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Research Report

Strategy and accuracy during information search on the Web: Effects of age and complexity of the search questions

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The present study addressed age-related differences in performance and strategies while searching for information on the Web while considering specific processes involved in the search activity on the Internet. To this end, 10 older and 10 younger adults were instructed to use Google to find information. The search questions varied and increased in complexity: three simple questions (participants had to use the keywords provided in the questions), three difficult questions (participants had to infer new keywords to find correct answers), and three impossible questions (no answer existed). The results showed that older participants were less accurate and used fewer efficient strategies compared to younger participants. The differences increased as a function of question complexity. Moreover, older participants tended to focus on the evaluation of the results provided by Google at the expense of opening up and examining websites. In contrast, younger participants controlled their own activities more often, thus allowing them to improve their strategies and obtain higher performances, contrary to older participants who used the same strategies regardless the complexity of the search question.

1. Introduction

Older people are one of the fastest growing groups of web users who profit from the wide range of Internet services that allow them to search for information and communicate (Aula, 2005; Stronge, Rogers, & Fisk, 2006; Sum, Mathews, Hughes, & Campbell, 2008). Older adults use Internet mainly to search for information on news, weather, travel, financial services and health (Chin & Fu, 2010; Gatto & Tak, 2008; Hardt & Hollis-Sawyer, 2007). However, many studies have shown that older adults experience more difficulties in searching for and finding information compared to younger adults. They often take longer time, find fewer correct answers compared to younger adults, and they utilize inefficient search strategies (e.g., Aula, 2005; Chevalier, Dommes, & Martins, 2013; Czaja, Sharit, Ownby, Roth, & Nair, 2001; Etcheverry, Baccino, Terrier, Marquié, & Mojahid, 2012; Sharit, Hernandez, Czaja, & Pirolli, 2008; van Deursen & Van Dijk, 2009). Searching for information on the Web often requires the use of search engines, such as Google or Yahoo!, among others. Within search engines, individuals have to generate words in the text box to formulate a query and evaluate whether the results provided by the search engine fit search objectives. If not, they have to modify the query by adding and/or removing words to reformulate queries and, in extreme cases, to change the search objective until they reach a satisfactory result. This activity involves different cognitive abilities, especially vocabulary abilities, to generate new words as well as cognitive flexibility to modify the query and eventually the search objective. This activity is complex, particularly for older people. Indeed, search difficulties experienced by older people were often explained by age-related declines in cognitive abilities, such as working memory, vocabulary, reasoning, and flexibility (Dommes, Chevalier, & Lia, 2011; Pak & Price, 2008; Queen, Hess, Ennis, Dowd, & Grühn, 2012; Sharit et al., 2008) and/or difficulties in learning new tools (e.g., Stronge et al., 2006). For instance, recent studies have shown that older adults feel more disoriented when browsing websites compared to younger adults because of age-related declines in spatial ability and mental model accuracy (Wagner, Hassanein, & Head, 2014) along with declines in short term memory and problem-solving abilities (Crabb & Hanson, 2014). Dommes et al. (2011) particularly showed that lower performance of older people resulted from age-related declines in cognitive flexibility, which is defined as the ability to switch cognitive processing strategies to adapt to unexpected conditions in the environment (Chevalier & Chevalier, 2009; Eslinger & Grattan, 1993). Flexibility score explains a large part of the variance in the reformulation, that is,

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more flexible people reformulate more often and get out of impasses. When faced with unsatisfactory results provided by the search engine, older web users who had lower cognitive flexibility scores generated fewer queries and fewer new keywords to overcome impasses compared to older web users with higher cognitive flexibility scores. This difference was particularly pronounced when they processed complex questions (questions that required reformulating queries and using words that were different from those provided in the search question; see Dommes, Chevalier, & Rossetti, 2010; Dommes et al., 2011). Based on these initial findings, we argue that it is important to deepen the knowledge on this topic to obtain a better understanding of both the strategies that older users develop and the cognitive difficulties they experience when they use search engines. Indeed, accessing the Web is challenging for older people because the Internet seems to foster independence and reduce isolation, increase communication and wellbeing, and keep mind active, thereby promoting better health, improving the older people's ability to perform everyday living tasks (Mellor, Firth, & Moore, 2008), and enhancing attention and memory efficiency (Slegers, van Boxtel, & Jolles, 2014). Moreover, as several cognitive abilities and processes are involved in this complex activity (as developed in Section 2), examining how older people search for information and actually use a search engine should offer new knowledge on the effect of age on information search problem-solving. To this end, the experiment we carried out focused on studying the role of specific cognitive processes in getting out of deadlock when searching for information using a search engine and on the associations of these processes with age.

