Age-related Difference in Conversational Search Behavior: Preliminary Findings

Zhaopeng Xing
University of North Carolina at Chapel Hill
zhaopeng@email.unc.edu

Xiaojun Yuan
University at Albany, State University of New York
xyuan@albany.edu

Javed Mostafa
University of North Carolina at Chapel Hill
jm@unc.edu

ABSTRACT

When it comes to emerging technologies, older adults are often those who can greatly benefit from the advancements but are vastly under-represented in research and designs. This study presents preliminary findings of older adults' search behavior with a spoken conversational search agent which represents the next generation search paradigm. Our findings show that, compared with their younger counterparts, older adults' search conversations lasted longer and included more requests. Their requests had greater length and tended to have a lower proportion of unique words, more grammatically complex sentences and short pauses. In addition, the older subjects preferred to start a request with "I" and request questions with modal verbs were less frequent. They reformulated spoken requests as competently as did younger adults but elaborations on requests were uniquely founded among older adults. They also tended to have more than one query or question in a single request and rephrasing requests was more frequently observed than younger adults. System implications and future research directions are discussed.

CCS CONCEPTS

• **Human-centered computing** → Human computer interaction (HCI); Empirical studies in HCI; Interaction paradigms; Natural language interfaces.

KEYWORDS

conversation search, aging, Wizard of Oz, information search behavior

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1 INTRODUCTION

Older adults have become an increasingly important cohort of voice-enabled user interfaces (VUIs) [39]. Intelligent voice-enabled agents (IVAs), such as Apple Siri, Amazon Alexa, Google Home are good examples [33, 51]. These agents enable a spoken language interaction modality that does not rely on one's technology experience and skills. Therefore it is easy to learn and use and can benefit older adults who have more challenges in text-based search engines (e.g., [4, 14, 21, 29, 50, 52]). IVAs have served as a potential alternative for older adults for accessing online sources [40, 49, 59]. A few studies have examined the influences of such text-to-voice modality transition on this cohort [12, 34, 35, 40, 59] and a positive attitude was widely reported regarding the use of IVAs for digital information access. However, older adults often had difficulty constructing requests and perceiving how IVAs operated, which led to undesired responses or search outcomes [12, 34, 40]. The interactions often suffered from challenges such as Automated Speech Recognition (ASR) errors [12, 35] and unexpected time-out issues [59]. Older adults also expected the interactions with an agent to be natural, human-like and interactive [12, 40].

Conversational search is a search paradigm where a user addresses information needs in a mix-initiative and multi-turn dialogue [2, 42, 54, 57]. When embedded in VUIs, this paradigm, or spoken conversational search (SCS), enabled a more interactive and collaborative search experience than the traditional one-shot search [22, 54]. This search paradigm aims to imitate a conversational communication between a trained librarian and a patron [18]. It thus offers the potential for assisting older adults in seeking digital information in a human-like and conversational manner. However, there is scarce SCS research that considers older adults. Some previous studies focused on the use of existing IVAs and the observations were susceptible to ASR errors [35, 59]. Some lacked a comparative study protocol with younger adults and the findings may not be unique to older adults [12, 34]. Therefore, we conducted a Wizard of Oz (WoZ) laboratory experiment to examine *how older users search for information with an SCS agent and does age make any differences in search behavior*? We delineated subjects' behavioral profiles in terms of requests characteristics (RQ1), search acts (RQ2) and query strategies (RQ3).

