A Systematic Review of Human Factors Literature About Voice User Interfaces and Older Adults

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We conducted a systematic literature review of the human factors literature at the intersection of voice user interfaces (VUI) and older adults among Human Factors publications. Our review was limited to research published in the past 50 years (1970 – 2020) in either the journal *Human Factors* or the *Proceedings of the Human Factors and Ergonomics Society*. While we included a broad array of search terms related to VUIs, we found very few articles about VUIs that were specifically focused on designing for older adults or used older adults as participants in studies. Of the 26 human factors publications we did find that were related to this topic, most found older adults take more time to operate VUIs and/or made more errors than younger adults, whereas a minority of publications found no age-related differences. We concluded that age-related differences in the use of VUIs are likely task specific.

INTRODUCTION

Voice User Interfaces (VUI) are technologies that enable a person to communicate with a spoken language application. VUIs include prompts, grammars, and dialog logic that allow them to process and respond to users in spoken language (Cohen, Giangola, & Balogh, 2004). To design effective VUIs for older adults, we need to understand how older adults perceive and interact with VUIs. Towards this end, we conducted a systematic literature review of human factors publications related to VUI and older adults published in the last 50 years, between the years 1970 and 2020.

Older adults, who we define here as adults over age 65, are the fastest growing age group in the world (He, Goodkind, & Kowal, 2016). Because of the increasing visual, physical, and cognitive impairments common among older adults, audio is a modality of choice for people without hearing impairments (Vacher et al., 2015). Given this preference for audio, older adults worldwide may be able to benefit from the accessibility provided by VUIs.

VUI technology holds promise to help meet the needs of older adults, especially in the home and vehicle settings. Conversational agents, in particular, have the ability to dynamically change older adults' interaction with and adoption of technology (Cohen et al., 2004). However, we found no systematic review of the human factors literature about use of conversational agents or VUIs more generally specifically considering age. In this paper, we analyze and discuss human factors research about VUIs and age-related factors.

The following 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?

METHOD

We conducted a systematic literature review to identify the human factors publications related to VUI and older adults. Though VUI-like technology has been around for some time in the form of Interactive Voice Response (IVR), it was primarily used in phones. However, research about IVR may be relevant to VUI. Therefore, we reviewed literature from the last 50 years and used multiple keywords.

Because we were interested in understanding the scope of human factors research related to VUI and age, we focused our search on two human factors publications: *Human Factors* and *Proceedings of the Human Factors and Ergonomics Society Annual Meeting.* We accessed these publications via the Sage Publications database ("Sage Publishing," 2020).

Table 1. Keywords for Search of Sage Database.

VUI Synonyms	
chatbot	virtual agent
conversation agent	virtual assistant
conversational agent	voice agent
conversational interface	voice interface
interactive voice response	voice user interface
IVR	voice-based interaction
language interface	voice interaction
speech interface	VUI
Older Adult Synonyms	
age	old
ageing	older adult
aging	senior
elderly	

Search Terms

There are many terms that are synonyms with VUI including conversational agent, virtual agent, virtual assistant, and chatbot. All of these terms refer to a technology that uses a conversational, auditory interface to receive input from, and provide output to the user (Cohen et al., 2004). To ensure we found all publications related to this topic, we included all the

synonyms we identified for VUI in our search. The final search query consisted of the keywords in Table 1 using the following syntax: [any VUI synonym] AND [any older adult synonym].

Manuscript Selection

We searched the Sage database for the keywords in Table 1. At first, we searched the 'abstract' and 'title' fields only, but this only returned eight results. Subsequently, we expanded our search using the *anywhere* option. This option allowed us to identify all articles that mentioned the keywords we were interested in, in any combination of fields. We conducted the search in January 2020 and limited our search to manuscripts published within the past 50 years (1970-2020).

We then selected manuscripts using the process suggested by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Moher, 2009). Figure 1 shows a flow diagram detailing our process. We screened titles and abstracts sequentially for relevance, and then excluded records accordingly at each stage of the review (see Figure 1).

