and health
Nayer and Coxon [11]	Usability testing	11 PwD	Personal digital media	Multimedia systems provide a rich media experience for PwD
Awada et al. [12]	Adaptive evaluation in the laboratory	25 elderly people with cognitive and memory problems	Adaptive user interfaces for healthcare application: IONIS	This study effectively increased the accessibility of PwD to interact with the system
Ceccacci et al. [13]	User-centered design, structured interviews	20 PwD	Home automation system	This study helped people with low to moderate dementia to understand and use touch interfaces

Gesture-based Interface

The nine studies in Table 3 discussed gesture-based interfaces in their literature review. These studies provided references on the design guidelines for the interaction technology for PwD. The primary purpose is to help users with dementia use gestures effectively while reducing guidance from caregivers by, among others, simplifying gestures and prompting animation to solve the problems of gesture switching and cognitive overload [21]. The research of [22] is on a gesture-based interactive platform developed by an interdisciplinary team to increase the sense of social participation for PwD. This platform uses interactive technology to provide dementia participants with audiovisual experiences of digital art through wearable devices and provide real-time data for therapists and nursing staff to help

PwD with their recovery. The combination of the two enabled the participants to perform physical therapy while enjoying artistic experiences.

Kinect gesture control is easy to use for dementia patients and has been proven to be feasible. This type of interface can improve cognition by stimulating the brain activity of patients. Sports rehabilitation games based on Kinect camera tracking support participants to sing and dance to the music in a virtual music room, but there is still room for improvement in understanding and operation techniques [8][9]. Another serious game study [23] used head-mounted displays to provide PwD with customized sports games that meet users' cognitive abilities. In addition, the smart TV interface provides cognitive-related video games for PwD as a simple and inexpensive alternative [24].

Due to cognitive and physical limitations, providing exercise guidance for PwD is not an easy task. The virtual environment's immersive experience allows PwD to use gesture interaction smoothly after a short adaptation period [25]. The studies of Rings et al. [26] and Yun et al. [27] both used virtual reality interactive interfaces to complete cognitive training. The former mainly focused on motor cognition, and the latter used a fully immersive experience to improve cognitive impairment for people with mild dementia. The hand image data captured by the hand motion tracking module helped PwD in performing gesture operations so that the PwD could complete the gesture task without being instructed.

Table 3. Gesture-based interfaces reviewed.

Author(s)	Study Design	Participants	Interface Type	Findings
Hackner and Lankes [21]	Field test, observation	4 PwD, 4 people without dementia	Android application: Mind training	This tablet computer game helps PwD use gestures intuitively and efficiently
Gardner et al. [28]	Proof-of-concept study	Approximately 20 older adults	Gesture-based interactive platform: ABLE	ABLE offers a range of physical, emotional, and social engagement benefits
Unbehaun et al. [9]	Semi-structured interviews	3 PwD, 2 caregivers, 3 relatives, a volunteer, the manager of the day-care center, and 2 physiotherapists	Interactive music exergame	Serious games offer music-based interventions to improve the physical condition of PwD
Unbehaun et al. [8]	Semi-structured interviews, observations	26 PwD and 6 informal caregivers	Video game system	The system improves the ability of PwD to face the challenges of everyday life in an outpatient and daycare setting
Eisapour et al. [23]	Questionnaire, observations, design feedback	6 PwD	Virtual reality games	Five different PwD sports games with customized physical parameters for each user, making the game easy to play
López et al. [24]	Questionnaire, user testing	18 PwD	Smart TV application focusing on cognitive games	Cognitive games improve the cognitive and social skills of PwD, and play an essential role in the early detection of and action on dementia symptoms
Bejan et al.	Group	5 persons with	Reminiscence-	PwD can explore appropriate

[25]	experimental test	mid-stage dementia	provoking a virtual 3D environment	gestures in memory and engage in immersive and pleasurable gesture interactions
Rings et al. [26]	Focus group interviews	Groups of 4–7	Exergame: Memory Journalist	Virtual reality sports games provide physical exercise and improve balance for PwD
Yun et al. [27]	Pilot study	10 physiatrists, 6 occupational therapists, and 11 persons with cognitive impairment and dementia	Virtual reality cognitive training program	Fully immersive virtual reality cognitive training regimens are feasible for persons with mild cognitive impairment and mild dementia

