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Examining the Use of Intelligent Conversational Voice-Assistants for Improved Mobility Behavior of Older Adults in Smart Cities

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ABSTRACT
Intelligent Conversational Voice-assistants (ICV) can interpret the speech of human and respond back using synthesized voices and are increasingly employed for interacting with different applications. ICV offers promising tool to address the increasing mobility accessibility challenge faced by older people. Yet, irrespective of the increased ageing population, studies that employed ICV to improve the mobility, walkability, and wayfinding of older people are scarce. This is because the development of ICV in the mobility domain presents several designs, technical, and linguistic challenges. A systematic literature review was adopted grounded on secondary data from the literature and descriptive analysis was employed. Grounded on user-centred design perspective based on the "ability-based design framework" and "ISO 9241-110 framework for ergonomics of human-system interaction." Therefore, this study describes the requirement specifications needed to design an ICV suitable for supporting the mobility behavior of older people. Findings from this paper identifies the perceived factors that influences the use of ICV by older people. Additionally, findings from this study discusses how ICV that simulates human-like behavior can provide personalized mobility, walkability, and wayfinding guide when older people walk in cities. This study provides recommendations for the implementation of a user-centred ICV for safe, independent, accessible mobility for older people in urban environment.

KEYWORDS
Older people; mobility behavior; independent walkability and wayfinding; conversational voice-assistants; perceived factors; requirement specifications

1. Introduction

Older people which refer to ageing population between the age of 65 and older, are one of the fastest increasing age groups in the society. This increased population of older people has exponentially increased in the last decade (Thakur & Han, 2018). In 2030 it is estimated that the number of individuals aged 60 years and above will increase by 34 percent, and in the year 2050, almost 2.1 billion people are projected to be aged 60 years or above (Arnold et al., 2022; Bokolo, 2023a). Thus, there is need to provide housing, medical, social, mobility, etc. support to older people to improve their welfare, wellbeing, and quality of health. As there is need to maintain independent living, safety, and social participation for the ageing population (Kenyon et al., 2002; Levin et al., 2012). Similarly, findings from the literature argued that the provision of accessible mobility support is one of requirements to promote safe and independent mobility of older people (Hjorthol, 2013; Krogstad et al., 2015). Accessible mobility refers to older people ability to access the services essential to meet their mobility needs through facilities and activities available within a short distance (Bokolo, 2023a). While there is an increasing need to sustain the welfare and wellbeing of older people there is also a need for cost effective solutions to improve the mobility of the ageing population in smart cities. Where smart cities refer to a complex urban systems where social and human dimensions interact, supported by digital technologies aimed to better use natural resources, reduce waste, and safeguard the natural environment (Bokolo, 2023b). In smart cities Digital Technologies (DT) can be adopted to support the mobility of older people using handheld devices, smartphones, tablets, and computers that show information and offers touchscreens/keyboards to input commands or data (Arnold et al., 2022; Musselwhite, 2023).

However, the increasing cognitive, physical, and visual impairments common among older people can make interfaces of handheld devices such as mobile phones difficult to use (Siren et al., 2015). As a result, an auditory interface is a modality of choice for older people without hearing impairments. The use of auditory interface as a preference for primary mode of communication, can improve accessible use of handheld devices among older people (Stigall et al., 2019). With ageing, older people may experience reduced function which may be supported by using digital technologies. Intrinsically DT such as machine learning, data mining, virtual reality, augmented reality, Artificial Intelligence (AI), Intelligent Conversational Voice-assistants (ICV), etc. can be adopted in smart cities as enablers to support the mobility

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of older people (Bokolo, 2023a). Therefore, a study that investigates the use of ICV by older people is an important and timely area given the limited studies that explored "out of home" use of ICV (McLean & Osei-Frimpong, 2019), by older people. Moreover, the proliferation of DT such as ICV can be adopted to improve independent living, and safety of the ageing population. Researchers such as Hallewell Haslwanter and Fitzpatrick (2017); Pradhan et al. (2020); Barros Pena et al. (2021a) called for studies in human computer interaction specifically those interested in older people to help fill this gap in knowledge by conducting studies on the design of ICV for the ageing population.

The application of ICV can provide personalization to various modes of operation, filtering travel information, and customization based on user preferences as well as the environmental awareness (Abdolrahmani et al., 2021; Jnr, 2024). ICV can provide support for planning (e.g., booking the journey) (Anthony & Petersen, 2020), navigation (e.g., getting comprehensive step-by-step directions), or exploration (e.g., querying and receiving information about the surroundings environment and needed Point of Interest (POI) for better environmental awareness). Findings from the literature argued that ICV are significantly influenced by individual experience and expectations in using these services (Brewer & Piper, 2017; Lazar et al., 2021). This is fundamental to user intention to use and in general the successful adoption of these interface design in complex multimodal interfaces where different needs can influence individual experience (Shaked, 2017). Thus, there is need to methodically explore the main requirement specifications to be considered in designing ICV for older people to create a multimodal holistic mobility experience that meets ageing populations needs and expectations. Therefore, this study will examine the following research questions:

- Which perceived mobility related factors influence the use of ICV by older people in cities?
- What are the requirement specifications to be considered in designing ICV suitable to support the mobility of older people?
- How can the use of ICV improve mobility behavior of older people when they walk in cities?

Accordingly, this study contributes to the body of knowledge by investigating key mobility related factors such as privacy, data, accountability, decision making, error recovery, ease of use, appearance, decision-making and personality, guidance, etc. that influences older people use of ICV in smart cities. Moreover, a user-centred design is proposed grounded on the ability-based design framework and ISO 9241-110 ergonomics of human-system interaction to identify the requirement specifications (e.g., see Table 2), needed to design an ICV that can support the mobility, walkability, and wayfinding of older people. The ability-based design framework was proposed by Wobbrock et al. (2011) as an answer to the challenges faced in creating accessible technology mostly in human-computer interaction research domain. Whereas the ISO 9241-110 ergonomics of human-system interaction is concerned with dialogue principles associated with the ergonomic design of conversation between users and interactive system (ISO, 2020). Further, this paper provides implication on how ICV can provide personalized mobility, walkability, and wayfinding guide through an auditory interface when older people walk in cities. Further implications from this study discusses how the *ability-based design framework and ISO 9241-110 ergonomics of human-system interaction* can support the mobility accessibility, safety, and independence of older people. This study is more align to walkability of older people due to mobility impairment faced by these demographics, but does not examine different type of hurdles, for example older people finding the place to sit, using the public escalators, taking buses and metro etc. as this has previously been explored widely in the literature (Bokolo, 2023a; Sato et al., 2017; Sobnath et al., 2020). The rest of this article is organized as follows. Section 2 introduces the theoretical background. Section 3 introduces the methodology employed in this study and Section 4 presents the findings. Section 5 provides discussion and implications. Section 6 is the conclusion.

2. Theoretical background

2.1. Overview of intelligent conversational voice-assistants

In the "world population prospects" report by the United Nations it was reported that 9 percent of the world population is above 65 years old, and this fraction will reach 16 percent in 30 years. The older population than 65 is even growing faster, and it is projected to reach 450 million by the year 2050 (Bokolo, 2023a; de Arriba-Pérez et al., 2023). In smart cities digital technologies such as Artificial Intelligence (AI) has become an important research area in the society over the years, particularly given the development of machine learning (Hoy, 2018). Similarly, advances in machine learning, specifically in neural networks, have enabled voice-based innovations to assist older people in their day-to-day routines, and promote their welfare and wellbeing towards personalized healthier lifestyle (Ermolina & Tiberius, 2021). The use of ICV on web and handheld devices offers older people with the opportunity to interact with AI based machine learning in a meaningful and useful form. Machine learning involves using statistical models and algorithms to execute tasks and suggest predictions without being programmed or following pre-defined instructions to perform the explicit task, possess the ability to learn individual preferences and the areas the individual is interested in Arnold et al. (2022). ICV refer to AI software for carrying out conversational user interfaces or auditory interfaces, which can recognize and understand human speech, execute services and tasks based on input queries, as well as reply via synthesized voices. ICV can be integrated into a different web, mobile, and wearable physical devices (Chen et al., 2021).

ICV present new possibilities for ease of use as compared to conventional computers and touchscreen mobile devices (Barros Pena et al., 2021a; Brewer et al., 2023; Pradhan et al., 2020). As such it is estimated that by the year 2024, the number of ICV in use globally is anticipated to reach 8.4 billion devices, doubling the 4.2 billion devices owned within 2020. Furthermore, the international voice recognition market is predicted to double by 2025. The use of ICV is expected to be widely in use in individual's everyday lives, including healthcare and home settings (Arnold et al., 2022; Jnr, 2024). ICV often provide medium to interact with the physical device, such as, through the use of a mobile/web application, tactile buttons on the device itself and most deployed via auditory interface (Hoy, 2018; McLean & Osei-Frimpong, 2019).

2.2. Categorization of intelligent conversational voice-assistants

According to Arnold et al. (2022) highlighted that ICV can be categorized into two main categories namely, "*embodied conversational agents*" and "*disembodied conversational agents.*" Figure 1 depicts the different categories of ICV as described in the literature.

The embodied conversational agents use graphical interphases, typically termed as an "avatar" or a "body" which possess the capability to engage in dialogue via speech or text using non-verbal communication, such as gestures and facial expressions with its users (Martin-Hammond et al., 2018). Embodied conversational agents engage in human-like conversations with their users by they recognize verbal and non-verbal input and relays information using verbal and non-verbal output (such as facial expressions, intonation, gaze, hand gestures, head movements, etc.). Due to these features, embodied conversational agents provide natural conversational auditory interface, in comparison with conventional graphical user interfaces. Embodied conversational agents are specifically useful for building engaging and intuitive systems, for individuals faced with age-related or associated cognitive impairments (Lazar et al., 2021; Petrie, 2023; Tsiourti et al., 2016a). Embodied conversational agents can make computers interactions significantly better for older people who face difficulties experience when they use the Graphical User Interface (GUI) of smartphones and computers (Petrie, 2023).

Conversely, the disembodied conversational agents communicate with individuals by using only text or a verbal/voice interface. Disembodied conversational agents are dialogue-based applications which includes personal voice-assistants which are also called virtual assistants or personal assistants. Examples of disembodied conversational agents include Microsoft's Cortana, Google Assistant, Amazon Alexa, Apple Siri, etc. which interacts with humans merely via speech recognition and synthesis employing unconstrained natural language input (Arnold et al., 2022; Martin-Hammond et al., 2019). Likewise, academics such as Chen et al. (2021) asserted that the embodiment of ICV in physical devices can be "*user attached usually handheld*" or "*wrist worn by individuals*" (for example the Siri assistant on iWatch and iPhone), or "*individual detached standalone*" which is usually associated to an "*explicit environment*" (for example smart lighting, smart speakers, and smart appliances with conversational functionality). These ICV including Apple's Siri, Microsoft's Cortana, Google's Google Assistant, and Amazon's Echo have all contributed to the changing way in which the society search for information, purchase products, complete tasks, uses content, etc. ICV uses machine learning and Natural Language Processing (NLP) to understand and interpret the language of users and processes response in real time (Hoy, 2018).