Criteria for Inclusion

We included only articles that addressed our research questions using the following inclusion criteria:

- the title, abstract or full text contained either the search term age or aging.
- about or related to voice user interfaces or voice control of a technology
- articles must report results from a study including older adult participants and/or an expert evaluation of VUI technologies considering aspects of aging.

RESULTS

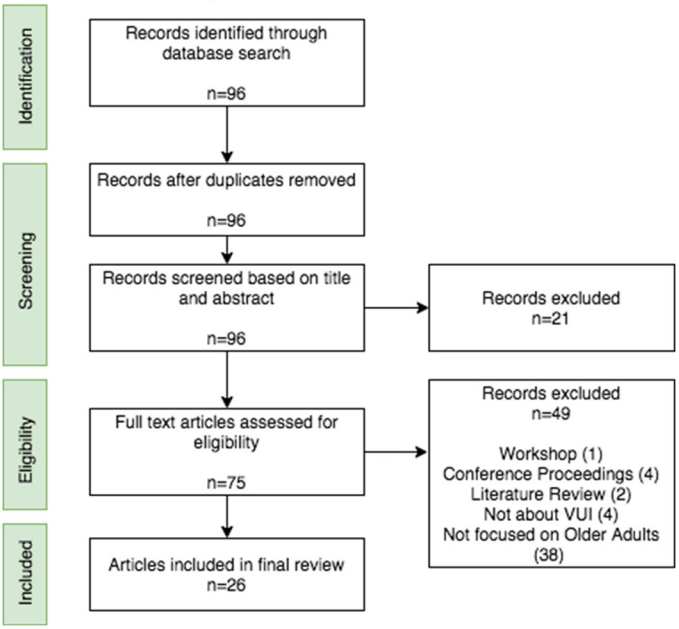
Our search of *Human Factors* and *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* yielded 96 articles. Because we only searched one database (the Sage Publications database) there were no duplicates to remove in the identification step. After reviewing titles and abstracts of these 96 articles, 21 articles were excluded at the screening step leaving 75 articles for full text review.

We then reviewed the full text of those 75 articles and excluded additional articles because they were either workshop papers (1), general conference proceedings descriptions (4), or not focused on VUIs (4; e.g., focused on gestures; Graichen et al., 2019). Furthermore, we eliminated 38 additional articles because they did not include older adult participants or focus on age or aging as a research consideration. At the completion of the selection process 26 articles remained and were included in the final review.

Three of the 26 articles (Li & Boyle, 2019; Song et al., 2017; Tsimhoni, Smith, & Green, 2004) are Human Factors journal articles and the rest are proceedings. Nearly half (42%) of articles that remained after exclusion were published in the last five years, despite the 50-year search span. Nearly one third of all studies in our results evaluated age related differences in human factors issues with in-vehicle systems.

Notably, when we removed aging keywords, we identified an additional 100 articles (for a total of 196) that addressed VUIs.

Figure 1. Flow Diagram for Article Selection



Methods in Studies About VUI and Aging

The primary methodology, which was used in all but two papers we studied, was an experiment. See Table 2.

Age differences in VUI Use

The studies reported in the human factors literature revealed several differences between how older adults use VUIs compared to younger adults and sometimes middle-aged adults. Differences in performance vary by the task attempted. For example, when speed or efficiency of use was measured, several studies suggested older adult participants are slower or take more time to do certain tasks using a VUI when compared to younger adults (DeGroot & Schwab, 1993; Gellatly & Dingus, 1998; Ponathil et al., 2019; Sawyer et al., 2016; Tsimhoni et al., 2004).

The findings about age-related differences were not consistent across the literature, however. Some studies found no differences between age groups (Baldwin, Branyon, Sethumadhavan, & Pak, 2015; Lee, Reimer, Mehler, & Coughlin, 2015; McWilliams, Mehler, Seppelt, & Reimer, 2019; Roberts, Silver, & Rankin, 2004). Although counterintuitive, another study found that older adults actually respond faster than younger adults to VUIs (Witt et al., 2010). The authors speculate that this difference may be due to younger adults multitasking, or giving an agent more time to respond, whereas older adults may speak to an agent as they would another human being.

Table 2. Study Characteristics and Findings.

