

Older Adults' Perception and Use of Voice User Interfaces: A Preliminary Review of the Computing Literature

Brodrick Stigall

bstigal@clermson.edu

Humans And Technology Lab, School of Computing
Clemson University, United States

Steven Baker

steven.baker@unimelb.edu.au

Interaction Design Lab, School of Computing and
Information Systems
The University of Melbourne, Australia

Jenny Waycott

jwaycott@unimelb.edu.au

Interaction Design Lab, School of Computing and
Information Systems
The University of Melbourne, Australia

Kelly Caine

caine@clermson.edu

Humans And Technology Lab, School of Computing
Clemson University, United States

ABSTRACT

Voice User Interfaces (VUIs) are quickly becoming ubiquitous. The natural language interface of VUIs may be more usable for some groups of users, such as those who may face challenges using physical input methods including older adults and people living with a disability. This study explores research on the use of VUIs by one such group, older adults. We conducted a systematic literature review of research published in the Association of Computing Machinery Digital Library that addresses perception and use of VUIs by older adults. We identified an emerging body of research examining older adults' use and perceptions of VUIs. This research revealed several potential benefits of voice interaction for older adults while also highlighting how the novelty of the technology may be a barrier to adoption. We conclude with a call for further HCI research in this area.

CCS CONCEPTS

• **Human-centered computing** → **Natural language interfaces**; *HCI design and evaluation methods*; • **General and reference** → *Surveys and overviews*.

KEYWORDS

aging, accessibility, voice user interface, older adult, natural language

ACM Reference Format:

Brodrick Stigall, Jenny Waycott, Steven Baker, and Kelly Caine. 2019. Older Adults' Perception and Use of Voice User Interfaces: A Preliminary Review of the Computing Literature. In *31ST AUSTRALIAN CONFERENCE ON HUMAN-COMPUTER-INTERACTION (OZCHI'19)*, December 2–5, 2019, Fremantle, WA, Australia. ACM, New York, NY, USA, 5 pages. <https://doi.org/10.1145/3369457.3369506>

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OZCHI'19, December 2–5, 2019, Fremantle, WA, Australia

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ACM ISBN 978-1-4503-7696-9/19/12...\$15.00

<https://doi.org/10.1145/3369457.3369506>

1 INTRODUCTION

Voice User Interfaces (VUIs) enable a person to communicate with an application through an auditory interface. Many VUIs allow users to complete their interaction with applications via natural language. Natural language is acquired by users as a normal part of maturation and socialization [13] and therefore requires very little training. Smart speakers such as Google Home and Amazon Echo are examples of new devices that rely on auditory interfaces.

Because VUIs enable people to communicate via natural language, they are particularly attractive to users who may otherwise struggle to use graphical user interface (GUI) or touch based interaction methods [24]. Perhaps for this reason, the use of VUIs is growing. About half of the Australian population (12 million people) has access to a VUI via a mobile phone. Siri is included on iPhones and Google Assistant is included on Android phones [2] both by default. Sixty one percent of Australians access the internet through a tablet, and many tablets too, are equipped with a voice-enabled assistant. Microsoft began including its Cortana voice enabled virtual assistant in all Windows 10 devices in 2015. At the same time, Apple began equipping all its computers with Siri. People also purchase and use standalone voice assistants such as Amazon's Alexa; five percent of adults in Australia have added a standalone voice assistant to their home [2].

Older adults, who we define here as adults over age 65, are the fastest growing age group in the world [8]. Increasing visual, physical, and cognitive impairments common among older adults can make interfaces difficult to use [24]. As a result, audio is a modality of choice for people without hearing impairments [24]. Given this preference for audio as a primary modality for communication, the worldwide population of older adults may be able to benefit from the added accessibility provided by VUIs. [24]. However, no work we are aware of has systematically examined existing publications about the methods of research, perceptions of older adults about VUIs, or possible benefits of VUIs to older adults.