2 METHOD

2.1 Study design

The WoZ is a method where a hypothetical system was mimicked by a human, or a Wizard agent (referred to as agent), and subjects were led to believe that they were speaking with a fully automated system [19]. This method frees observations from impacts of ASR errors and enables us to capture natural interactions between subjects with an SCS agent [30]. We recruited two age groups of English native speakers (18-35 and over 59, respectively) from an online

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research recruitment platform[1], campus mailing list and local senior centers. Each subject completed a search task with the agent within 10 minutes. The agent searched for information on behalf of the subjects with an interface implemented using Bing search API[2]. The agent's responses were converted to speech using a text-to-speech API[3]. The communication was completely by spoken language and retrieved results were not visible to the subjects. Both the subjects and agent were required to wear headphones. We embedded a search topic [20] in a scenario to simulate real information needs [8]: *Depression is a common and serious medical illness that negatively affects one's feelings, thoughts and actions. Antidepressant medications are commonly used to cure patients. However, the medications may no longer benefit a patient after a period of time in some cases. You want to find out three possible causes of this situation.*

Before the task, we asked subjects about the use frequency of search engines and IVAs with a five-point Likert scale (One as "Never" and five as "Everyday"). We also assessed subjects' search self-efficacy, i.e., belief and perception of their search ability [6], with a 10-point scale assessment [10] (One as "not confident at all" and ten as "very confident"). We selected seven questions concerning three factors of search self-efficacy, i.e., the overall task success, query development, advanced search skills.

The agent was designed to function based on prior SCS behavioral models [5, 42, 54, 57]. Specifically, the agent was able to interpret subjects' requests, perform searches, summarize or read results (Top three results on the search engine result page (SERP) by default), navigate through the result set, answer vague questions, ask for clarifications when subjects' intents were ambiguous, maintain dialogue context. The agent was constrained to behave only upon subjects' requests to reduce the agent-induced variations. That is, the agent could not provide any suggestions on queries, results or search strategies, which otherwise could unexpectedly affect search paths [58]. It was the subject who determined what to search, how to explore the search space, and which result to hear. The subjects were informed of such interaction mode and encouraged to develop their communication and search strategies with the agent during the task. Three undergraduate students having experience with IVAs were recruited to simulate the agent. Prior to the study, each agent was trained using the same guideline with the first author for two sessions to get familiar with the interface and the agent's interaction mode.

2.2 Measurement and data analysis

Each search dialogue was audio-recorded and transcribed using Amazon Transcribe[4]. A proofreader listened to each audio recording and proofread the transcript. The first author then followed the same procedure and proofread each transcript for another three times [38, 55]. To answer the RQ2 and RQ3, we conducted a thematic analysis on each transcript. Two annotators coded the search acts, query forms and reformulation strategies independently, with the inter-rater reliability calculated using Cohen's kappa [17], and disagreements were resolved by both annotators. We defined a turn as a speech by a speaker without interruptions [53].

[1]https://researchforme.unc.edu
[2]https://www.microsoft.com/en-us/bing/apis/bing-web-search-api
[3]https://developer.mozilla.org/en-US/docs/Web/API/Web_Speech_API
[4]https://aws.amazon.com/transcribe/

2.2.1 Request characteristics. We computed the type-token ratio (i.e., the proportion of unique words), parts of speech (i.e., nouns, verbs, adjectives, adverbs, pronouns, preposition), and stop words. We also counted the instances of filler words (e.g., "uh," "um," "you know") [9, 36], short (i.e., 2-5 seconds) and long (i.e., over 5 seconds) pauses in each request [38]. As in the previous studies [3, 24], the parsing depth of the requests was calculated for each subject to measure the grammar complexity.

2.2.2 Search acts. We defined a *search act* as an atomic behavior that communicated a search-related intent of a subject and each turn may contain multiple search acts. Given the interest in age-related effects, we focused on two primary types of subjects' search acts, i.e., information requests and feedback. We developed initial codes based on prior conversational search behavior models [23, 41, 54, 57]. Three types of requests were identified, (1) (re) formulated queries for retrieving a new result set (i.e., the top three results on the SERP); (2) requests for specific information within the result set (referred to as follow-up questions); (3) requests for access to a particular result at a title, snippet or website document level or for a summary of the top three results. Unlike the follow-up questions, the third type often indicated navigation behaviors within a result set and did not convey any information needs, e.g., "Can I check the first result?" "Go back to that website." The latter two types can co-occur, e.g., "Check the website for the causes of antidepressants not working." To avoid confusion, we defined a turn that contained at least one request act of the first two types as a *request turn*. We thus considered the last example as a request turn. The feedback acts indicate if a subject was satisfied with retrieved information (referred to as positive and negative).