Disembodied conversational agents run on purpose within built speaker devices or handheld devices. The application continually listens for a specified key word to activate or wake it up. Once the system hears that key word, it records the individual's voice and then sends it to a dedicated server, which processes and analyzes it as a command. Depending on the command sent by the user, the dedicated server will supply the ICV with appropriate data to be read back to the individual by playing the as information back to the user (Hoy, 2018). ICV differ from prior voice-activated technologies such that they can considerably respond to several commands and questions as the systems are supported

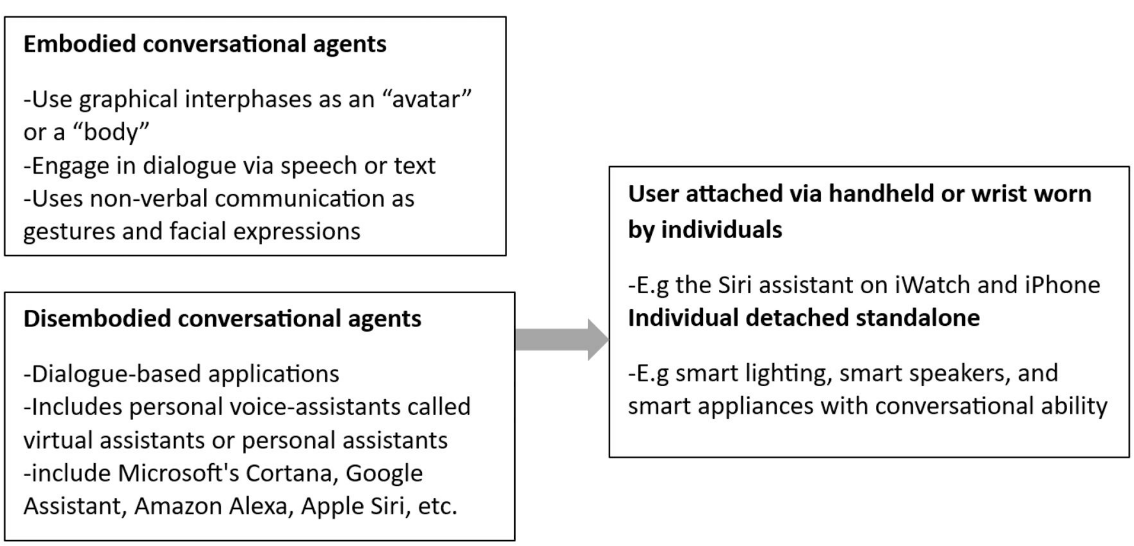

Figure 1. Categorization of intelligent conversational voice-assistants.

by natural language processing known as computational linguistics, which helps to create meaningful replies quickly. Natural language processing reduces the user dissatisfaction of prior voice recognition systems, which needed definite phrases and patterns to effectively work. ICV can parse requested phrase into different ways and translate what the individual is most likely to need (Ermolina & Tiberius, 2021; Hoy, 2018).

ICV are mainly aimed at providing older people with better communication with a system, providing personalized recommendations and highlighting the presentation of certain information (Shaked, 2017; Valtolina & Hu, 2021). ICV can provide older people with information, assist with managing connected devices via voice commands, and offers personal support for making appointments, handling calendars, providing wake-up calls or reminders, and more (Arnold et al., 2022; Petrie et al., 2018). ICV differs from the standard interfaces in that they are anticipated to change their actions and behavior autonomously through the state of the system and the individuals' actions based on the progression of the interaction between the user and the system (Barros & Seabra, 2020). Using voice or auditory interface as an interaction mode should help address the GUI based challenges faced by the older population (Martin-Hammond et al., 2019). Also, factors that impacts the designs of these ICV and how these might affect older adults' uses is presented in Table 2 and also Figure 9 identifies the requirement specifications that could be useful for the older adults when designing ICV.

Furthermore, prior studies in the literature have generally investigated ageing and technology. Among these studies Brewer et al. (2023) studied on how to achieve an equitable and fair speech technologies developed for older black adults. Furthermore, Petrie (2023) discussed that digital technologies for older people is failing to address the lack of consideration and stereotypical views about older people and the tendency of academics to consider older people as a homogeneous group. Chen et al. (2023) carried out a real-world use of voice assistants with older adults residing independently to investigate how a built-in touchscreen may support older adults. Findings from the study suggested that identified different design suggestions that can support future senior-friendly voice assistants for improving quality of life and managing healthcare. Barros Pena et al. (2021a) researched on the significant perspectives of older adults and the value dissonances they encounter in designing future digital technologies. Similarly, Barros Pena et al. (2021b) focused to explore older people experiences of financial technology usage and investigated the role technology played in decreasing the impact of mental health on older people economic circumstances.

Fitzpatrick (2021) examined the social-emotional skills required by people to practically engage with future digital issues for capable technical design work. A recent study by Lazar et al. (2021) introduced an approach that examines difference to produce new empirical understandings centered on older adults. Trajkova and Martin-Hammond (2020) explored why older adults may utilize or not use ICV in their homes based on a focus groups. Evidence of the study contributed towards achieving a better perception of plausible reasons why older adults do not engage with ICV and how ICV may better support independent living and aging in the future. In addition, Martin-Hammond et al. (2019) explored older adults' beliefs about the use of intelligent assistants for consumer health information management. Lazar et al. (2018) researched telehealth home care as a companionship technology that can support aging in place and further provided suggestions for the design of avatar-based distant companionship. Martin-Hammond et al. (2018) explored how to involve older adults in the participatory design of smart tools for intelligent health search. Petrie et al. (2018) provided a synopsis of the descriptions and roles of technologies and also provided a guide for researchers working on technologies developed for aid older people. Brewer and Piper (2017) highlighted the importance of human voice for accessible social platforms towards community participation by discussing the design for age and disability. Hallewell Haslwanter and Fitzpatrick (2017) investigated the development of assistive systems for older people and father identified the challenges that affect successful practice. Another study by Loup et al. (2017) investigated older adults' perception with regards to technology by underlying the socioemotional impacts of technology throughout the ageing process.

As ICV are still a new technology and the use of this technology by the ageing population is still in an investigative phase, with the goal of understanding perceived factors that influences their uptake and further examine requirement specifications needed for successful implementation (Arnold et al., 2022). Although, it was highlighted that other problems may arise, such as older people knowing how and what to say to ICV (Bokolo, 2023a; Sayago et al., 2019). There are fewer studies that examined the requirement specifications to be considered in ICV suitable for older people. Lastly, research that investigated how ICV can improve the mobility, walkability, and wayfinding when older people walk in cities is needed.

3. Methodology

A systematic literature review was adopted in this study to identify relevant sources as recommended in the literature Kitchenham and Charters (2007); Denyer and Tranfield (2009), towards selecting the relevant sources to be included in this study. A systematic literature review procedure aims to provide transparency, heuristic, inclusivity, and explanatory to a study area. By transparency the review study should be explicit and open about the procedures and approaches employed by using review protocol (the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA)), as seen in Figure 2. Additionally, a systematic literature review should be conveyed in such a way, that there are evident links between the findings and the drawn conclusions (Arnold et al., 2022; Elbert et al., 2020). For inclusivity the selected sources included in the study for inclusion should be explicitly stated, whereas the explanatory

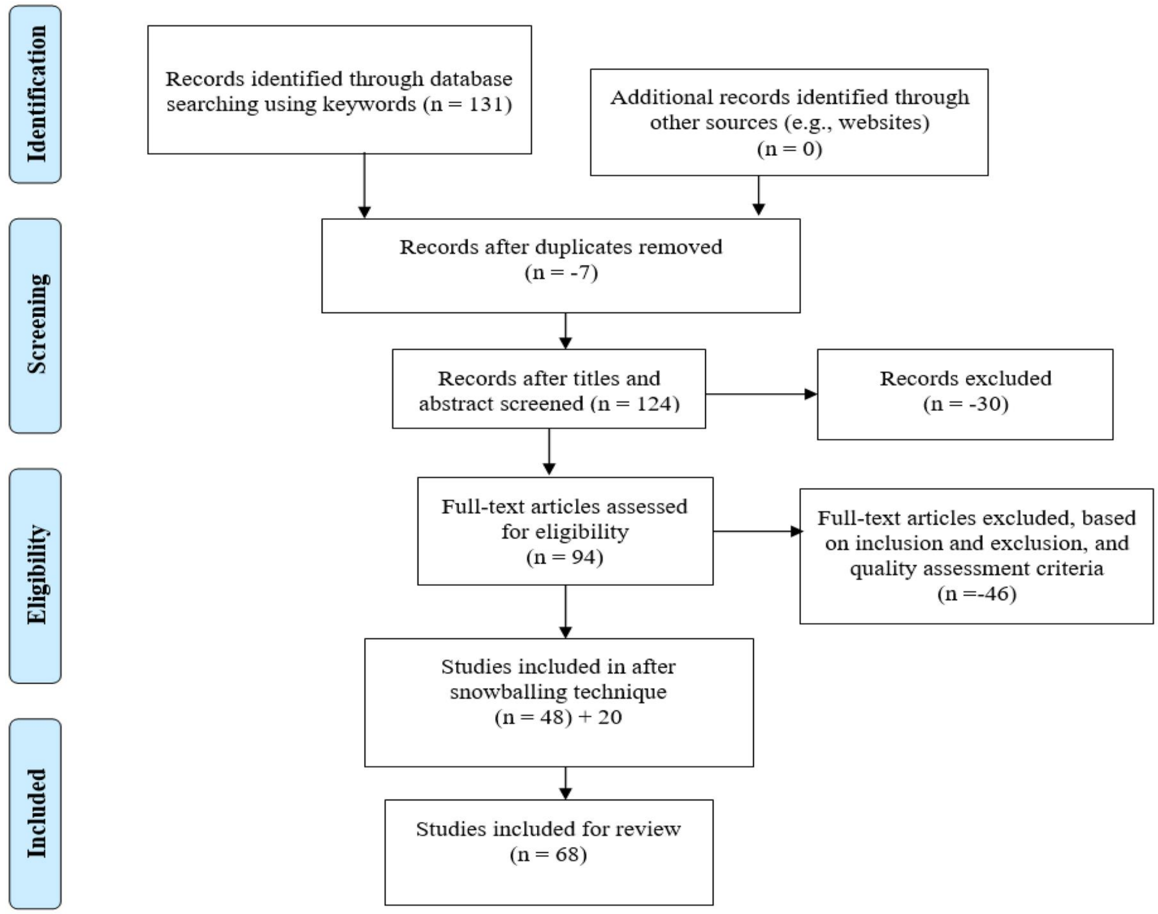

Figure 2. Overview of the search process for the identified of sources.

phase helps to describe secondary data synthesis and extraction from relevant literature. This involves the systematic presentation of the selected sources and the analysis of their impact to overall study area in focus. Also, the heuristic ensures that recommendations for action are derived from the findings (Elbert et al., 2020).

Overall, these aforementioned four procedures are translated to the following five primary phase for carrying out a systematic literature review which includes formulation of research questions, form search query strings and the execution of the search, study selection and evaluation, analysis and synthesis of the selected sources, and reporting and using the results. The first phase involves specification of possible research questions to be investigated in the study. In this study the research questions are formulated as seen in the introduction section of this article. Next, in the second phase query strings as keywords are derived to support searching of potential sources that will provide secondary data to address the research questions. Accordingly, in this study different query strings from the title, keywords, and abstract were carried out with Scopus and Web of Science online database. Scopus and Web of Science online database was selected in this study as they are one of the largest international peer-reviewed databases for technology, science, management, engineering, etc. and they cover most relevant or high-quality peer-reviewed journals, conference proceedings, and books/book chapters for the research topic being investigated in this study as seen in reference section of this paper. Accordingly, the following search queries were applied based on the title, keyword, and abstract.