To better understand the current state of research about the perception and use of VUIs by older adults, we conducted a systematic literature review of research published in the ACM Digital Library. We focused our search on empirical research exploring the use of VUIs by older adults.

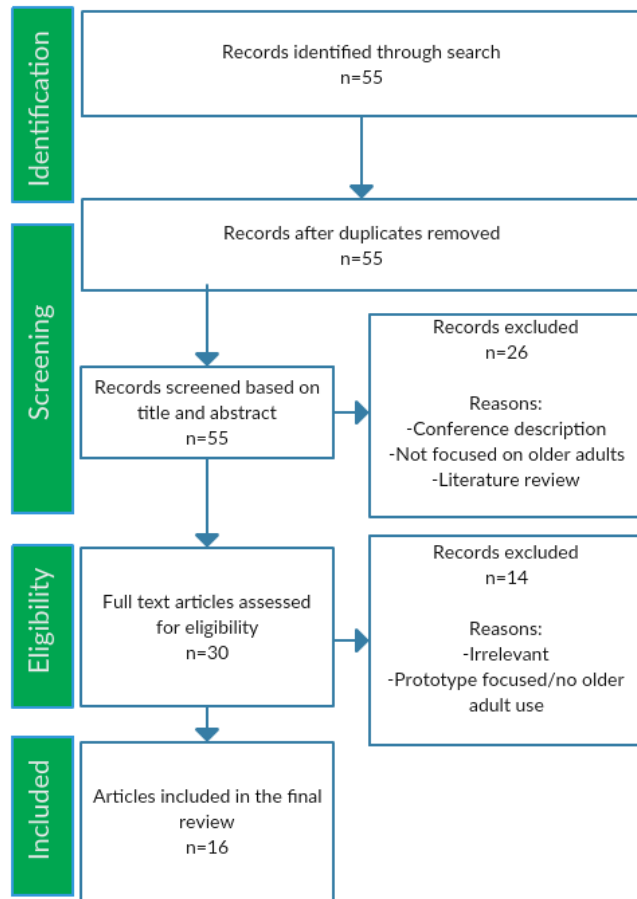


Figure 1: Flow Diagram for Study Selection

The following three research questions guided our systematic literature review:

- (1) What are the dominant methodologies used to research older adults' use of VUIs?
- (2) What has research revealed about older adults' perceptions and use of VUIs?
- (3) What empirical evidence exists to suggest that VUIs are beneficial for older adults?

2 METHODS

We conducted a systematic literature review to identify publications that addressed VUI perceptions and use by older adults. This review is a preliminary review that will inform future empirical work aimed at examining the use of VUIs by older adults. Our search focused exclusively on the ACM Digital Library. Our goal was to obtain an understanding of current human computer interaction (HCI) literature on this topic. We plan to expand this systematic literature review to additional databases in the future.

2.1 Search Terms

There are many terms used to refer to a VUI including: conversational agent, virtual agent, virtual assistant, and chatbot. All of these terms refer to a technology that uses an auditory voice interface to exchange input or output with the user [6]. To ensure we found all publications related to this topic, we included all of these terms in our search. Similarly, there are many terms that could indicate a manuscript addressed the age of users, so we also included synonyms for older adults and age. The final search query consisted of the following keywords and operators:

"voice user interface" OR "VUI" OR "conversational agent" OR "conversational interface" OR "conversation agent" OR "chatbot" OR "language interface" OR "virtual assistant" OR "virtual agent" OR "interactive voice response" OR "IVR" AND "older Adult" OR "senior" OR "aging" OR "ageing" OR "elderly" OR "age"

We searched both titles and abstracts. We limited our search to manuscripts published within the past 20 years (1999-2019).