2.2.3 Query strategies. For the RQ3, we focused on query forms and reformulation patterns. Spoken requests are diverse in forms, such as natural language questions, keyword-based queries, commands [24, 32, 54]. We were interested in how subjects expressed information needs and if older adults had any different expression preferences. Query reformulation refers to modifications to queries with the same information needs [26–28]. The practice of spoken request reformulations shares a similar function with text-based reformulations, i.e., to narrow down (specification), renew (rephrase), expand (generalization) the search space to reflect information need changes (e.g., [12, 28, 48]). Unique patterns have also been observed in spoken requests, such as the use of phonetic emphasis [28], partial reformulations by instructions [48]. We were curious whether older adults were able to reformulate spoken requests and if there were any age differences. Based on previous reformulation taxonomies [27, 37, 43], we created initial codes that described the reformulation patterns of the request turns (i.e., reformulated queries and follow-up questions).

To investigate the above RQs, Poisson regression models were constructed to analyze the effects of age on behavioral measurements. We also included the agent ID as a control variable and added the total number of request tokens and request turns as an offset to the RQ1 models and RQ2, RQ3 models, respectively. The model of parsing depth used a gaussian distribution. The significance of the age effects was computed by the χ^2 statistic using the likelihood-ratio test against a null model without the age group [1].

Table 1: Descriptive statistics

Statistics	Younger (SD)	Older (SD)
Search engine use frequency	5(0)	4.80(0.70)
IVA use frequency	3.45(1.28)	2.75(1.65)
IVA search frequency	3.15(1.23)	3.35(1.09)
Self-efficacy	57.40(10.06)	49.40(17.63)
# Turns (subject only) **	12.50(3.98)	15.75(5.10)
# Request turns **	2.60(1.60)	4.95(2.87)
Length of request turn in word **	10.53(3.27)	17.22(6.92)
Length of request turn in sentence **	1.30(0.38)	1.83(0.83)

* p<.05, ** p<.01, *** p<.001

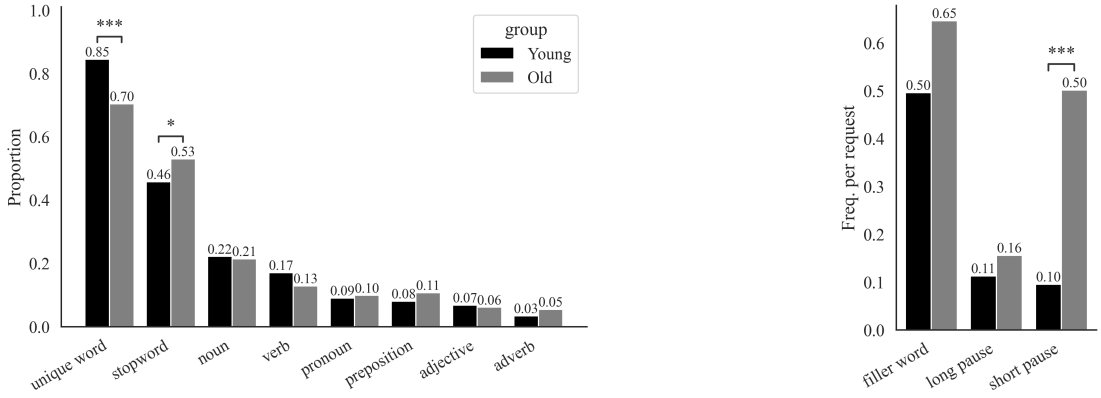

Figure 1: Request characteristics (left) and filler words and pauses (right)