In the next two sections, we first present related work on the cognitive processes and strategies involved in information search activity in relation to age and the definition of search complexity (Sections 2). We then specify the objectives and hypotheses (Section 3) as well as the method (Section 4). The results obtained are presented in Section 5 and discussed in Section 6. In Section 7, we conclude the article by reviewing the implications and limitations of this study.

2. Related work

2.1. Processes and strategies involved in information search

Marchionini (1989) defined information search in electronic system as a special case of problem-solving,[1] which includes recognizing and interpreting the information problem, establishing a plan of search, conducting the search, evaluating the results, and if necessary, iterating through the process again to solve the information problem. More recently, considering the Web, Tabatabai and Shore (2005) defined information search as an ill-defined problem solving (in line with the problem-solving definition suggested by Chi and Glaser (1985)) because the path and the goal of the problem are changing. Indeed, to find information on the Web, different paths can be followed, and the information can be presented on more than one website. Consequently, information search activity on the Web can be a complex problem-solving activity, which involves various cognitive processes. Such processes include understanding the information presented by the search engine and/or on websites and decision-making (selecting relevant information to be processed or to modify search strategy) to solve information problem (for a review on information search models, see e.g. Dinet, Chevalier, & Tricot, 2012).

The information search activity can be carried out in two ways by (1) using a search engine tool to formulate queries and/or (2) navigating on website(s) to identify the information needed. In the current experiment, we focused on information search using a search engine. Based on the model of information search using a search engine developed by Sharit et al. (2008), problem-solving in the information search activity may be divided into the following three stages: (1) the representation of the problem to be solved in which the problem statement is internalized in order to build up a mental representation of the information elements to be searched; (2) the planning that consists of generating a method for coming up with a solution. It often requires dividing the problem into sub-goals; and (3) the execution that involves carrying out the operations that were elaborated during the planning process. These three stages are iterative as planning may generate further insights into the problem and thus promote modified problem representation.

When individuals use a search engine, such as Google or Yahoo!, they have to generate keywords relevant to their queries, evaluate the relevance of the results provided by the search engine, and then select one or more web pages to find the required information. If the search engine does not provide expected results, the information searching activity becomes more complex: the individuals have to reformulate their first query by adding and/or removing keywords and possibly modify their search strategies. Reformulating unsuccessful queries is a highly demanding task, which involves control processes. Consequently, three cognitive processes seem particularly involved in information search activity using a search engine:

1. Planning: individuals elaborate a plan to achieve information search goal. The plan allows them to formalize the first query, divide the problem to be achieved into sub-problems, and develop a search strategy to be followed.
2. Evaluating: individuals process and evaluate relevance of information displayed by search engine or on websites by comparing it with the problem to be solved.
3. Controlling: if the first quest does not provide any relevant result(s), individuals have to modify the strategy to find information. They examine whether their actions allow them to achieve the search goal and if not, they may need to adapt these actions.

The involvement of these processes may vary according to problem complexity and the age of participants. For instance, any increase in problem complexity may require more cognitive resources to be involved. Thus, individuals, especially older people who engage fewer cognitive resources compared to younger ones (Queen et al., 2012) or people who face difficulties in general (see, e.g., White & Drucker, 2007), may need to use strategies that minimize the amount of information considered.

More details on the search complexity are presented in Section 2.2. For instance, Matsuda, Uwano, Ohira, and Matsumoto (2009) found that users tend to look at search results provided by a search engine longer when completing informational tasks (finding a specific information that may be displayed on several websites) compared to navigational tasks (identifying information provided only on a specific website). In a previous study, Lorigo et al. (2006) examined queries and eye scans of Google's results for navigational and informational tasks. They observed that both the time spent on examining the results provided by Google and the number of abstracts viewed below the one that was eventually clicked was greater for navigational search tasks than for informational search tasks. In these two previous studies, participant's age was not considered. However, Chin, Fu, and Kannampallil (2009) identified two search strategies depending on the participants'