2.2 Manuscript Selection

We selected manuscripts using the process suggested by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[15]. Figure 1 shows a flow diagram detailing our process. We conducted the search in July 2019. We screened titles and abstracts sequentially for relevance, and then excluded records accordingly at each stage of the review (see Figure 1). We included only articles that addressed our research questions using the following inclusion criteria: articles must report results from a study aimed at older adults' use and/or evaluation of VUI technologies with respect to older adults. We excluded all other manuscripts.

3 RESULTS

3.1 Search Results

The search of the ACM Digital Library using the query identified in the section 2.1 of the methods section yielded 55 articles. In contrast, the ACM Digital Library shows 1581 records when age related terms (e.g., "older adult") are removed from the query.

Figure 1 shows the process and outcome at each stage for choosing the articles in this review [15]. Because we only searched one database there were no duplicates to remove in the identification step. In the screening step, 25 articles were removed because they either: did not focus on older adults (18), were general conference description (that is, they described whole conferences, rather than specific papers) (6), or was a literature review itself (1) which summarized four existing publications about this topic [3].

We then assessed the full text of the 30 remaining articles during the eligibility step. An additional 14 articles were excluded for being insufficiently relevant to our research questions. These articles either did not focus on VUIs or focused on proposals of technology that would serve older adults but did not report any results of studies including older adult participants.

At the completion of the selection process, 16 articles remained and were included in the final review. These articles can be grouped

| Reference | Year | Method | Sample | Medium of Agent | Embodied | Agent Gender |
|-------------------------|------|----------------------------------|--------|-------------------|----------|---------------|
| Ali et al. [1] | 2018 | Interview/Use | 25 | Computer | Yes | Female |
| Bickmore et al. [4] | 2005 | Survey/Interview/Use | 10 | Dedicated PC | Yes | Female |
| Brewer et al. [5] | 2017 | Diary/Interview/Use | 7 | Phone+keypad | No | Not Specified |
| Constantin et al. [7] | 2019 | Think Aloud/Survey/Interview/Use | 19 | Laptop | Yes | Male |
| Hosseinpanah et al. [9] | 2018 | Survey | 30 | 15.6 inch Laptop | Yes | Male |
| Kowalski et al. [11] | 2019 | Interview/Use | 7 | Google Home | No | Female |
| Mehrotra et al. [14] | 2016 | Survey/Focus group | 22 | Robot/Computer | Yes | Not Specified |
| Opfermann et al. [16] | 2017 | Video of Usage | 14 | Not Specified | Yes | Male |
| | | | 53 | | | |
| Schlogl et al. [18] | 2013 | Focus Groups | 10 | Smartphone/Tablet | No | Female |
| | | | 8 | | | |
| Sidner et al. [19] | 2018 | Surveys/Interview/Use | 44 | Robot/Computer | Yes | Female |
| Sin et al. [20] | 2019 | Surveys/Interview/Use | 5 | Robot/Computer | Yes | Female |
| Singh et al. [21] | 2011 | Surveys/Use | 61 | Computer | Yes | Female |
| Thakur et al. [22] | 2018 | Scraping Twitter | - | No Agent | No | N/A |
| Tsiourti et al. [23] | 2014 | Focus Group/Interview | 20 | Paper Mockup | Yes | All Genders |
| Yamanaka et al. [25] | 2016 | Use | 11 | Computer | Yes | Male |
| Ziman et al. [26] | 2018 | Interview | 15 | Tablet | No | Not Specified |

Table 1: Study Methods, Sample Size, and Agent Characteristics ([14, 16, 18] reported multiple studies).

into two categories: (1) articles evaluating older adults' general perceptions of VUIs and (2) VUI technology specifically designed to benefit older adults, and older adults' evaluation of that technology. Before investigating these categories in more detail, we begin by describing the types of research methods reported in manuscripts in our sample to better understand the types of empirical research that informs our current knowledge about VUIs for older adults.