3 RESULTS

3.1 Descriptive statistics

Forty subjects were recruited, 20 younger (18-34, 15 females) and 20 older subjects (60-92, 16 females). Most subjects have at least a bachelor's degree (80% of the older and 75% of the younger group). The inter-rater reliability was $\kappa = 0.81$, $\kappa = 0.89$ and $\kappa = 0.78$ for the search acts, query type and reformulation type, respectively. As shown in Table 1, there were no significant differences between the two groups in the prior experience with the search engine, IVAs, using IVAs to search for information. Older subjects had lower self-reported search self-efficacy but the difference was not significant. For the search task, there were a total of 1092 turns from 40 dialogue recordings. Seventeen younger and 11 older subjects completed the task within 10 minutes. Compared with the younger subjects, the older subjects had significantly longer conversations and more request turns. Each request turn was longer in both word and sentence on average in the older group.

3.2 RQ1: Request characteristics

As shown in Figure 1 (left), the older subjects' requests had a lower proportion of unique words($\beta = -0.20$, $SE = 0.06$, $\chi^2(1) = 11.58$, $p < .001$) and higher proportion of stop words ($\beta = 0.15$, $SE = 0.07$, $\chi^2(1) = 4.60$, $p < .05$). Older subjects' requests, on average, had more short pauses ($\beta = 1.27$, $SE = 0.38$, $\chi^2(1) = 14.97$, $p < .001$) (Figure 1 right) and a greater maximum parsing depth (M=8.60 (SD=3.25) vs. M=12.10 (SD=3.14))($\beta = 3.44$, $SE = 1.02$, $\chi^2(1) = 118.02$, $p < .01$).

3.3 RQ2: Search acts

There were nine types of search acts identified, with a total of 531 instances, 60.82% from the older group. The request acts consisted of initial queries (7.53%), reformulated queries (14.50%) and follow-up questions (12.24%). The navigation-related acts consisted of the access to a title (20.90%), snippet (16.01%), website document (11.30%) and SERP summary (0.56%). The positive and negative feedback took up 3.58% and 12.43%, respectively. We also found that subjects interrupted the agent to terminate the search, e.g., "Hey could you stop" (0.94%). As shown in Figure 2, compared with the younger per request turn, the older subjects accessed fewer results by title ($\beta = -0.40, SE = 0.20$, $\chi^2(1) = 4.12$, $p < .05$) and snippet ($\beta = -0.50, SE = 0.22$, $\chi^2(1) = 4.90$, $p < .05$) but reformulated more queries ($\beta = 0.56$, $SE = 0.27$, $\chi^2(1) = 4.60$, $p < .05$) per request turn. To further understand the difference, we examined the adjacent search acts and found that older subjects had more "reformulated query → reformulated query" ($\beta = 1.90$, $SE = 0.74$, $\chi^2(1) = 11.21$, $p < .01$) and "follow-up question→follow-up question" ($\beta = 1.75, SE = 1.04$, $\chi^2(1) = 4.74$, $p < .05$).