Graphical User Interface (GUI)

Among the reviewed studies, only two focused on GUI (Table 4). The nursing guidance system designed by Kim et al. [29] allows nursing staff to query and understand nursing knowledge through a GUI, text-based chats for real-time guidance, and videos for learning. Scene examples of PwD are created in the GUI to facilitate the accurate operation of the interface by nursing staff. In addition, Gullà et al. [30] also designed a smart home system based on GUI features. This GUI is designed with two different user interfaces: normal mode and wizard mode. The wizard interface minimizes the amount of information that users need to understand and manage, can change the information display mode, and provides auxiliary information to help the operator realize the control of the smart home equipment.

Table 4. Graphic user interface (GUI) reviewed.

Author(s)	Study Design	Participants	Interface Type	Findings
Kim et al. [29]	Online survey, interviews	4 female experts who have worked for more than 10 years in caring for PwD	Care guide system	This system provides caregivers with appropriate nursing guidance depending on the situation
Gullà et al. [30]	Pretest–posttest	8 PwD	New home automation system	New smart home systems support people with early dementia to live independently and increase the time they spend at home

Voice User Interface

The most direct interaction method for PwD is voice interaction, which can produce higher efficiency [31]. Some studies have detected the language ability of PwD through automatic language recognition [32]. Without voice interaction, it is challenging for PwD to use a computer smoothly. Dethlefs et al. [33] provided a spoken natural language interface for interactive operating computers with speech recognition. In addition, due to changes in the vocabulary and syntactic structure of PwD, adaptive technology in speech is another problem [34]. The reminder system developed by Tokunaga et al. [35] established an animated chat that simulates dialogues between people, using spoken dialogues to boost users' confidence.

In order to improve the efficiency and accuracy of the user interface, speech recognition should also consider the caregiver's accent to support users in completing complex tasks [36]. In the study of Li et al. [37], intelligent voice assistants assisted nursing staff in managing the daily diet of PwD. The user's voice input is received first, and then the voice is converted into text through automatic voice recognition, allowing the system to recognize the user's intention and offer suggestions and solutions.

Table 5. Voice user interface reviewed.

Author(s)	Study Design	Participants	Interface Type	Findings
Kanno et al. [31]	Experiment	2 Alzheimer patients, 1 caregiver, and 1 family member	Accessible interface based on augmented reality (AR)	Higher efficiency can be achieved through voice interaction on the AR interface
Shibata et al. [32]	Control experiment	18 PwD	Smartphone-based dementia screening application: VocabChecker	VocabChecker measures language ability through automatic speech recognition
Dethlefs et al. [33]	Experimental interventions, interviews	13 healthy elderly people and 10 PwD	Spoken natural language interface	It is possible to use spoken natural language for computer-based cognitive stimulation of PwD
Tokunaga et al. [35]	Agent service experiment	7 PwD	Reminder service	Virtual agents are effective for PwD through voice, touch interaction, and the display of captions and pictures
Wolters et al. [36]	Focus group	6 PwD, 2 carers, and 4 people without dementia	Intelligent cognitive assistants	The voice interface enables people with dementia to perform daily tasks
Li et al. [37]	System evaluation, qualitative evaluations	5 testers	Artificial intelligence-powered voice assistant	Natural interactive interfaces support effective food management

Tangible User Interface

Due to short-term or long-term memory loss, PwD may forget how to use the products that were once familiar to them. Therefore, establishing a direct relationship between the user and the external features of the product is essential in the design of a typographic interface [38]. In addition, stylish music players need to meet individuals' ever-changing needs and preferences by, among others, providing non-technical users with various options of input components [39]. Houben [40] designed a music player called Turnaround. PwD and caregivers can interact with each other by holding the two ends of Turnaround and collaborate to create music during turning and spinning. Another music playback device [41] can provide various physical connections according to the abilities of PwD. For example, in the selection of songs and volume control functions, the shape of the ball and buttons can be used as an input interface and the fabric surface can be touched for interactive purposes.