3.2 Study Characteristics

3.2.1 Methods. When studying older adults and VUIs, researchers employed a number of different research methods. The majority of the studies in our sample reported a mixed method approach (see Table 1). Eleven of the 16 manuscripts reported multiple methods.

Twelve of 16 results used interviews or focus groups to capture qualitative data from older adult participants. Interviews were often paired with some form of a questionnaire or survey (both surveys and questionnaires are referred to as 'surveys' for the purpose of this work). Survey instruments were used in seven of 16 studies.

Studies that captured quantitative data usually used the agent itself to capture this data. Variables assessed quantitatively included frequency of use, task, and how quickly older adults were able to use the VUI. Only two of the studies [9, 21] captured quantitative data only, while only one study [23] captured qualitative data only.

Quantitative measurements, used in 10 out of 16 studies, included frequency of older adults' use the technology, whether it was deployed in the home, error rate in completing an assigned task, and how quickly older adults were able to use the VUI.

The number of older adult participants in studies varied but was overall consistent. Only three of the results had a sample size higher than 30 (see Sample column in Table 1).

3.2.2 Agent Medium, Embodiment, and Gender. Analysis of the papers in our study sample revealed a preference to study one

particular subset of VUIs, namely, embodied conversational agents. An embodied conversational agent or ECA is a virtual agent that has a visual representation or avatar that communicates verbally and non-verbally [17]. Eleven of 16 studies used an ECA.

The gender of the agent also varied across studies. Agents were primarily female (7). Four results used male agents. Another four did not specify the gender of the agent, and one study did not have an agent at all (See Agent Gender column in Table 1).

The results suggest that characteristics of the agent were chosen based on the task the agent was doing [7, 21, 23], in consultation with a focus group [1], or modified to fit the target population [4, 19]. These results support research that traditional gender norms play a role in VUIs[12].

3.2.3 Data Captured. Our analysis of the manuscripts revealed a strong emphasis on capturing older adults' views on usability [4, 7, 21, 26]. Key usability questions raised in the papers relate to topics such as older adults' views about the ease of use of VUIs [1, 4, 19, 26] and whether they prefer VUIs to have a physical (such as being part of a robot), or a virtual (voice assistant) form [14, 19, 20]. According to [14], older adults are particularly drawn to agents (robot or virtual) with a human-like appearance. However making the agent too human can lead to discomfort with an artificial agent that "tries to fully replace a human being" [14].

One study stood out for its unique methodology. This study [16] used an ethnomethodological conversational analysis [10] where researchers analyzed logs of the agent along with video of participants using the agent to make behavioral observations. There is virtually no human interaction with the participants. This methodology was chosen instead of other methods to capture what participants "think they do" by observing what they display in their own actions without much researcher influence [16].

3.3 Older Adults' Perception of VUIs

Many studies assessed whether older adults prefer voice interfaces compared to other interfaces. Several results suggested older adult participants do favor voice interfaces over other interface options such as clicking, keyboards, and touch screens [7, 9, 11, 18]. However, interface preference was not consistent across all papers. While older adult participants rated VUI usability higher than keyboard interfaces in [26], they still preferred the keyboard.

The results suggest that the medium by which they interacted with the agent [22] is important. Laptop and smartphone assistants were viewed more favorably whereas smartwatches and desktop assistants were viewed less favorably [22]. Three of the studies in our sample compared older adult preferences for gender of an agent, and these few results suggested a preference for VUIs with female voices [7, 18, 23], with [7] suggesting that older adults be allowed to customize their agents.

Results also suggest that the likability of VUIs is associated with high perceived usability and perceived accessibility [7, 11, 26]. Usefulness was also measured in [7] and in that case high participant ratings of perceived usability and accessibility correlated with high ratings of usefulness. Results also revealed interest in how virtual agents establish trust [4, 9, 19]. Participants in [4], for example, showed high trust in virtual agents (6.4 on a 7 point scale). However in a similar study that compared virtual agents to robots, [19] older adult participants trusted robots more than virtual agents rating them 5.14 vs 3.88 on a 7 point scale with 1= No trust at all and 7=very much trust. Only one study had both young adults and older adults as participants [9]. Participants in this study rated verbal and non-verbal behaviors of an agent. Compared to younger adults, older adults rated agents as more trustworthy, and empathetic [9]. These studies suggest older adults have positive perceptions when exposed to VUIs, however when compared to other means of input, VUIs sometimes received less favorable views.