- ("voice-assistants " OR "voice agents" OR " virtual assistants") AND (outdoor mobility* OR walkability OR wayfinding) AND (safety OR independence OR accessibility) AND (older people OR older adults OR elderly)
- "digital voice-assistants" AND walking conditions * AND (senior citizens OR ageing population*)
- "intelligent personal assistants" AND chatbot companion * AND (out-of-home activities OR public transportation*)
- "conversational dialogue systems" AND voice user interfaces* AND (virtual assistive companion OR enhance mobility *)

For study selection and evaluation, which involves specifying explicit inclusion and exclusion criteria to help in identifying studies that rare related to the current state of research on the design of intelligent conversational voice-assistants for older people in general. The explicit inclusion and exclusion criteria considered in the study is showed below.

- This study included sources published between 2000 and 2024 and written in English language.

- Also, peer reviewed journal articles, conference proceedings, policy reports, and book/book chapters are included.
- Sources that provide possible discussion and implications to research questions based on title and abstract content are included.
- Sources that employed either quantitative, qualitative, modelling, and experimental studies are included.
- The included sources are either indexed in Scopus or Web of Science online database to ensure that only with high-quality and relevant sources are included.
- Sources that are not written in English language, or not related to the study area, and does not provide clear objectives and well-defined research methodology are excluded.

Figure 2 illustrates the study selection process carried out for the selected sources conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) as employed by prior review studies (Anthony Jnr, 2023; Elbert et al., 2020).

In the early stage of the search process, 131 potential sources were retrieved from the online databases as seen in Figure 2 using the above-mentioned keywords. 7 articles were found as duplicates and were removed. Hence, the total number of remaining articles becomes 124 which titles and abstract were screened to be in line with the study area ICV for older people or older adults. Then 30 sources were removed as the titles and abstract were not fully aligned to the study area resulting to 94 sources which is passed for the full-text assessment. In this phase, the corresponding author read all the sources and checked that their contents are related to the research question in the first phase. At the point no sources were removed. Then the 94 sources were assessed against the inclusion and exclusion criteria. Therefore, 46 sources were excluded as these sources did not meet the inclusion criteria. This resulted to 48 sources. After which 20 sources were added to provide evidence on mobility, ageing, and technology via snowballing technique to guide the review process resulting to a total of 68 sources as seen in Figure 2 and the reference section of this article. Next, the study proceeds to analysis, extract, and synthesis of secondary data (i.e., evidence collected from prior studies), from the selected literature using data thematization to cluster the collected data related to the research questions being examined. Next, the collected data was reported using descriptive analysis as suggested in the literature (Arnold et al., 2022; Elbert et al., 2020), as seen in the subsequent sections.

4. Findings

4.1. Descriptive analysis of secondary data

In the following, a descriptive analysis of the sources is conducted with focus on the distribution of sources, year of publication, country of the publishing research institution, methodology employed, and examined research domain related to use of ICV by older people. Findings from this study based on the selected 68 sources, 44% (N = 30) are journal articles, 46% (N = 31) are conference proceedings, 7% (N = 5) are book/book chapters, and lastly 3% (N = 2) are technical policy reports. The list of the selected sourced included can be found in the reference list of this article.

Findings from Figure 3 suggest that majority of the included sources was published in 2021 with N = 14, followed by 2020 with N = 11. In 2019 and 2018 N = 7 sources were published related to older people use of ICV in different areas respectively. 2023 recorded N = 7 sources. 2017 had N = 5 sources and 2022 had N = 4 sources, whereas 2016 and 2015 both had N = 2 sources. Finally, 2024, 2013, 2012, 2011, 2009, 2007, and 2002 had only N = 1 included. This finding suggest that only fewer studies have been published in this important area and this necessitates more research related to the mobility, welfare, wellbeing, and health of older people.

Figure 4 indicates that in analyzing the 68 sources, most of the sources included in this article adopted literature

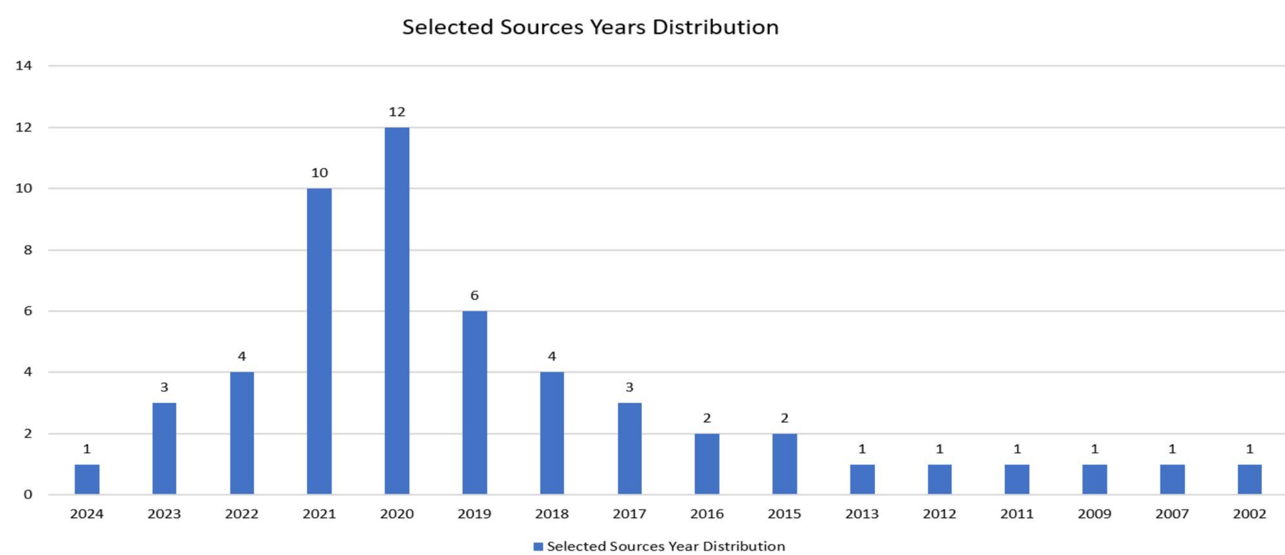

Figure 3. Distribution of selected sources years distribution.

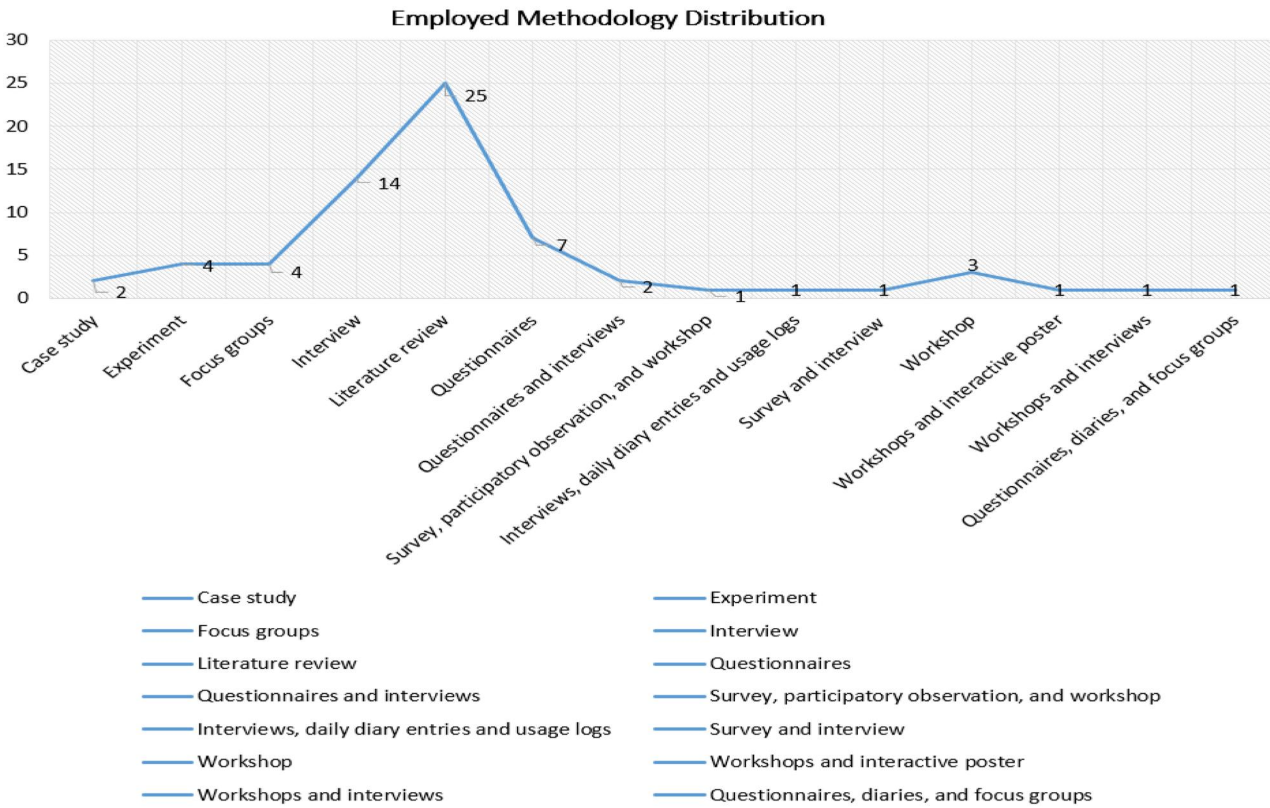

Figure 4. Distribution of employed methodology.

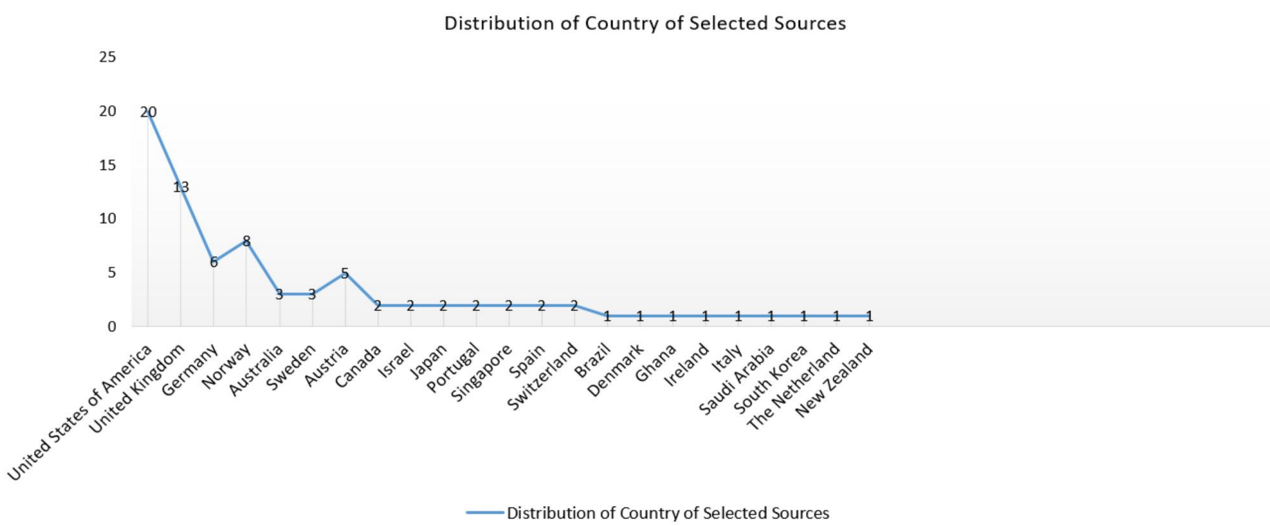

Figure 5. Distribution of country of selected sources.

review as method in their research with 24 sources, followed by interview with 14 sources and questionnaire with 7 sources. Findings from Figure 4 also depicts other method employed such as experiment, focus groups, case study, and questionnaire and interview. The other remaining sources employed survey, participatory observation, and workshop, and interviews, daily diary entries and usage logs as seen in Figure 4. Lastly a few authors employed survey and interview, workshops, workshop and interactive poster, and workshops and interviews This finding indicates that the use of ICV in older adults across different areas is still a promising topic as such there is need for more research-based studies.