Authors	Method	Total N	Range and (n) for each Group	M/F	Findings
(Baldwin et al., 2015)	Experiment	69	65-75 (16), 18-26 (53)		Social facilitation effect could not be replicated in human machine interfaces. No differences in older adult vs. younger adult accuracy.
		98	65-75 (36), 18-26 (62)		
		45	65-75 (7), 18-26 (38)		
(Beer, Fisk, & Rogers, 2015)	Experiment	24	64-80 (24)	12/12	Older adults regardless of mobility prefer more control of a robot; cognitive judgment of usefulness varies by user perceptions of loci of control.
(Beer, Fisk, & Rogers, 2009)	Experiment	40	64-75(20), 18-27(20)	20/20	Older adults have difficulty recognizing emotion in VUIs.
(Beer, Fisk, & Rogers, 2010)	Experiment	84	65-85(40), 18-28(40)	42/42	Older adults have difficulty recognizing emotion in different types of VUIs. They have more difficulty recognizing emotion in VUIs that are less humanoid.
(Beer et al., 2012)	Experiment	12	68-79(12)	6/6	Older adults prefer voice control in robots (75%). Half preferred visual feedback 1/3 didn't want any; Older adults' perceptions of advantages and disadvantages were device specific.
(Carter & Graham, 2000)	Experiment	32	55-70 (16), 21-35 (16)	16/16	People make mistakes when multitasking with an in- vehicle VUI. Older adults make more mistakes when multitasking than younger adults.
(DeGroot & Schwab, 1993)	Experiment	192	60-70 (64), 40-50 (64), 20-30 (64)		60-year-olds spent more time on the phone, were less successful at forwarding calls, and reported different attitudes toward the announcer, the system, and IVRs in general.
(Gellatly & Dingus, 1998)	Experiment	12	65-78 (6), 21-27 (6)	6/6	Older adults work slower than younger adults. They also made more errors.
(Lee et al., 2015)	Experiment	80	55-69 (20), 40-54 (20), 25-39 (20), 20-24 (20)		Perceived usefulness influences attitudes and behavioral intentions to use. Perceived ease-of-use affects perceived usefulness and attitudes toward use of VUI in automobiles. No age differences.
(Li & Boyle, 2019)	Experiment	24	55+ (6), 40–54 (6), 25–39 (6), 18–24 (6)	12/12	Older drivers (55+) showed an increase in tactile detection response task (TDRT) response time compared with drivers in youngest group. Females take longer to respond than males.
(Lopez et al., 2019)	Heuristic Evaluation				Google home mini violates several heuristics for older adult use such as between system and the real world, consistency and standards, and recognition rather than recall.
(McWilliams et al., 2019)	Experiment	22	55-69 (11), 20-24 (11)	11/11	No significant differences between simulator use and real-world environment or age and gender.
		24	55-69 (12), 20-24 (12)	12/12	
(Payton, McLachlan, Weiss, & Rahman, 2017)	Experiment	11	33-83 (11)		Captions can increase usability of a VUI. Users prefer accuracy in captions over speed.
(Ponathil et al., 2019)	Experiment	54	60-87 (24), 18-30 (30)		Older adults take more time to complete tasks with a VUI than younger adults.
(Rau & Hsu, 2002)	Experiment	24	50-70 (24)		Older users using touch screens were faster and less frustrated than older users using voice control and mouse. Older adults are more frustrated and commit more errors with voice control.
(Roberts et al., 2004)	Experiment	89	25-71 (89)	44,45	No differences among age, gender, income, and education for preferred voice.
(Sadowski, 2006b)	Experiment	16	over 40 (8), under 40 (8)	8/8	Verbal shadowing is effective as an enrollment method for speech recognition systems.
(Sadowski, 2006a)	Experiment	8	over 40 (4), under 40 (4)	4/4	Humans can detect differences between read and shadowed speech regarding intelligibility and naturalness.
(Sawyer et al., 2016)	Experiment	53	60-69 (23), 20-29 (30)	29/24	Older drivers devote more temporal attention rearward to maintain situational awareness than younger drivers when multitasking is not involved. A VUI can preserve situational awareness when multitasking.
(Schneider, Wilkes, Grandt, & Schlick, 2008)	Experiment	90	60-75 (30), 40-59 (30), 20-39 (30)	54/36	Eye-gaze input and keyboard input, regardless of age, leads to the best performance. Eye-gaze input has the poorest results when combined with voice control.
(Sharit, Czaja, Nair, Lee, & Chin Lee, 2001)	Experiment	195	60-82 (60), 40-59 (61), 18-39 (74)	71/124	Older adults have usability difficulty with completing tasks and using IVR's to solve problems.
(Smarr, Fisk, & Rogers, 2011)	Experiment	60	65-85 (29), 18-26 (31)	30/30	Older adults have difficulty recognizing emotion animations.