The purpose of the other two tangible user interface studies is to provide recall activities for PwD. A tangible user interface consisting of a chest of drawers was designed [42], taking

into account the abilities of people with moderate to severe dementia and simplifying physical items and applications as much as possible. In addition, tangible multimedia books as recall triggers have been tested by people with varying degrees of dementia to explore the feasibility of books as interactive devices [43].

Table 6. Tangible user interface reviewed.

Author(s)	Study Design	Participants	Interface Type	Findings
Seymour et al. [39]	Informal feedback sessions	10 PwD	Tangible music player: AMI	AMI provides independence and better access to music through visual and physical control of the music playback
Houben et al. [40]	Pilot study	7 PwD and 6 professional caregivers	Collaborative Musical Interface: Turnaround	Professional caregivers can work with PwD to make music and engage in social interaction
Thoolen et al. [41]	Engagement workshops	PwD	Music player interface: Sentic	Sentic can be customized according to the functional abilities of users
Ly et al. [42]	Observations, focus groups, interviews	56 PwD	A chest of drawers using a tangible user interface	The user interface allows dementia patients to perform their memory activities and live independently
Huldtgren et al. [43]	Observation, single sessions, focus group	8 PwD and 4 caregivers	Tangible Multimedia Book	Interactive books have the potential to modulate memory and communication in PwD

Natural User Interface (NUI)

NUI is an interface designed specifically for a particular type of human interaction. PwD can overcome cognitive and physical injury obstacles and have fun by using a NUI suitable for multi-modal interaction. The study of Gündogdu et al. [44] highlighted that aquariums can spark memories and joy. Therefore, a touch table made by the surface computer provides instant feedback between virtual reality and PwD. The natural touch allows gesture-based interaction between PwD and the virtual fish to arouse personal interest and experience. In future research, the olfactory perception will be added to the NUI. This multi-modal interactive system is well adapted to improving the happiness and quality of life of PwD.

Table 6. Nature user interface reviewed.

Author(s)	Study Design	Participants	Interface Type	Findings
Gündogdu et al. [44]	Observation, individual and group session tests	16 PwD	Interactive aquarium application	Nature user interactive multimedia system helps build and improve communication with PwD

3.2 RQ2: How can these user interfaces help PwD?

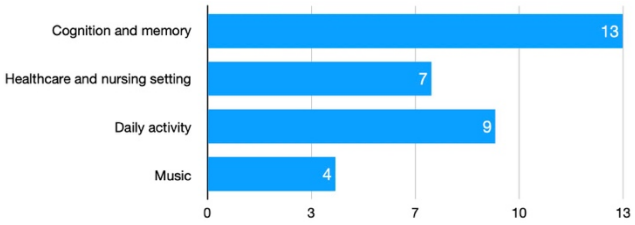

Fig. 3. Topics of the user interface.

Cognition and memory

A decline in cognitive ability can affect the daily life and independent functions of PwD. The most common symptoms of dementia are cognitive deterioration and memory loss [45]. In interface research aimed at improving the cognition and memory of PwD, cognitive training and stimulation are common strategies. Immersive cognitive training brings multi-sensory stimulation to people with mild dementia [27]. Compared with participating tasks, cognitive stimulation strengthens learning and memory with the people as the center [33]. As an auxiliary tool, intelligent cognitive assistants provide a choice of modes from the perspectives of user initiative and system initiative in the face of individual differences. People with moderate to severe dementia can obtain daily guidance [36]. In addition to their solutions for dementia patients, cognitive activities can also be shared with family members and informal caregivers [15], for example by saving the memories of PwD in memory savers or interactive books in advance, such as photos, music, and videos full of life memories. These meaningful activities give PwD reliable memory support [14] [43] [20]. The activities can also improve the quality of life in long-term care settings [42]. In addition, cognitive games have a particular preventive and interventional effect on dementia [21]. These games not only provide physical exercise for people with dementia [26] [23] but also improve their cognition and social interaction [24] [9].