Figure 5 shows that a total of 23 countries of the authors based on their publish affiliation. The results suggest that most contributors to the study area in use of intelligent conversational voice-assistants by older adults across different areas are mostly in United States of America (USA) with 20 studies and United Kingdom (UK) with 13 studies. This is followed by Norway with 9 studies and Germany each with 6 studies included and as compared to other regions as seen in Figure 5. Austria was recorded with 5 sources, Sweden, and Australia with 3 sources. The other countries reported 2 and 1 sources as seen in Figure 5.

Furthermore, out of the 68 sources included in this study Figure 6 summarizes the context of the study examined in the selected studies. The result suggests that most of the study explored technology and ageing, chatbot companion, intelligent voice assistants, voice-assistants, older people, and transport needs in old age. Also, Figure 6 suggest that most studies explored voice-controlled personal assistants, mobility of the visually impaired, and digital voice-assistants mostly employed to support the health and welfare of older people. However, only fewer studies have examined how to use intelligent conversational voice-assistants for safe, independent, accessible mobility for older people in urban environment especially for older people with associated disabilities.

Figure 7 summarizes the disciplines across which the 68 sources included in this study are published. Findings suggest that the disciple of HCI is mostly published with =21 sources, then urban mobility with =7 sources, and then gerontology, health information management, human factors in computing systems, intelligent technologies and systems,

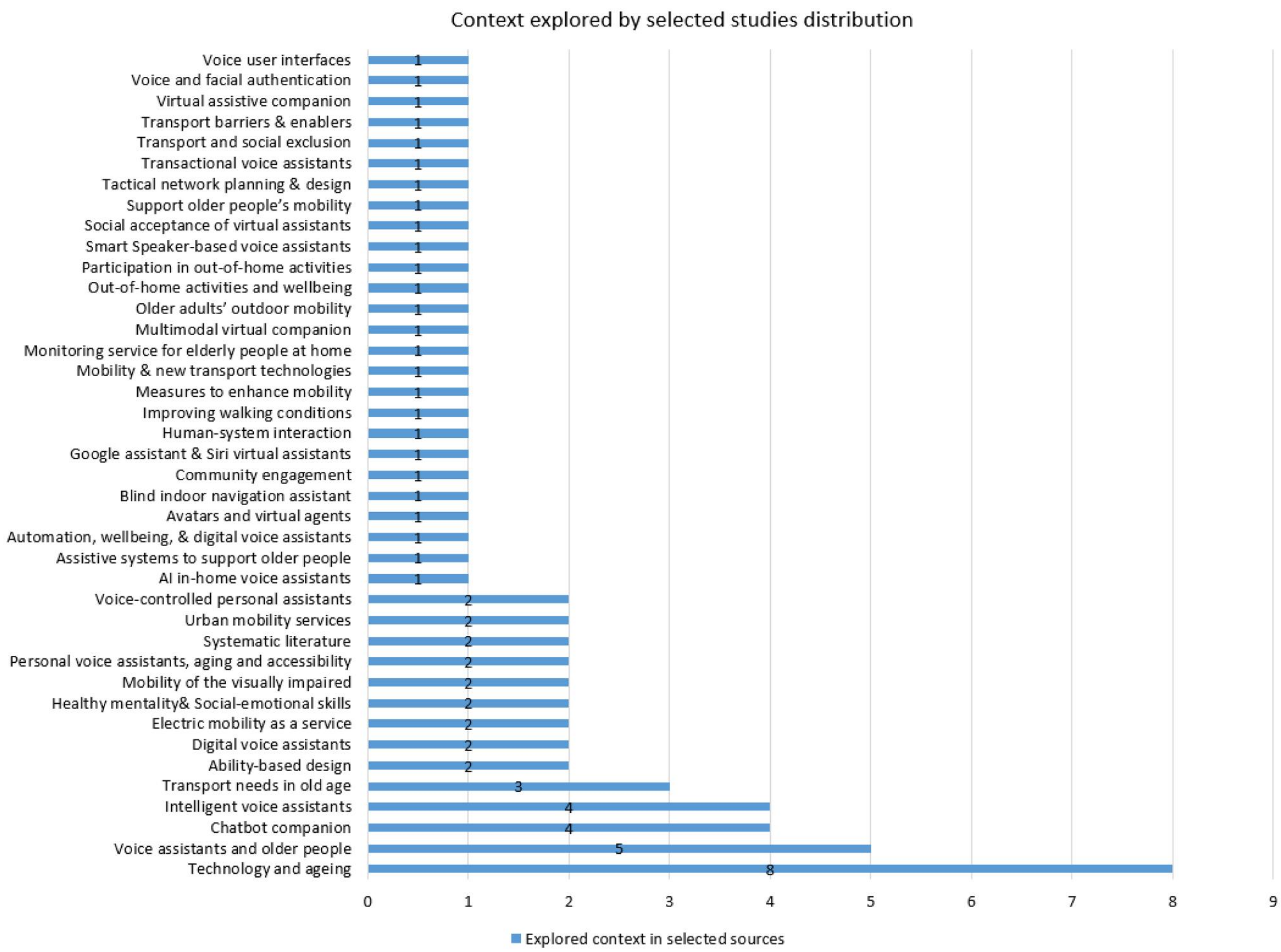

Figure 6. Distribution of explored context in selected sources.

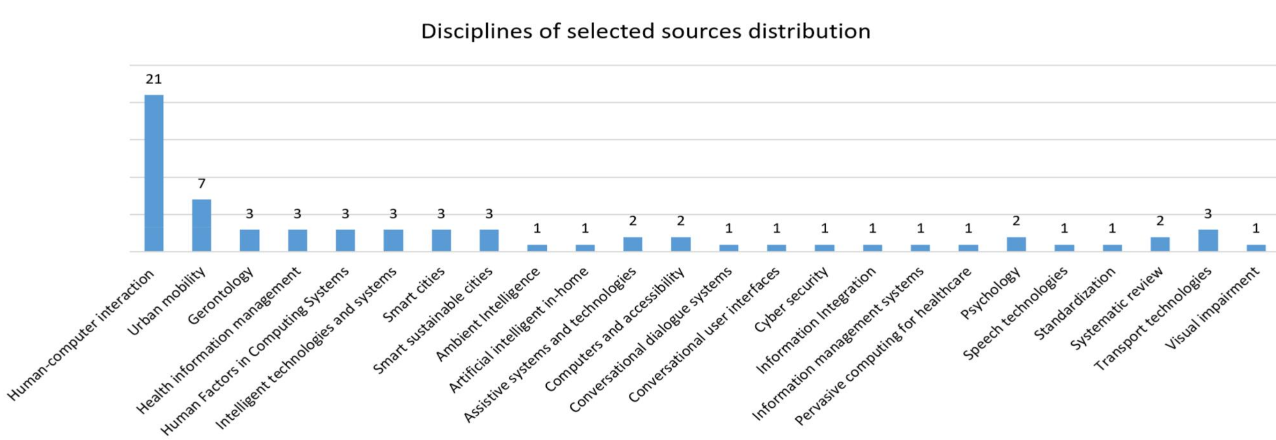

Figure 7. Distribution of disciple explored in selected sources.

smart cities, smart sustainable cities, and transport technologies with =7 sources respectively. As seen in Figure 7 other disciples are also captured as related to intelligent conversational voice-assistants for older people mobility.

4.2. Intelligent conversational voice-assistants for older people

In smart cities there is need to design innovative solutions to enhance the living conditions of older people, specifically those who live alone (de Arriba-Pérez et al., 2023). AI based ICV can engage in complex dialog with individuals to execute multiple end user requests (McLean & Osei-Frimpong, 2019). ICV employ natural language processing that enable older people to communicate this technology is predominantly attractive to the ageing population especially those who usually struggle to use touch-based interaction or Graphical User Interface (GUI) methods. ICV have become ever more useful in the current digital environment, with digital technologies like Siri providing mobile services or Amazon Alexa offering personal home assistants (Valtolina & Hu, 2021). A unique characteristic of ICV is that they provide an eyes/hands free mode of interaction, making these technologies appropriate for non-visual access across different contexts by diverse users, including older people especially for those with disabilities. This is because the non-visual form of communication presents an opportunity for older people who are blind and visually impaired to have equal and equitable access to often otherwise inadequately accessible, or completely inaccessible, interfaces or services (Abdolrahmani et al., 2021).

ICV have several benefits in improving the quality of life experienced by older people. First, these voice-assistants providing social support and reduces loneliness of older people due to their capability of being able to converse with the individual and even engaging the individual in some kind of activity through playing music, games, or even reading out the latest weather and news (Loup et al., 2017). First, ICV offer technology access for the ageing population who do not use conventional computing devices. Usability challenges caused by small buttons or font are eliminated, which is particularly useful for older people with limited sensory, motor, or cognitive functions. It is useful or older people with disabilities like impaired hand movement or limited vision and can support older people with intellectual disabilities to better manage different aspects of their daily lives (Hallewell Haslwanter & Fitzpatrick, 2017). Additionally, it can be beneficial to assist with daily wellbeing activities such as dietary planning, medication management, or health tracking contributing to support independent living (Schlomann et al., 2021). Recent research has revealed that ICV can be beneficial to older people with dementia by providing a system that can answer the same questions repeatedly. For the ageing population, reading instructions provided by physician can be difficult as such ICV could also read, prescription, list, and documents to users (Hoy, 2018).

Although, the adoption ICV are currently gaining prominence in the Human Computer Interaction (HCI) community. Prior research on ICV has mostly not examined the growing segment of older people (aged 65+) (Sayago et al., 2019). Thus, research in HCI is starting to explore how individuals interact with, perceive, and integrate ICV into their everyday lives. Notably, fewer of these studies have focused on older people. As research in this area is still at an early phase. ICV enable older people to communicate commands to a computer device such as a mobile phone via speech rather than typing. As such ICV have been integrated with smart physical devices and personal computers over the years due to its practicality (Wahsheh & Steffy, 2020). Furthermore, ICV can be employed to provide cost-effective solution to assist older people in various ways for example as a reminder system, by managing loneliness by instilling positive moods, providing social support, and as a means of communication (Ermolina & Tiberius, 2021).

Older people need assistance with management of their day-to-day mobility, to be aligned with their daily and social activities. Accordingly, the use of ICV can pave the way for the provision of safe, independent, and accessible mobility for older people especially for older people with disabilities (physical, on wheelchair or with legal blindness/vision impairment, sensory, and learning impairment) (Fitzpatrick, 2021). ICV interacts with older people using a multimodal interface which includes a graphical touch-based user interface, text-to-speech, and automatic speech recognition (de Arriba-Pérez et al., 2023). It can provide navigation support to older people by locating signs and symbols, offering guidance and reminders. It also provides connection to emergency support centers in case of falls or injuries faced when older people walk across and within cities. ICV is able to remember routes, direction, and connect remotely with public transportation modes, family, care givers, and emergency service centers. Over the decade some studies have been dedicated to exploring the design and use of digital technologies such as ICV to improve the welfare and wellbeing of older people in different domains. The reviewed 20 studies presented in Table 1 presents research that have been done as related to older people use of ICV in general.