(Song et al., 2017)	Experiment	78	54-88 (39), 18-30 (29)	31/37	Younger drivers are more affected by fatigue than older drivers but benefit significantly from an alertness maintaining task (AMT). Older are not as affected by fatigue, and driving did not deteriorate with AMT condition, although their speed was more variable with the AMT.
(Stuck, McDonald, & Rogers, 2018)	Interview	24	67-96 (24)	2,22	When participants were asked to describe what their ideal robot care provider would be like or not be like, they primarily focused on behavioral characteristics as compared to physical.
(Tsimhoni et al., 2004)	Experiment	24	65-72 (12), 20-29 (12)	12/12	Older participants are slower in entering addresses using voice control than younger participants.
(Witt et al., 2010)	Experiment		over 45, under 45		Older adults respond faster to VUIs.

DISCUSSION

We found 26 articles in the human factors literature (see Table 2) that addressed the intersection of older adults and VUIs. Despite the 50-year search span, nearly half (42%) of the articles were published in the last five years indicating that much of the research at the intersection of VUIs and older adults is recent. Furthermore, nearly half (96 of 196) of the human factors publications that address VUIs consider age or aging in the evaluation.

We found that the human factors literature suggests that there are differences between older adults and other age groups in VUI use. Older adults tend to take more time to complete the same tasks as younger adults and sometimes commit more errors. However, this phenomenon does not occur in every situation and the age differences in use of VUIs seem to be task specific. In several studies, there were no differences in time or errors between age groups.

When avatars are part of a VUI design, studies consistently suggest that older adults perceive certain emotions differently than younger adults. These studies suggest that designers of virtual agents should consider only using emotions that are universally recognizable such as happiness or ensure that recognition of complex emotions is not necessary to use the system.

Human Factors vs. ACM Literature

As compared to a recent review of the ACM literature (Stigall, Waycott, Baker, & Caine, 2019) our review of human factors publications revealed that the human factors literature contained far more studies about VUIs which compared younger to older adults. Nineteen of the 26 manuscripts we reviewed had both older and younger participant groups. Furthermore, nearly a third of the papers (eight of 26) reported age groups subdivided into additional categories such as "young old" and "old old".

The review of the ACM literature revealed 55 initial results, 16 selected articles, and 1581 results when all aging keywords were removed from search (Stigall et al, 2019). In addition to the inclusion of young age groups for analysis, the human factors publications also report larger average sample sizes when compared to the ACM literature (Stigall et al., 2019). The average sample size across all studies reported in human factors publications was 55 vs. 23 in the ACM literature. Only 12 studies in the human factors literature reported less than 30 participants, whereas eight reported more than 75.

In contrast to the ACM literature (Stigall et al., 2019), human factors literature put less emphasis on embodied conversational agents. Only four human factors studies addressed embodied agents (Baldwin et al., 2015; Beer et al., 2009, 2010; Smarr et al., 2011). Three of those four studies evaluated older adults' ability to recognize emotion, the other (Baldwin et al., 2015) evaluates the social facilitation effect.

When we compare the human factors literature to the ACM literature, we see that, despite having roughly eight times the number of articles mentioning VUIs, 97% of the ACM Digital Library articles did not consider age or aging in the research of VUIs.

LIMITATIONS

We focused our review exclusively on the *HFES Proceedings* and *Human Factors*. There are other databases and publications where researchers who are interested in VUIs and aging may have published relevant research. In future work, we hope to explore those databases and publications.