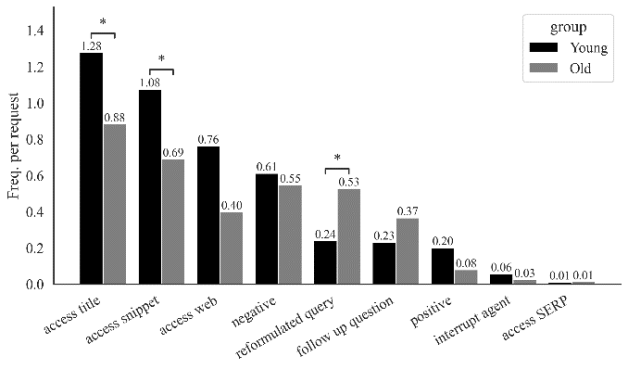

Figure 2: Search acts

3.4 RQ3: Query strategies

3.4.1 Query forms. There were a total of 184 queries and questions, 69.89% from the older group. Five types of requests were identified (1) natural questions (52.69%), e.g., "Why antidepressant medication stops working"; (2) command queries (8.60%), e.g., "Look for information about depression medication"; (3) keyword queries (6.99%), e.g., "Benefit of antidepressant drug"; (4) statements with "I" (16.23%), e.g., "I want to find out three possible causes of depression"; 5) questions with modal verbs (15.59%), e.g., "Can you tell me some more about depression." As shown in Figure 3 (left), compared with the younger subjects, the older subjects issued more "I" statement requests ($\beta = 1.55,\ SE = 0.61, \chi^2(1) = 9.32,\ p < .01$) and fewer questions with modal verbs ($\beta = -0.79,\ SE = 0.28,\ \chi^2(1) = 4.27,\ p < .05$).

3.4.2 Reformulation strategies. There were 142 instances of reformulation by 31 subjects, 75% by 13 older subjects. Four types of queries were identified in both queries and follow-up questions: (1) rephrase (40.97%): subjects kept the search entity the same and rephrase the request, e.g., "Can you tell me why antidepressant medications stop working"→"Other reasons why the antidepressant medicine stops working"; (2) specification (27.08%): subjects added search criteria or replaced search entities with the one representing a more specific concept, e.g., "Antidepressant medication"→"The benefit of the antidepressant medication"; (3) new (26.39%): subjects changed information needs or search entities, e.g., "What are the benefits of antidepressant medications"→" Why would the medication no longer benefit the depression" (4) generalization (5.56%): subjects removed search criteria or replaced search entities with the one representing a broader concept, e.g., "What are the long-term effects of antidepressants medication"→"Let's talk about the medication again" As shown in Figure 3 (right), older subjects had more rephrase, new and specification reformulations but only the rephrase was significant ($\beta = 0.67, \mathrm{SE} = 0.33,\ \chi^2(1) = 4.64,\ \mathrm{p} < .05$).

3.4.3 Other findings. There were eight instances where older subjects added information after the agent clarified their requests, which was not found in the younger group, e.g.,

Agent: If I am understanding it right, you want to look at what are the benefits of antidepressant medications. Is that right? [clarification]

Subject: Yes, on the long-term benefits [query reformulation].

In addition, we found eight instances where older subjects elaborated requests with context information, e.g., "I'm just trying to find out what antidepressants are the most successful um, with effectiveness? [initial query]. Um, some you might have to change every year, some um every six months from studies in the past [context]. Which three antidepressants are the longest lasting for effectiveness? [query reformulation]."

4 DISCUSSION AND FUTURE WORK

Older adults are unrepresentative in the research and development of conversational technologies [47]. This study reports early findings of age-related differences on the search interactions with an SCS agent, with regard to request characteristics, search acts and query strategies.

For the RQ1, older subjects had longer and more grammatically complex requests which had a lower proportion of unique words. This is partially consistent with previous studies [25] and may be related to age-induced changes in language production efficiency [25, 31], preferences towards an elicit communicative mode [56] or unfamiliarity with the agent. This difference may impose challenges for an SCS agent to decode their search intents [40]. Further research is needed to examine drivers of such difference and how SCS agents can elicit information needs from older adults properly. No significant age differences were found in the use of filler words, consistent with [36] but not with [25]. Many factors may come to play, such as search scenarios, and need to be further investigated. The frequent short pauses among the older group may be associated with their difficulties constructing proper requests [35, 40]. This may cause agent's failures to detect when a turn is completed, which partially explains the common IVA's time-out issues with older adults [59].

For the RQ2, our findings suggest two trends. First, older subjects reformulated more queries, accessed fewer titles or snippets per request. This seems to be inconsistent with their behavioral profiles in text-based search, where they had fewer query reformulations but engaged deeply in result examinations [13–16, 21, 45]. This may suggest that the interaction modality, to some extent, affects how older adults allocate attention and time to search activities [15, 44]. Secondly, they tended to issue more than one query or question in a single request turn, e.g., "Jessie, I'm looking for some, some of the causes of antidepression or of depression, excuse me . . . of depression and the antidepression medications that would work best for me." This consolidates the prior finding that the conversational requests tended to contain more than one search acts in a single turn [12, 54] and further proves that this was more obvious among the older subjects.