Table 1 depicts how current studies, despite being in other contexts have inform ICVs for mobility. Table 1 also show the gap in knowledge similar to prior studies (Arnold et al., 2022; Elbert et al., 2020), as related to the domain of older people mobility, walkability, and wayfinding which has not been well addressed in the literature. As shown in Table 1 some studies have been dedicated to examining the design and use of ICV by older people across different domains. *However, there are fewer studies that focused on investigating how to ICV can be used to improve the mobility and walkability needs of older people to improve their safety, independence, and maintain long-term accessibility.*

However, a recent study by Jnr (2024) presented a user centered AI based approach for voice assistants to promote a safer mobility targeted for older people in municipalities. Likewise, the majority of existing studies are based on touchscreen-based devices accessed through input and Graphical User Interface (GUI) based output (Chen et al., 2021, 2023; Trajkova & Martin-Hammond, 2020; Valtolina

Table 1. Related studies on the use of intelligent conversational voice-assistants for older people.

Author(s), year, and contributions	Explored research themes	Methodology employed	Research context	Countries
Arnold et al. (2022) explored the use of personal voice-assistants among older adults and associated outcomes.	• Personal voice assistant • Older adults • Ageing in place	Literature review	Examined the degree of personal voice-assistants utilized for older adults, their technology readiness level.	Canada
de Arriba-Pérez et al. (2023) suggested an automated detection of cognitive impairment in older people.	• Intelligent systems • Monitoring • Cognitive impairment	Experiment	Developed a system that can assess cognitive abilities of older people using machine learning algorithms.	Spain
Chen et al. (2021) investigated the barriers and design opportunities of using voice-assistants.	• Gerontechnology • Accessibility • User experience design	Interviews	Provided insights regarding the issues for designing technologies for older adults, particularly related to healthcare.	United States of America
Duque et al. (2021) examined how to improve wellbeing of older people using digital voice-assistants.	• Automation • Conversational agents • Design ethnography	Interviews	Indicated that digital voice-assistants aids older people in a dialectic relationship with automated content.	Australia
Gollasch and Weber (2021) researched on age-related variations preferences for using voice-assistants.	• Voice interaction • Conversational user interfaces	Survey questionnaire	Identified the particular age-related preferences of older people when they use a conversational user interface.	Germany
Mundhra et al. (2021) designed a humorous chatbot for senior citizens.	• Chat-bot • Information retention	Questionnaire	Assessed information retention in older people conversing with a chatbot.	Singapore
Schlomann et al. (2021) studies the capability and drawbacks of digital voice-assistants in older adults.	• Voice-assistants • Speech assistant • Smart speaker	Literature review	Proposed detailed research designs to offer better insights into the adoption and use of voice-assistants in advanced age.	Germany
Valtolina and Hu (2021) developed a chatbot to improve the quality of life of older adults.	• Conversational interfaces • Chatbots usability • Interaction design strategy	Interview	Described a chatbot discussing with older people, with age-related difficulties and the level of acceptability by older people.	Italy
Miura et al. (2020) deployed and assessed feedback feature for monitoring service for older people.	• In-home long-term care • Monitoring system • Sensing agent	Experiment	Aimed to automatically provide feedback and guidance to improve the current mental state situation of older people.	Japan
Pradhan et al. (2020) examined the use of intelligent voice-assistants by older people with less technology use.	• Conversational interfaces • Voice-assistants • Smart speakers	Daily diary entries, usage logs and interviews	Provided understanding on how older adults occasionally perceive and utilize voice-assistants .	United States of America
Ryu et al. (2020) designed a chatbot service to improve the mental health care of older people.	• Interaction • Mental health care • User-oriented design	Field study Interview	Implemented a mental health care chatbot to helps in decreasing depression and anxiety among older people.	South Korea
Pradhan et al. (2019) explored the classification of smart speaker voice-assistants by older people.	• Personification • Ontology • Voice-assistants	Interviews	Contributed how existing theories of anthropomorphism can be employed to voice-assistants.	United States of America
Sayago et al. (2019) investigated open issues faced in use of voice-assistants among older people.	• Conversational user experience • Voice-assistants design	Literature review	Studied adoption of voice-assistants for older people and explored perceptions and barriers to use of voice-assistants .	Spain, Australia, Ireland
Shalini et al. (2019) explored the design of voice-assistants to improve independence of older adults.	• Voice-assistant • Older adults • Speech recognition	Focus group Test scenarios	Focused on human-computer design, mainly in voice-assistants to support older people to manage their health.	United States of America
Stigall et al. (2019) investigated older people use and perception of voice user interfaces.	• Accessibility • Voice user interface • Natural language	Literature review	Presented the benefits of voice interaction for older people and barriers limited the adoption of this technology.	United States of America, Australia
Ho (2018) suggested a voice-controlled virtual assistants for older people faced with visual impairment.	• Visual impairment • Voice-controlled smart speakers	Literature review	Discussed on how virtual assistants assist the daily lives of older people with visual impairment to improves their wellbeing.	United Kingdom
Thakur and Han (2018) explored social acceptance of virtual assistants by older people.	• Virtual assistants • Social acceptance • User experience	Sentiment analysis of tweets developed using RapidMiner	Utilized the concept of sentiment analysis to analyze the beliefs of older people use of virtual assistants.	United States of America

(*continued*)

Table 1. Continued.

Author(s), year, and contributions	Explored research themes	Methodology employed	Research context	Countries
Shaked (2017) researched on virtual agents and avatars in relationship interfaces for the older people.	• Decision making tools • Virtual agents • Home care monitoring	Literature review	Presented the challenge that impacts the design of interfaces can enable smooth interaction for the older users.	Israel
Tsiourti et al. (2016a) designed a framework as a multimodal virtual companion for older adults.	• Artificial social companions • Autonomous agent	Focus groups interviews Paper based surveys	Presented an architecture on the decision making and perception components which impacts affective behavior.	Switzerland Portugal Austria
Tsiourti et al. (2016b) designed a virtual assistive companion for older adults.	• Conversational agents • Agent architecture • Multimodal interaction	Focus groups interviews Questionnaire	Carried out a user-centred design research that supported the design of the companion.	Switzerland Portugal Austria

& Hu, 2021). *The use of ICV to provide safer and more independent mobility, walkability, and wayfinding for older people to support user centred sustainable mobility still remain untouched in the literature.*

Therefore, there is need to use ICV to provide text-to-speech and speech-to-text based application developed to support older people through a multimodal auditory interface that employs automatic speech recognition to support independent mobility and safe walkability and wayfinding. Accordingly, the focus of this study is to explore how to design an ICV that support safe, independent, and accessible mobility for older people in urban environment. ICV is proposed in this study to provide accessible, on-demand mobility, real time walkability, and wayfinding information to older adults using voice commands. ICV can provide voice, and verbosity as replies or offer non-speech auditory notifications of information (referred to as earcons), or vibration feedback. The provision of navigation preferences that allow older people to adapt their mobility needs such as the routing that provides elevator directions as compared to climbing up the stairs, confirmation if individuals are on the right route to their planned destination or if they are headed off track either verbally or through vibrations.

4.3. Intelligent conversational voice-assistants for improved mobility behavior

4.3.1. Provision of safe, independent, and accessible mobility

Currently public transportation systems are so far less accessible (refers to the inadequate ease with which older people cannot get access to different mobility services when needed), nor inclusive (provision of mobility services tailored fit for all), for the aging population with varying mobility needs and capacities. Thus, there is need to improve mobility inclusion (provision of new or enabling of available mobility services), to achieve inclusive and safe age-friendly mobility (Bokolo, 2023a). Digital technologies may provide resources to develop personalized tools to support healthy and active ageing. These resources may include conversational voice-assistants, as a promising solution to minimize the increasing mobility and walkability challenges faced by older people (Tsiourti et al., 2016b). ICV can help older people when they leave bus/train stop/station and when they need support access for transportation services to help arrange public transportation. ICV can help older people with is memory reduction and cognitive impairment by promptly asking the user if she/he requires help to remember a journey and can helps her/him to confirm the journey itinerary or timetable (Valtolina & Hu, 2021). Findings from a focus group sessions stated that ICV could provide travel assistant by providing a selection from available and accessible transportation options (Brewer & Piper, 2017), offer direction in different zones and locate the car/driver in different areas (Abdolrahmani et al., 2021).

By utilizing ICV individuals can send query via travel assistant agents, or they can be notified of different multimodal mobility options with different journey duration and cost-effective choice they could select from. ICV can assist in booking the mobility service, boarding, and by specifying when the users can get off the public transport as it notifies the user of other connecting public transportation. It could offer them general directions or, when leaving an unfamiliar bus stop or station, it could provide step-by-step directions to a desired location (Abdolrahmani et al., 2021). In summary ICV provides information on getting mobility options, choosing from the available options, provision of ride service information, real-time update of the mobility service status, direction towards the public transportation zone, and locating of the public vehicle (Anthony Jnr et al., 2020; Bokolo et al., 2022). Since the tool is to be employed by older people the design of ICV application needs to be adaptable and customizable to the personal preferences of an older user (Brewer et al., 2023). These involved providing customizing to various modes of operation, filtering the travel information provided, and customization based on personal user preferences as well as the environmental awareness for independent mobility and safe navigation (Abdolrahmani et al., 2021).

4.3.2. Support of safe, independent, and accessible, walkability and wayfinding

ICV can help to improve walkability by providing solutions such as audible and haptic vibrotactile/feedback indicators based augmented systems for older pedestrians, which would provide wayfinding information about their location (Sobnath et al., 2020) for movement and orientation. ICV can promote independent navigation for older people mostly those with legal blindness/vision impairment has been of great interest and prominence to mobility accessibility. Older people with legal blindness/vision impairment uses technological assistive devices for improving mobility safety such as such as robotic aids, electronic white canes, GPS for accessibility, or navigation tools from talking maps and on-trip information, as well as supported tools for virtual reality (Lazar et al., 2018; Zimmermann-Janschitz et al., 2017). Several technologies have been proposed both in research and through the industries to improve navigation and multimodal functionalities in urban environment.

Examples of commercially developed outdoor navigation platforms developed for people with vision impairments incudes NearbyExplorer (tech.aph.org/neandroid/), BlindSquare (blindsquare.com/), ariadneGPS (ariadnegps.eu/en/), etc. Similarly, there have been efforts devoted to improving the accuracy of turn-by-turn wayfinding within last-few-meters near the defined destination, the deployment of interactive maps, and techniques to improve the communication between individuals and wayfinding/navigation device or sighted/human guide. Another successfully developed research-based indoor navigation tool is the “NavCog3” which is a turn-by-turn navigation application that identifies points of interest (POI) along the route integrated with a disembodied conversational agent (Sato et al., 2017). Over the years much developmental iterations on NavCog3 have helped to evaluate navigation accuracy and feedback on landmark, the inclusion of virtual navigation and addition of touch gestures and fixing of errors that results from difficulty faced by users in following rotational directions. Examples include NavCog3 (Sato et al., 2017), Google Maps, Waze, etc., which provide users with options to use tactile and voice commands.

However, we have not been able to locate work that examines how a voice assistant that works in tandem with navigation, itinerary, and other applications can adopt multimodal input and output functionality to enhance interaction (Abdolrahmani et al., 2021; Lazar et al., 2021), of older people in smart cities environment. Figure 8 depicts the main functionalities for ICV towards improving the mobility, walkability, and wayfinding of older people. Findings from the literature mentioned that individuals were interested in using ICV that is operated in several modes, providing travel information to the user based on mobility, walkability, and wayfinding. These involved the support for planning (e.g., booking the journey) (Anthony & Petersen, 2020), navigation (e.g., getting comprehensive step-by-step directions), or exploration (e.g., querying and receiving information about the surroundings environment and needed Point of Interest (POI) for better environmental awareness).