CONCLUSION

Based on a review of 96 human factors publications, we found that there are some task specific differences between the way older adults and other age groups use VUIs. Because the differences are task specific, we cannot conclude that there are absolute differences in VUI use between age groups. In cases where there are differences, designers of VUIs may need to make different choices to accommodate the different ways older adults perceive and interact with VUI technology.

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REFERENCES

Baldwin, N., Branyon, J., Sethumadhavan, A., & Pak, R. (2015). In Search of Virtual Social Facilitation Effects. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *59*(1), 90–94. https://doi.org/10.1177/1541931215591019

Beer, J. M., Fisk, A. D., & Rogers, W. A. (2009). Emotion Recognition of Virtual Agents Facial Expressions: The Effects of Age and Emotion Intensity. *Proceedings of the Human Factors and Ergonomics Society*

Annual Meeting, *53*(2), 131–135. https://doi.org/10.1177/154193120905300205

Beer, J. M., Fisk, A. D., & Rogers, W. A. (2010). Recognizing Emotion in Virtual Agent, Synthetic Human, and Human Facial Expressions. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *54*(28), 2388–2392. https://doi.org/10.1177/154193121005402806

Beer, J. M., Fisk, A. D., & Rogers, W. A. (2015). Commanding Home Robots: A Comparison Between Older Adults With and Without Mobility Loss. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *59*(1), 70–74. https://doi.org/10.1177/1541931215591015

Beer, J. M., Prakash, A., Smarr, C.-A. A., Mitzner, T. L., Kemp, C. C., & Rogers, W. A. (2012). ``Commanding Your Robot'' Older Adults' Preferences for Methods of Robot Control. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *56*(1), 1263–1267. https://doi.org/10.1177/1071181312561224

Carter, C., & Graham, R. (2000). Experimental Comparison of Manual and Voice Controls for the Operation of in-Vehicle Systems. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *44*(20), 3–289. https://doi.org/10.1177/154193120004402016

Cohen, M. H., Giangola, J. P., & Balogh, J. (2004). *Voice User Interface Design*. Addison-Wesley.

DeGroot, J., & Schwab, E. C. (1993). Understanding Time-Compressed Speech: The Effects of Age and Native Language on the Perception of Audiotext and Menus. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *37*(3), 244–248. https://doi.org/10.1177/154193129303700307

Gellatly, A. W., & Dingus, T. A. (1998). Speech Recognition and Automotive Applications: Using Speech to Perform in-Vehicle Tasks. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *42*(17), 1247–1251. https://doi.org/10.1177/154193129804201715

Graichen, L., Graichen, M., & Krems, J. F. (2019). Evaluation of Gesture-Based In-Vehicle Interaction: User Experience and the Potential to Reduce Driver Distraction. *Human Factors*, *61*(5), 774–792. https://doi.org/10.1177/0018720818824253

He, W., Goodkind, D., & Kowal, P. (2016). An Aging World : 2015 International Population Reports. *Aging*, *March*, 165. https://doi.org/P95/09-1

Lee, C., Reimer, B., Mehler, B., & Coughlin, J. F. (2015). User Acceptance of Voice Interfaces in the Automobile. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *59*(1), 1641–1645. https://doi.org/10.1177/1541931215591355

Li, N., & Boyle, L. N. (2019). Allocation of Driver Attention for Varying In-Vehicle System Modalities. *Human Factors*, *0*(0), 0018720819879585. https://doi.org/10.1177/0018720819879585

Lopez, J., Textor, C., Hicks, W. B., Pryor, M., McLaughlin, A. C., & Pak, R. (2019). An Aging-focused Heuristic Evaluation of Home Automation Controls. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *63*(1), 6–10. https://doi.org/10.1177/1071181319631446

McWilliams, T., Mehler, B., Seppelt, B., & Reimer, B. (2019). Driving Simulator Validation for In-Vehicle Human Machine Interface Assessment. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *63*(1), 2104–2108. https://doi.org/10.1177/1071181319631438

Moher, D. (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *Annals of Internal Medicine*, *151*(4), 264. https://doi.org/10.7326/0003-4819-151-4-200908180-00135

Payton, G. M., McLachlan, J., Weiss, B., & Rahman, M. (2017). Telephony Speech-To-Text: An Adequate Analog to Internet Protocol Caption Telephone Services. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *61*(1), 125–129. https://doi.org/10.1177/1541931213601515