3.4 VUIs Benefit Older Adults

Our results suggest that VUIs are being researched for their benefit to older adult populations. VUIs can help older adults manage their health. Health interventions using VUIs include encouraging exercise [4], preparing for doctor's visits [7], conducting telehealth visits [20], and assessing communication attitudes of people with dementia [25]. Several studies explore virtual agents' capacity to serve as assistive companions for older adults [14, 16, 19, 23]. These results of studies suggest that virtual agents can help older adults with various tasks. An embodied conversational agent can help older adults navigate the web, thereby making them more capable users [21]. The ECA makes websites more learnable, and online shopping more understandable [5, 21]. VUIs may also help older adults develop social skills [1].

Despite these many perceived benefits of VUIs, the results also suggest some barriers to adoption by older adults. In particular the novelty of the technology can be a barrier to older adult users, potentially resulting in a less comfortable and familiar experience[1].

Despite the high perceived ease of use of natural language, several studies revealed older adult discomfort with the structured nature of VUI dialog. [1, 7, 19, 26]. Participants expressed feelings that conversations with VUIs are one sided, and they don't have

the opportunity to ask or say everything they want. Furthermore, they may face issues such as timeouts when giving input or entering/speaking unintended words [26].

The use of a VUI resulted in privacy concerns from participants in several of the manuscripts we reviewed such as [19, 23]. To address this concern the VUIs destroyed the gathered information after it was analyzed or did not record any information at all.

4 DISCUSSION

We only found 16 articles in the ACM Digital Library that addressed older adults' perception and use of VUIs and therefore met our search criteria. In part, this reflects the emerging nature of VUI technology. Siri, Amazon Echo, and Google assistant were all released less than 10 years ago (2010, 2015, and 2016 respectively). The increasing momentum of research into older adults using VUIs is evident with the acceleration of results in the past two years. More than half of the papers reviewed were published in this period.

When all age related keywords are removed from the search query, the ACM Digital Library shows 1581 records which suggests that the vast majority of VUI research (97 percent) does not consider age or the aging population. Because age-related differences may affect how older adults perceive and use VUIs, more research with this population is needed. Only one study in our data set compared older adults to younger adults [9]. The findings in the other studies we reviewed may be general to all age groups, but more needs to be learned about the differences between older adults and younger age groups, in terms of perception and benefits. Knowledge of these differences could potentially inform design decisions for VUIs in the future.

5 LIMITATIONS

A limitation of our study is that we focused our review exclusively on the ACM Digital Library. There are other databases and publications where researchers who are interested in VUIs and aging may have published relevant research. However, for this study, we wanted to identify HCI research which is published in the ACM library. Additionally, we did not identify all relevant keywords prior to our search. We have since identified the following keywords: "speech* interface", "old* users". We will extend our systematic literature search to other databases and include additional keywords.

6 CONCLUSION

We found very few articles about VUIs that discussed designing for older adults, or used older adults as participants in studies, and therefore were able to draw few conclusions about designing for that population. This gap in the literature is notable because VUIs may be particularly useful for older adults. Human computer interaction researchers, especially those interested in aging, can help fill this gap in our knowledge by conducting research about VUI design for older adults, particularly with older adult participants.

7 ACKNOWLEDGMENTS

This material is based upon work supported by the National Science Foundation under Grant No. 1829436 via the Institute of International Education Graduate International Research Experiences Fellowship and National Science Foundation Grant No. 1565268.

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