Another set of features advised in the study by Abdolrahmani et al. (2021) comprised adjusting the settings of ICV in relation to the interaction with the system itself by customization of name and settings of speech output such as speed, voice, and verbosity of the replies and non-speech auditory notifications of information (referred to as earcons), or vibration feedback. ICV can provide navigation preferences that allow older people to adapt their mobility needs such as the routing that provides elevator directions as compared to climbing up the stairs, confirmation if individuals are on the right route to their planned destination or if they are headed off track either verbally or through vibrations (Abdolrahmani et al., 2021).

4.4. Factors that impact use of intelligent conversational voice-assistants

Findings from the literature stated that ICV are now being adopted for example Amazon Alexa is reported as the most widely used voice-assistant by older people for searching for information, setting up reminders, and checking weather condition (Arnold et al., 2022). Thus, ICV are designed to be more human-like and intended to be an important part of older people’s everyday life, assisting with daily life chores such as setting alarms, turning lights off and on, task scheduling, providing personalized news information, managing online purchasing, and checking order status, etc. (McLean & Osei-Frimpong, 2019). The *technology readiness level* in ICV is high, although the evidence level is low as there are fewer studies that have been carried out to examine the adoption of this technology by older people (Arnold et al., 2022; Barros Pena et al., 2021a; Bokolo, 2023b). Hence, studies that investigate if the use of personal voice-assistants can support older people’ mobility, walkability, and wayfinding is still unknown. Despite the proliferation and adoption of

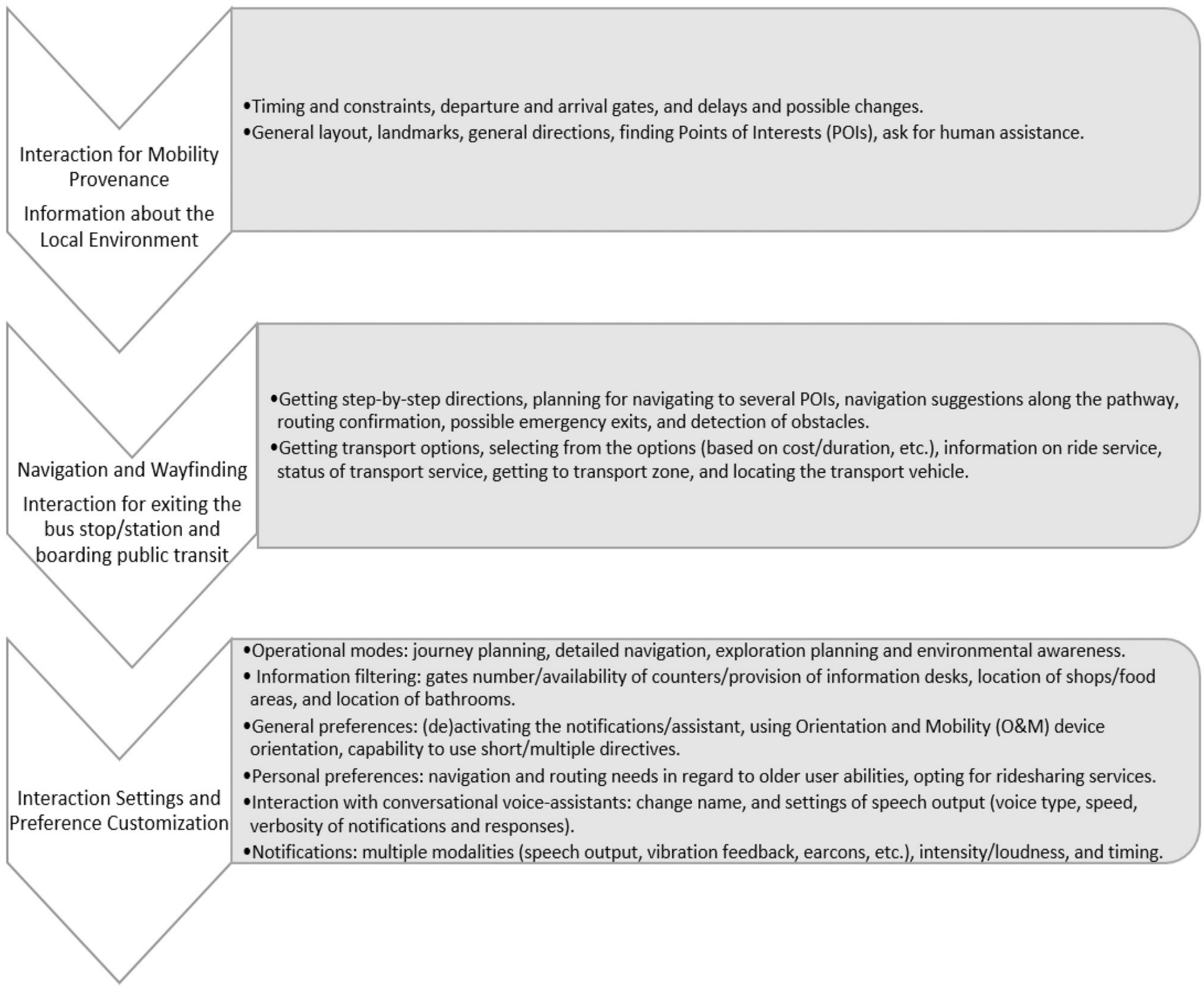

Figure 8. Intelligent conversational voice-assistants for improved mobility behavior.

ICV, *there is little studies that have explored what factors influences older people use of this digital technology* (McLean & Osei-Frimpong, 2019). Some factors have been identified as guidelines to be considers enhancing the design and development of ICV for older people as discussed in Table 2.

Table 2 summarizes the factors as guidelines that impact use of ICV to supports older people. ICV require an extensive set of software permissions to implement their predefined tasks (McLean & Osei-Frimpong, 2019). There is also potential intrusion to user privacy as ICV when deployed in devices are always connected to users' device microphone which are connected to the Internet (Ho, 2018; Schlomann et al., 2021), which may result to privacy concerns related to the use, disclosure, and protection of personal data (Ermolina & Tiberius, 2021). Besides, when machine learning is deployed to improve the performance ICV, data are required to be trained the machine learning models. At present, given that users personal data may be shared by a company with other using third-party firms who listen to individual's audio recordings to enhance the quality of ICV towards improve mobility related service (Ermolina & Tiberius, 2021). Additionally, most mobility enterprises, municipalities, and institutions are hesitant to adopt ICV, mainly due *to legal compliance and GDPR* concerns as these data are collected from individuals. For older people who do not frequently use the internet or are new to using the internet-based devices there may be issues (Pradhan et al., 2020), due to fact that they will lack credible judgement skills and will also experience setbacks in gaining access to mobility and walkability information using ICV. Another issue is related to the fact that the interaction with ICV with humans are often observed to *follow a pre-defined form of dialogue which limits the auditory abilities* of ICV.

Findings from prior studies showed that *older people faced distress* with the structured dialog nature of ICV. As users expressed feelings that dialogues with ICV are one sided as they are faced with timeouts when giving input or entering unintended words (Hoy, 2018). Further findings from Pradhan et al. (2020) suggested that older people *remembering certain keywords needed* to invoke ICV or to navigate within the application to achieve specific goals is a challenge in using this type of application. Similarly, older people often have *difficulties remembering the specific*

Table 2. Factors that impact use of intelligent conversational voice-assistants to supports older people.

Factors	Description
Ease of use	This factor is concerned with how easy and user friendly ICV is to older people when they navigate the auditory interface. This factor assessed if it requires a lot of learning effort for older people to use ICV to support mobility services. This requirement is necessary to accommodate the older people physical and cognitive abilities.
Visualization	This factor is concerned with the external appearance or avatar of the ICV within the device being deployed whether the avatar is a human-like agent, an image an animal, or just an application user interface. This requirement assesses how likeable the ICV is and how well it characterizes or personalized the mobility needs of older people user (Shaked, 2017).
Personalization	The personality of the Persona or the Avatar is conveyed via speech, visual, facial, and possible emotional gestures can influence the use of conversational voice-assistants. Personalization relates to how ICV will be able to provide different services particularly personalized to the daily mobility needs and walkability tasks (Shaked, 2017).
Availability of analytics	This factor plays a crucial role in achieving personalization. The provision of analytics facilitates the establishing of user mobility patterns and this offers predictions for future mobility behavior for older users.
Error recovery	This factor involves the capability of ICV to easily recover from a dialogue misunderstanding or mistake rather than creating an infinite conversation loop and an unpleasant interaction experience (Shaked, 2017). It is important to create a smooth interaction with older people especially in a dialogue for wayfinding and walkability (Shaked, 2017). Error recovery is challenging to avoid and requires use of data analytics technologies integrated with NLP module.
Latency	This factor is important to improve user experience as the delay response between input into the system and the desired reply or output (Barros Pena et al., 2021a). Latency highly affects the quality of the interaction as well as the dialog flow. Thus, high latency which is the time taken in seconds per interaction may be observed in by older people as lack of ability to understand him/her and this create a sense of misunderstanding (Shaked, 2017).
Integration	ICV should possess the ability to incorporate different input/output technologies into the dialogue that enables older people to choose which auditory interface is preferable to accommodate the older users' capabilities.
Gamification	This factor involves the inclusion of gaming functionality and rewards for task execution is highly recommended for as it supports the continuity and familiarity of ICV with older people (Shaked, 2017).
Appearance	There is need for ICV with a realist and a friendly voice and face that makes older people feel comfortable. Findings from the literature suggested that availability of different virtual characters, with different looks base on different age and gender, realistic human-like expression is preferred over cartoonlike appearance and formal as compared to informal look (Tsiourti et al., 2016a).
Verbal and non-verbal capabilities	This factor involves the provision of a ICV that has seamless communicative proficiencies, such as the capabilities to perceive and interpret vocal and non-audio input (for example verbal language and facial expressions), and to express voiced and non-vocal behavior (Tsiourti et al., 2016a).
Decision-making and personality	The ICV should show emotional responses and coherent behavioral that can be understand by older people as indication of natural and social personality (Tsiourti et al., 2016a).
Perception and awareness	ICV should be able to perceive their deployed environment once its operational and it should be aware of the current location/condition of the older people. Older people envisioned a ICV that can understand their emotional state (e.g., sadness, joy, etc.) and activity (e.g., walking, idle) and utilize this data to adapt its behavior to offer mobility and walkability support.
Safety	ICV should be able to monitors older people and recognizes abrupt human body motions that indicate instability or a sudden fall or a call for help, based on a predefined voice command. In the case of an emergency, it should initiate a dialog to acknowledge the detection and reassure the user and if necessary, automatically dispatches a phone call to a designated caregiver or emergency center (Tsiourti et al., 2016a).
Guidance	Since older people are disposed to forgetfulness, it is expected that ICV can recognize emergency situations (e.g., injury, falls), and help older people detect objects such as signs, symbols, etc. in the build environment utilizing real-time vision-based detection of prior learned objects, when possible (i.e., when a physical object is in the area of view of the phone camera) (Tsiourti et al., 2016a).
Privacy	Furthermore, in accordance with General Data Protection Regulation (GDPR) other associated risk factors that impact use of ICV relates to the perceived threat to user's privacy due to the data that is collected by the system based on the individual's information (Chen et al., 2021; Hoy, 2018; McLean & Osei-Frimpong, 2019; Pradhan et al., 2020). Although ICV provide benefits to older people, the adoption of digital technologies such as AI based machine learning can pose threats to users' privacy. As there is a possibility for data to be stolen or leaked (Hoy, 2018).
Security risk	Findings from the literature stated that ICV such as the Amazon Echo have security risk that can be manipulated by individuals with unauthorized access. ICV can execute high priority tasks utilizing private account details, assist in making appointments, look up available travel service information, reserve mobility modes on behalf of older people, and make payments on behalf of user and the payment details can be faced with security issues.
Data access	Another issue with ICV is data security. Anyone with access to ICV based system can query it, get information about the personal accounts and digital services connected with the device, and query it to perform tasks. This can be a security risk as these devices will read out emails, SMS, calendar contents, and other personal information (Stigall et al., 2019). To address this type of unauthorize data access Google has lately upgraded its voice assistant software to incorporate voice printing, which distinctively identifies each user using their voice to stop the device from reading out personal information to unauthorized voices. Apple is also training Siri to recognize an individual's voice, whereas Amazon's Alexa is working to deploy a similar voice printing module. There are now options to set a voice activated passcode to confirm user accounts (Hoy, 2018). Another approach to address access concern in ICV all collected data should be destroyed after analysis or no data should be recorded (Stigall et al., 2019).

auditory commands needed to operate command the use of ICV (Pradhan et al., 2020; Schlomann et al., 2021). Other technical challenges identified in the literature ranges from voice recognition problems associated with the *device "timing out"* or delay *before the "speech input by the user"* is complete, and reliance on the capability of the paired computing device which results to system errors (Pradhan et al., 2020).