Ponathil, A., Firat Ozkan, N., Bertrand, J., Welch, B., & Chalil Madathil, K. (2019). Conversational systems for family health history collection for geriatric population. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *63*(1), 47–48. https://doi.org/10.1177/1071181319631175

Rau, P.-L. P., & Hsu, J.-W. (2002). A Study of Interaction Devices and WWW User Interface Design for Older Adults. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *46*(2), 219–223. https://doi.org/10.1177/154193120204600211

Roberts, L. A., Silver, E. M., & Rankin, L. L. (2004). Selecting a Voice Persona. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *48*(4), 712–716. https://doi.org/10.1177/154193120404800402

Sadowski, W. J. (2006a). A new approach to evaluating the intelligibility and naturalness of shadowed speech. *Proceedings of the Human Factors and Ergonomics Society*, *50*(5), 733–736. https://doi.org/10.1177/154193120605000525

Sadowski, W. J. (2006b). Exploring Verbal Shadowing as an Effective Method of Enrolling in a Speech Recognition System. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *50*(5), 737–741. https://doi.org/10.1177/154193120605000526

Sage Publishing. (2020). https://us.sagepub.com/en-us/nam/home

Sawyer, B. D., Lee, J., Dobres, J., Mehler, B., Coughlin, J. F., & Reimer, B. (2016). Effects of a Voice interface on mirror check decrements in older and younger multitasking drivers. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *60*(1), 16–20. https://doi.org/10.1177/1541931213601004

Schneider, N., Wilkes, J., Grandt, M., & Schlick, C. M. (2008). Investigation of Input Devices for the Age-differentiated Design of Human-Computer Interaction. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *52*(2), 144–148. https://doi.org/10.1177/154193120805200202

Sharit, J., Czaja, S. J., Nair, S., Lee, C. C., & Chin Lee, C. (2001). Age group differences in subjective perceptions of telephone voice menu systems. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *45*(3), 216–220. https://doi.org/10.1177/154193120104500304

Smarr, C.-A. A., Fisk, A. D., & Rogers, W. A. (2011). Dynamic vs. Static: Age-related Differences in Recognizing Emotive Facial Expressions in a Virtual Agent. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *55*(1), 1957–1961. https://doi.org/10.1177/1071181311551408

Song, W., Woon, F. L., Doong, A., Persad, C., Tijerina, L., Pandit, P., Cline, C., & Giordani, B. (2017). Fatigue in Younger and Older Drivers: Effectiveness of an Alertness-Maintaining Task. *Human Factors*, *59*(6), 995–1008. https://doi.org/10.1177/0018720817706811

Stigall, B., Waycott, J., Baker, S., & Caine, K. (2019). Older Adults ' Perception and Use of Voice User Interfaces : A Preliminary Review of the Computing Literature. *Proceedings of the 31st Australian Computer-Human Interaction Conference, OzCHI 2019*, 5.

Stuck, R. E., McDonald, E. M., & Rogers, W. A. (2018). Older Adult Preferences for Robot Care Providers. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *62*(1), 1032–1036. https://doi.org/10.1177/1541931218621238

Tsimhoni, O., Smith, D., & Green, P. (2004). Address entry while driving: Speech recognition versus a touch-screen keyboard. *Human Factors*, *46*(4), 600–610. https://doi.org/10.1518/hfes.46.4.600.56813

Vacher, M., Caffiau, S., Portet, F., Meillon, B., Roux, C., Elias, E., Lecouteux, B., & Chahuara, P. (2015). Evaluation of a Context-Aware Voice Interface for Ambient Assisted Living: Qualitative User Study vs. Quantitative System Evaluation. *ACM Trans. Access. Comput.*, *7*(2), 5:1--5:36. https://doi.org/10.1145/2738047

Witt, S. M., Rolandi, W., Zuber, E., Brooks, T., Master, A., Loose, R., & Hubbell, J. (2010). Optimizing Successful Turn-taking in Spoken Dialog Systems. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *54*(19), 1425–1429. https://doi.org/10.1177/154193121005401915