Healthcare and nursing setting

Long-term care of dementia patients brings a high economic burden and pressure to the family, nursing staff, and society. Its social cost exceeds the total cost of caring for stroke, heart disease, and cancer patients [46]. Current dementia screening is mostly physically invasive, and dementia screening based on automatic speech recognition technology has attracted specific attention [32]. Professional and non-professional nursing staff need to acquire appropriate nursing guidance to take better care of PwD [29]. The IONIS platform supports different environments, offers various solutions for PwD and their caregivers to cope with daily activities, and provides various information related to health monitoring [12]. The NUI supports nursing staff in managing the diet of PwD [37]. The smartphone applications developed can help caregivers pay attention to their health and reduce stress [18] [16]. Finally, ensuring the safety of PwD and extending their time alone at home is another way to reduce the pressure on healthcare and nursing staff [19].

Daily activities

The improvements to activities of PwD include both physical and mental aspects. On the physical aspects, the augmented reality interface prompts medication and recognizes

medication by executing language commands directly [31]. In addition, the virtual agency service that simulates dialogues between people also provides daily reminders for PwD [35]. The user-centered home automation system provides the possibility of effective management and control of home appliances for PwD through a touch screen and an adaptive intelligent environment [30] [13]. In spirit, the combination of art projects and multimedia systems brings a pleasant experience and the value of social participation to PwD [22] [11]. Video game systems have a certain potential to impact the lives of PwD positively [8]. The NUI based on multi-modal interaction provides an immersive experience for PwD and improves their quality of life [44] [25].

Music

The music elements introduced in social work interventions have a positive impact on the prevention and improvement of PwD [17]. In this type of study, music intervention entails two modes: active and receptive. Active music intervention requires participants to sing, research, or improvise together. Receptive music intervention involves participants listening to music in a safe, comfortable, and pleasant environment [22]. These activities are usually combined with other activities, such as using different music media. The musical user interface adds visual and structuring control and personalized customization to bring better music access to PwD [39] [41]. Another interface study on music emphasizes the social interaction of PwD through a collaborative interface. It establishes a physical connection among users in carrying out creative music activities [40].

4 Discussion

There are various types of user interfaces for dementia patients, and the common purpose of these interfaces is to provide convenient and effective assistance to PwD. Among them, the touch screen interface, which is based on mobile devices, has the most extensive applications, covering all aspects of the rehabilitation and life of PwD. The touch screen-based user interface has advantages in operability and environmental applicability, and it still has corresponding development potential in the future. However, the needs of dementia users are different from other users. The specific physical and psychological needs mean that the development of a user interface for dementia should not provide only one solution. A further comparison of the differences and connections among strategies will allow us to meet the needs and challenges of dementia users.

In the future, regardless of whether it is a community-based or a family-based retirement goal, it will require the collaboration and support of all sectors of society. Although these studies are about designing a user interface for PwD, the participants in the selected studies were not limited to PwD. Nursing staff, medical professionals, family members were included. Therefore, the research, diagnosis and care of PwD require the participation of experts and non-experts. It is not difficult to find through the literature review that artists, music therapists, rehabilitation therapists, sports experts, and medical experts have brought their own insights and support to dementia.

On the time aspect, the early user interfaces mainly focused on the rehabilitation and health issues of PwD. However, recently, user interfaces have shifted to making PwD feel the sense of social participation. PwD are no longer passive recipients but active and equal

participants in the nursing relationship [40]. Research aimed at improving the quality of life and wellbeing suggests that it is more critical for PwD to have a better medical and health experience than improve their cognition. For the family or professional nursing staff, the user interface is to bring efficient and comprehensive assistance to nursing work and relieve their nursing pressure. Such a user interface is in line with the people-oriented care concept for dementia.

5 Conclusion

This study investigated some of the user interfaces designed for PwD. After a systematic literature review, 33 studies were extracted for synthesis. The results show that user interface development has shifted from satisfying the basic physiological needs of PwD to creating a more meaningful life for them. In the different environments of families, nursing homes, nursing centers, and hospitals, the development of digital technology combined with non-pharmaceutical interventions have specific potential to relieve the social burden. Such a user interface can effectively help to improve the quality of life and increase the happiness of people with disabilities.

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