4.5. Requirement specifications for designing conversational voice-assistants

Older people face or will in time use digital technologies embedded with conversational or auditory interface used through daily activities such as in mobility. According to the findings from prior studies (Gollasch & Weber, 2021), users' intention to use speech-only technology can be seen among

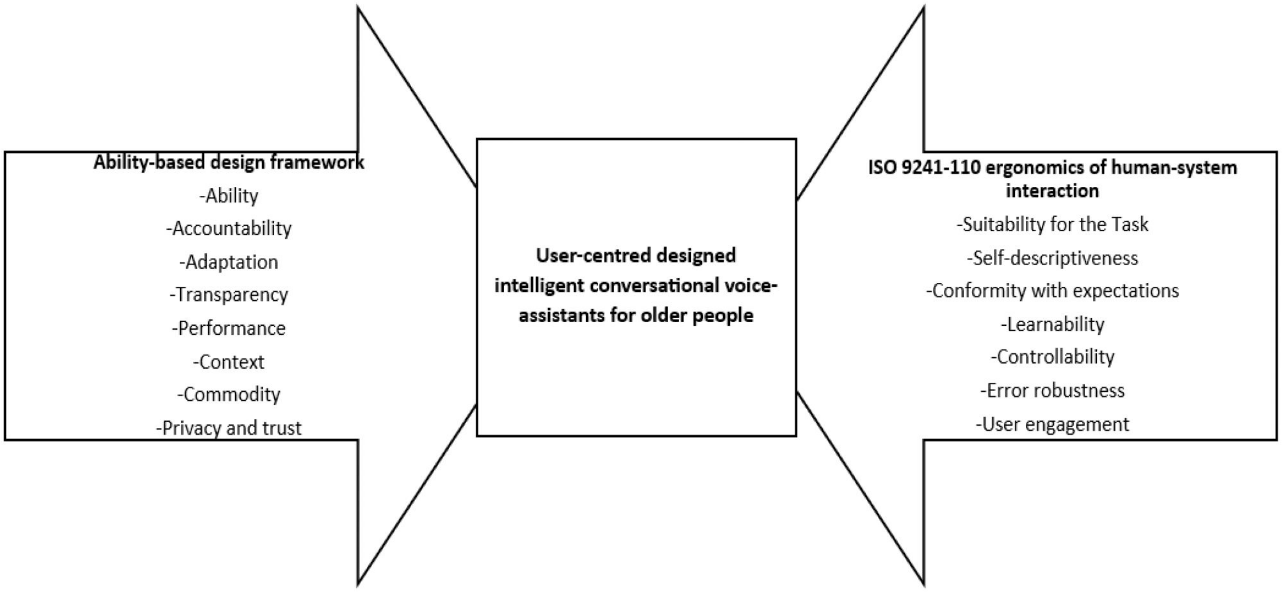

Figure 9. Requirement specifications for designing conversational voice-assistants.

older people, suggesting that the ageing population are interested in this development. However, the use of these technologies among the older population is associated with the challenge they face in coping which is a viable requirement to be considered when designing age-specific systems (Gollasch & Weber, 2021). Secondly, while most of the recent research in this field has focused on improving the functionalities of ICV (Thakur & Han, 2018), there are fewer research done to analyze the requirements to be considered in designing ICV to supports specifically mobility and walking accessibility, safety, and independence of older people. Findings from Gollasch and Weber (2021) suggested that older adults expect or prefer that in using ICV there should be simultaneously less information, more guidance and patience as well as clear, slow, and loud auditory/voice interface. Accordingly, this study employs a user-centred design approach based on the "*ability-based design framework*" and "*ISO 9241-110 ergonomics framework for human-system interaction*" to specify the requirements needed to design ICV as seen in Figure 9.

Figure 9 depicts requirements needed to design ICV grounded on a user-centered approach which comprises of the ability-based design framework and the ISO 9241-110 framework for ergonomics of human-system interaction principles. The ability-based design was proposed in the literature (Wobbrock et al., 2011; 2018), as a framework to which focuses on older people ability, instead of their disability, when designing interactive technologies for the ageing population (Chen et al., 2021), (e.g., it aims to transfer the existing technical skills of older people to ICV use). Overall, the seven principles of the ability-based design framework are employed to support the design of ICV that will support the mobility accessibility, safety, and independence of older people.

As suggested in the literature (Chen et al., 2021; Ermolina & Tiberius, 2021; Hoy, 2018; McLean & Osei-Frimpong, 2019; Pradhan et al., 2020), the application of ICV should improve "data privacy and trust" of older people concerns when they use digital technologies for mobility related services. These are included as one of the requirements as seen in Figure 9. Also, 7 design principles were identified from the literature (Gollasch & Weber, 2021), based on the 7 dialogue principles (suitability, self-descriptiveness, conformity, learnability, controllability, error robustness and user engagement), proposed within ISO 9241-110 framework for ergonomics of human-system interaction (ISO, 2020), as seen in Figure 9. The identified requirements are reviewed in Table 3.

5. Discussion and implications

5.1. Discussion

Due to technological advances in AI and machine learning as well as increasing deployment of natural language processing, ICV, speech recognition, etc. have gained popularity in research and practice over the last years. It is predicted that the chatbot market will grow from $17.17 billion in 2020 to almost $102.29 billion in 2026, suggesting the high relevance of this area. ICV are used to automate routines in a wide variety of areas, such as customer support, education, entertainment, health, etc. to guarantee 24/7 availability to increase effectiveness (Janssen et al., 2021; Petrie, 2023). While ICV are increasingly becoming part of the society, specific vulnerable user groups such as older people that might benefit from this technology are often less considered in research. Given the rapid development of digital technologies in smart cities in providing mobility related services, it is significant to consider the use of ICV as a promising tool able to maintain and enhance mobility, walkability, and wayfinding activities for a wide range of older people. As there is still a digital divide between the older and younger generations, the ageing population might benefit from the use of DT such as ICV. Older people especially those with disabilities are at high risk of digital exclusion and digital

Table 3. Requirement specifications and strategies for designing intelligent conversational voice-assistants for older people.

Methods	Requirements	Description and user-centered strategies
Ability-based design framework (Chen et al., 2021; Wobbrock et al., 2011; 2018)	Ability	Re-enforces the need to focus on the ability and not on the dis-ability, thus striving to capitalize on the capabilities of older users to augment what they need to do. • Older people should ubiquitously access mobility availability and accessibility information using auditory interface without requiring many efforts and time when they are walking in cites. • The system should also allow older people to easily change pre-configured settings based on their mobility and walkability need (e.g., enable/disable ICV connected to a specific feature in their device). • The provision of avatars or visual output for enhanced social communication and user interaction experience. • Availability of multimodal output to support mobility when older people with sensory impairment use these systems.
	Accountability	Encourages system designers to improve performance by changing the systems and not trying to change older users, thus it is recommended to leave older users as they are. • ICV needs to accurately understand older people intent and provide procedure to restore interaction upon system failures when in use by older people walking in cities or in transit in public transportation.
	Adaptation	The auditory interfaces may be user-adaptable or self-adaptive to offer the best possible match to suitable to older people mobility needs and ability. • Personalized response should be based on older people mobility interests and hobbies. • The provision of personalized on-demand active mobility and safe walking advice.
	Transparency	The auditory interface can offer users awareness of any adaptations and the resources to check, reverse, reject, change back, preview, store, retrieve, and pre-test those adaptations for improve mobility recommendations. • Older people should have easy, clear, and plain guidance during system troubleshooting and setting up phases.
	Performance	The systems can monitor users' usage performance by logging and predicting measures to improve performance usage. • ICV should be able to sense and compute older people mobility pattern to provide personalized guidance.
	Context	The systems should be able to sense context or environment when in use and propose recommendation to improve mobility and walking for older people based on their existing ability. • Older people should be able to plan their mobility needs and adapt to the pedestrian environment using ICV.
	Commodity	The deployed system should consist of readily available, inexpensive, low-cost device hardware and software. • The integration of ICV into current technologies should not require high cost of ownership for older people.
	Privacy and trust	The system should employ privacy by design measures during the development for improve security and privacy of older people data and to increase user trust of the technology. • Employ measures to guarantee user confidentiality mostly for contextual data and unintended speech, as well as to improve the trust between older people and ICV.
ISO 9241-110 ergonomics of human-system interaction (Gollasch & Weber, 2021; ISO, 2020)	Suitability for the task	The speech recognition module should be able to recognize different group of older people (between the age of 65–74, 75 and older), to address usability issues faced by older people amidst use of these ICV. • The speech recognition module should be able to understand indistinct accents or pronunciation (this may be due to the local dialects, idiom or speech impairment faced with older people between the age of 65 and older. • It should possess the capability to handle and process repetitions, pauses in speech, and incomplete words. • Use simplified activation word and possess the capability to process different languages if possible translation
	Self-descriptiveness	The system should be able to manage the presentation of several information to older people by being able to cope with complex conversations using simple step-by-step dialogues during movement. • Since the system is intended for older people it is recommend incorporating simplicity in the sentence structure with short sentences with few statements per sentence. • The system should be able to understand single question in each dialogue, preferably, yes/no questions and to some extend be able to decode complex questions. • The system should signal user request to speak (as input phase) with limited marginal error.
	Conformity with expectations	Involves high expectations from users who perceived the interaction with ICV to be human like dialogue. • The system should be able to cope with change of topic, perceive topic switches, and ambiguous communication in different conversation context such as in mobility and walkability/wayfinding. • The possibility to show variation in the construction of output statements, rephrasing of similar or same statements. • Reiterating statements in combination with common, renewed, and rephrasing reference to the current discourse of mobility and walkability with older people. • There should be balance with the speech speed and clarity. Thus, speaking slowly and clearly, using frequent tone of voice, thereby optimizing voice clarity over speed • Better sensitivity for recognizing the activation word and always reacting to the activation word, even for older people with unclear accents or pronunciation.

(*continued*)

Table 3. Continued.