For the RQ3, the result suggests four trends. Firstly, the natural question requests were the most common in both groups [24]. Unlike [32], which focused on text-based conversational search queries, the command-like queries were not frequent in our study. Secondly, the older subjects tended to start a request with the singular first-person pronoun, e.g., "I would like to. . .", "I want to. . .",

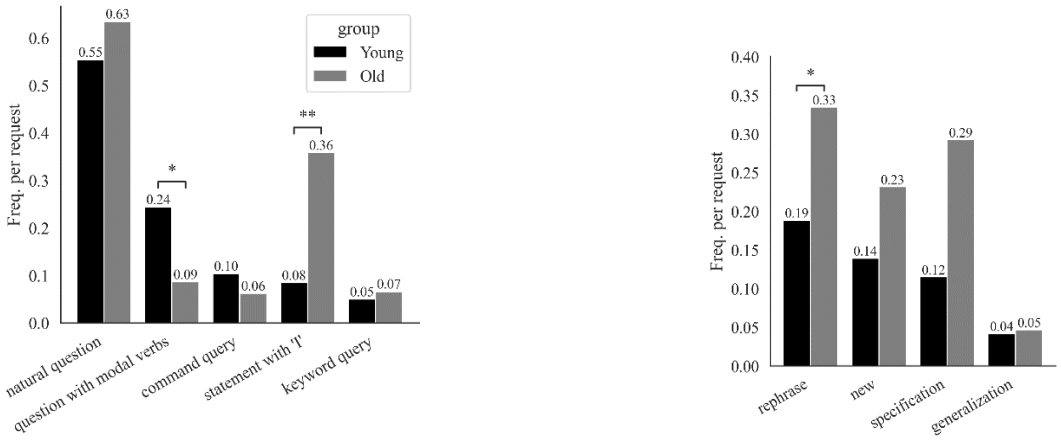

Figure 3: Query forms (left) and reformulation strategies (right)

rather than "Can you search. . .", "Could you look for. . .". This may reflect their different communicative goals [56] or a self-oriented perspective [7, 11] they tended to take with the SCS agent. Thirdly, older subjects reformulated spoken requests as competently as did younger subjects. In the text-based search, older adults used reformulation strategies (e.g., add or remove terms) less frequently than the young [29]. The absence of this discrepancy in the SCS paradigm may again suggest that the interaction modality affects older adults' query behavior. In addition, the frequent use of rephrasing requests among the older group may be related to their efforts to access more results or improve search outcomes [12]. An SCS agent should be able to detect such patterns as relevant feedback and refine the result set accordingly. Lastly, older subjects tended to elaborate requests (e.g., add information after the agent's clarification and/or add context to the request). This mirrors the finding in the RQ2 that the adjacent reformulated queries and question acts were more frequent among the older subjects. This also furthers the findings in [12] that elaborations are more common among older adults.

This study signifies the importance of considering aging factors in the research and designs of the SCS paradigm. It also calls attention to the impacts of the text-to-voice search paradigm transition on older adults' online information activities. Many questions remain unanswered. For example, search tasks can influence older adults' search behavior and performance (e.g., [14, 46]). The analysis of this study was conducted on the training session interactions and thus the findings were limited by the quantity and diversity of search tasks. Further investigations are needed to examine the role of the task characteristics (e.g., complexity) on older adults' conversational search interactions. Another example can be how older adults perceive the SCS paradigm. They think positively about the use of IVAs (e.g., [51]), but usability challenges widely exist when they search for digital information (e.g., [12, 34, 40]). How they expect an SCS agent to function, especially the way the SCS agent elicits information needs, presents audio-only information and conducts the dialogue, is also worth being studied.

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