Methods	Requirements	Description and user-centered strategies
	Learnability	• Involves inclusion of precautionary questions as safety check to mitigate unplanned irreversibly actions.
		• Make recommendations that proactively improves the personalization.
		• Provide help with directions and support that proactively improve mobility and safe walkability/wayfinding.
	Controllability	• Provision of options to change the voice or audio (volume, pitch, type, speaking rate, etc.), as well as personality and customizability of pronunciation.
		• Prevent unintentional interruption of the conversation when in use not to compromise safe mobility.
	Error robustness	• Employing checking procedure to assess what has been understood by the user by prompting for repeat entered information.
		• In case of an error message the level of information provided as an error message should be less detailed.
		• In case of any unforeseen misunderstandings the system should prompt user and ask for repetition when needed.
	User engagement	• The system should preferably use formal communication in relation to informal communication and provide positive feedback to improve the mode of older people. Also, personal communication is preferred as compared to neutral communication.
		• When the user introduces themselves to ICV, the system should provide an introduction of itself back to the user to build trust.

technologies such as ICV have hardly been designed and investigated for this target group (Petrie et al., 2018; Schlomann et al., 2021).

Psychologically, older people with legal blindness/vision impairment display higher prevalence of depression, anxiety, and have lower quality of life. The adoption of ICV can enable older people with reduced vision and limited experience with handheld devices to use such gadgets such as mobile phones by simply talking to them. This work provides preliminary insights into how ICV can facilitate safe, independent, accessible mobility for older people in urban environment. Evidence from this study reports on factors as barriers that acts against the adoption of ICV such as issues in the system correctly understanding voice commands. The findings also examine the perceived factors that influence the use of ICV by older people in smart cities. Preliminary finding from this study highlights that irrespective of the limitations faced by older people who used ICV that this technology may be valuable for older people. This finding is similar to results from Pradhan et al. (2020) where the authors revealed that prior studies have become progressively interested in exploring how DT such as ICV might be more suitable for the heterogonous older people community. The author pointed out that for older people the approachability and accessibility of ICV interfaces may provide new opportunities to the ageing population (Pradhan et al., 2020).

Furthermore, findings from this study explore the requirement specifications to be considered in designing ICV for older people. Findings from Stigall et al. (2019) revealed that only few studies have been carried out on that discussed the design requirements of ICV for older people or used older people as participants in designing intelligent conversational or dialogue-based systems for the ageing population. Evidence from this study suggest that ICV can improve the mobility, walkability, and wayfinding when older people walk in smart cities. As stated in reported in the literature Arnold et al. (2022) advocated that the application of voice-assistants can be particularly useful for older people to improve mobility, walkability, and wayfinding of older people. In addition, for mobility inclusion as well as digital inclusion of older group in the use of digital technologies to improve safe, independent, and accessible mobility, better usability of technological artifacts used by older people should be followed through a series of human-system interaction requirements (Barros & Seabra, 2020; Schlomann et al., 2021). Findings from researchers such as Pradhan et al. (2020) advocated for studies that investigate the design of voice-assistants' response based on end user's request particularly for the ageing populations. To this end this study contributes to provide an understanding on the use of ICV by older people and further expands on prior studies by investigating the factors that influences older people perceptions and use of ICV.

Results from Stigall et al. (2019) stated that older people prefer voice/auditory interfaces in comparison to the convention touch screens, clicking, and keyboards. Similarly, survey results from Ermolina and Tiberius (2021) suggested that use of voice-assistants has gain more trust among older people over the years resulting in their widespread use in health care. Whereas it was reported that while older people rated conversational voice-assistants' usability higher than conventional keyboard interfaces, most still chose the keyboard (Stigall et al., 2019). Further results suggest that the physical devices used by older adults such smartphones, tablet, laptop, or other handheld devices used to interact with the ICV is important (Martin-Hammond et al., 2018). The result suggest that the use of laptop was perceived as more favorably whereas the use of ICV in smartwatches was viewed as less favorably by older people (Stigall et al., 2019). Additionally, research by McLean and Osei-Frimpong (2019) specified that the perceived privacy risks negatively impact the usage of ICV. As concerns of stolen person details, and the perception of voice-assistants possibly listening to private conversations is perceived as a privacy risk that may be faced in use of this technology. Concurrently, this research provides new understandings of mobility in relation to ICV in smart cities, demonstrating the usefulness of this technology which provides new opportunities for exploration on user-centred design to enhance the welfare and wellbeing of older people.

5.2. Practical implications

The global population of older adults aged 65 and above is projected to triple to 1.5 billion in the year 2050, as reported by the World Health Organization. The increasing demand for services to support the welfare, wellbeing, and quality of life of the ageing population has stimulated researchers worldwide to explore the deployment of digital technologies such as AI based machine learning and Natural Language Processing (NLP) to support older people to cope with the challenges of ageing and live safely and independently (Jnr, 2024). ICV which are computer programs that exhibits a certain level of autonomy and intelligence as well as social skills to imitate human face-to-face dialogue, and the capability to sense and react to user affect. The use of smartphone among older people aged 60 years or older has been rapidly rising and results from the literature suggested that the use of voice-assistants were proven to be useful in increasing conversation time, notwithstanding the shortness in the length of replies as compared to humans (Ryu et al., 2020). As reported in the literature (see Table 1), a number of ICV systems have been developed for different target applications to assist older people to address various needs.

This study investigates design requirements as strategies for developing and implementing an ICV that can dialogue with the older people and helps them improve the safe, independent, accessible mobility, walkability, and wayfinding of older people in urban environment. The ICV is capable to provide personalized multimodal/intermodal mode of travel, and identify signs and symbols, and recommend safer routes that can be useful for the prevention of falls, or injuries faced by older people. Using machine learning the ICV offers possible personalization with the ability to understand the older people walkability patterns and mobility interaction choices which is critical to provide guidance. Using handheld devices equipped with camera ICV supported by machine learning can help for visual recognition of signs, symbols, and objects when older people walk across the urban environment to reduce injuries and falls. To the best of the author(s) knowledge, this study is the first to investigate the requirement specifications needed to develop as ICV for safe, independent, accessible mobility, walkability, and wayfinding of older people grounded on *ability-based design framework* and *ISO 9241-110 ergonomics framework for human-system interaction* to sustains dialogues with older people, based on natural language processing techniques for behavior generation for human-machine communication. ICV are suggested to be employed in this study to respond to older people mobility needs and assist them to when they walk within and across cities as they accomplish their day-to-day routine.

Additionally, evidence from this study synthesized prior research in the context of AI based voice-assistants and examined how ICV can improve the mobility, walkability, and wayfinding when older people walk within and across cities. Building on this, a specific designs requirements are identified to provide better insights into the development, implementation, and adoption of ICV suitable for the ageing population. The use of ICV for safe, independent, accessible mobility, walkability, and wayfinding of older people in urban environment presents a new form of interaction with AI technology that is envisioned to be embedded as part of older people everyday life enhancing social activity. This study provides implications that will be beneficial to system designers, researchers, and engineers who develop smart devices with built-in voice-assistants to support the welfare and wellbeing of the ageing populations. Evidence from this study identifies key factors as perceived barriers that should be accounted for in policy design of more intelligent conversational voice-assistants. The findings also advance the literature by providing an interdisciplinary approach to transportation studies to promote mobility inclusion using digital technologies.

5.3. Theoretical implications

ICV employes AI technology which utilizes natural language processing and machine learning to learn and understand user's preferences. Currently, we are seeing the adoption of AI based ICV which provides an effective tool to improve life routine and self-management of healthcare, leading to the improved quality of life for older people. However, accessing and adopting innovative technologies such as ICV is often not easy for the ageing population, who are often consequently left behind as it is challenging for older people to use, learn, and interact with devices with auditory interface (Chen et al., 2021). ICV allow users to naturally communicate with digital systems eye-free and hands-free. This makes them useful for future mobility, specifically among ageing populations in the society. With the increased use of intelligent conversational voice-assistants, prior studies have examined how older people are using voice-assistants to support their daily routines, as well as the potential barriers impeding their adoption. While prior studies focused mainly on the older people experience after adopting existing voice-assistants' functionalities on a specific type of voice-assistants embedded in a smart-home device (Chen et al., 2021).

The requirements, needs, challenges, factors, and design strategies need to improve the development of ICV tailored for the mobility, walkability, and wayfinding of older people are still unexplored. Findings from prior research (Gollasch & Weber, 2021), revealed that older people are interested to use speech-based or voice-assistants technology but differences in cognitive abilities and language comprehension has led to specific requirement specifications for older users. Nonetheless, knowledge of the key success factors to improve the uptake and adoption of ICV by older people are not well known. Therefore, this article makes an attempt to address this gap. The focus of this current study is to provides different modalities and functionalities needed to support a safe, independent, accessible mobility, walkability, and wayfinding of older people in urban environment. Therefore, this study identifies key factors that influence the use of ICV by older people in smart cities. Findings from this study further the conceptualize the requirement specifications to be considered in designing ICV for older people grounded on the *ability-based design framework* and *ISO 9241-110 ergonomics framework for human-system interaction.*

Findings from the literature suggested that introducing the Internet enabled devices to the older people can help improve their welfare and psychological wellbeing, contributing to their sense of independence, autonomy, and empowerment, through provision of entertainment, news, weather, and obtaining information online. While high percentage of the working-age people regularly access the Internet, the older age group (over 80 years), are less likely to do so. Findings from a recent study in USA indicated that Internet use among older people has steadily increased over the last year, with the "younger seniors" (65–74) almost twice as likely to use the Internet as compared "older seniors" those from 75 and older (Ho, 2018). Even though the use of ICV offers several benefits it still faces significant barriers in gaining traction among older people cohort as older people are least likely to surf the Internet and most are not able to afford such handheld devices, and most do not have broadband or internet connections. Additionally, older people with co-existing speech or hearing impairment may not benefit from ICV (Ho, 2018), due to auditory challenges.

6. Conclusion

This article describes the perceived factors that influences the use of ICV by older people. This study explicitly focused on investigating how ICV can offer promise to improve navigation for older pedestrians. Requirement specifications for designing ICV based on the ability-based design framework and ISO 9241-110 framework for ergonomics of human-system interaction was designed in this study as a user-centred design to describes the requirement specifications needed to design an ICV. Findings from this study is based on existing literature employed to guide policy and practice, and also to investigate the readiness and use of digital technologies such as ICV by the ageing population in the society. A systematic literature review was adopted grounded on secondary data from the literature and descriptive analysis was employed. Findings from this article discusses how ICV that simulates human-like behavior can support mobility, walkability, and wayfinding guide when older people walk within and across cities. Evidence from this study provides recommendations for the implementation of a user-centred ICV for safe, independent, accessible mobility for older people in urban environment.

This study aims to examine the perceived factors that influence the use of ICV by older people in smart cities. Furthermore, findings from this study explore the requirement specifications to be considered in designing ICV for older people and also evidence from this study suggest that ICV can improve the mobility, walkability, and wayfinding when older people walk in smart cities. Additionally, this article presents user-elicited recommendations that aids the need for the future design of ICV to facilitate follow a human-human conversation mode. More specifically, the findings discuss design implications for implementing ICV. Findings from this study can be used as a starting point for future researchers involved in developing ICV personalized for the mobility of older people who use public transportation in a real-world setting.

Additionally, in the future it is planned to implement ICV that can help to provide personalized recommendations to improve the mobility, walkability, and wayfinding when older people walk in smart cities. This study is more align to walkability of older people due to mobility impairment faced by these demographics, but does not examine different type of hurdles, for example older people finding the place to sit, using the public escalators, taking buses and metro etc. Future research will contribute to address this research area. Also, machine learning algorithm and natural language processing will be used to provide real-time data driven conversational dialogue for older people. Furthermore, proper safety and privacy measures will be considered to promote best practices and integration of ICV into use by older people. Finally, a participatory design grounded on user-centered design will be adopted by conducting an in-person co-design workshops with representative of older people, caregivers, family members, and municipality care and coping departments to elicit more insights on how ICV can support the mobility, walkability, and wayfinding of older people.

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