[1] According to Chi and Glaser (1985), a problem has three components: initial state, goal state, and a path that connects the first two components. Problem solving occurs when the current state of information is less compared to the desired state and when some barriers appear between the initial state and goal state.

age: (1) the bottom-up interface-driven strategy used mainly by younger people implies that users open up more links, leave web page quickly, and visit a greater number of within-category links; (2) the top-down knowledge-driven strategy used mainly by older people implies that users open up fewer links, take longer to click on another link, which means that they stay longer on the same web page, and visit a greater number of between-category links. The first strategy appears to be particularly efficient for solving well-defined search problems (i.e., problems for which the participants search for precise information with a unique solution, usually contained in a single web page). In contrast, to solve ill-defined task (i.e., more than one solution), the second strategy is more efficient. Consequently, the strategy developed by older people seems appropriate and efficient for solving ill-defined problems. This strategy leads older people to achieve better performance compared to their younger counterparts when solving ill-defined search problem. The reverse is observed when the search problem is ill defined.

However, when a strategy fails to solve the problem, Chin and Fu (2010) also showed that older adult users had trouble changing strategy for a more efficient one (see also Stronge et al., 2006). In the study led by Chin and Fu (2010), the definition of strategies was based on the time and the links provided the search engine. Other authors defined strategies based on the evaluation made during the information search activity. For instance, Klöckner, Wirschum, and Jameson (2004) and Aula, Majaranta, and Räihä (2005) distinguished two profiles of evaluators: (1) the economic evaluation means that users scan at most half of the results displayed by the search engine before undertaking their first action; (2) the exhaustive evaluation means that users scan more than half of the results or even scroll down the result page provided by the search engine before starting their first action. Their eye-tracking study revealed that the economic evaluation was more efficient for search problems for which the results displayed by the search engine lead to relevant information. Less advanced users are more likely to use the exhaustive evaluation type (Aula et al., 2005), which is related to fewer successful problems (Aula, Khan, & Guan, 2010). We argue that these two profiles may also be related to the task complexity. When it is easy to find information, the participants may develop economic evaluation whereas when the information is hard to find, the participants have to deepen their strategy to develop the exhaustive profile. Consequently, complexity of the search questions was manipulated to influence the solving process, since complexity has a strong impact on this activity.

2.2. Complexity of the information search problem to be solved

Different definitions of complexity can be found. For instance, in psychology, Campbell (1988) defined two dimensions of task complexity: (a) objective task complexity is a characteristic of the task that is independent of the individual whereas (b) subjective task complexity is a psychological experience or perception of a task by the individual who performs the task. Similarly, for Arguello (2014), task complexity is an inherent property of the task independent of the individual while task difficulty refers to a user's assessment of the amount of effort required to complete the task.

In the information search area, problem complexity has been measured in different ways, and it has various dimensions. Barsky and Bar-Ilan (2012) as well as Chevalier, Maury, and Fouquereau (2014) provided information problems for which keywords mentioned in the statement (instructions) matched the words displayed on the website (they called them "simple problems") vs. information problems for which words displayed did not match the keywords of the statement (the called them "complex problems"). In the last case, participants had to infer the correct link related to the problem. For Chin et al. (2009), low and high complexity refers to well-defined and ill-defined problems, respectively. In well-defined problems, participants had to find a precise fact (e.g., to find a definition) whereas in ill-defined problems, they had to collect various information elements from several websites (e.g., to collect information to write a document on a specific topic). For Sihvonen and Vakkari (2004), a simple problem presents specific and familiar concepts in the domain, whereas a difficult problem includes terminology that requires greater domain knowledge. Queen et al. (2012), in search information tasks and decision quality in consumer decision-making tasks, manipulated complexity through the number of information elements provided to make a choice. Finally, search task complexity can also be defined by the level of cognitive complexity required by the information search task (i.e., level of elaboration, amount of cognitive processing, cognitive effort, Arguello (2014)).

Based on these different definitions, the present study examined objective task complexity and considered the amount of cognitive requirements imposed on participants while solving information problems. Problem complexity was manipulated by the presence or absence of terms in the instructions given to participants that were directly related to the information to be found and by the fact that this information was seemingly believable, but in reality, no answer was possible When no useful terms were given in the problem instruction, the individuals had to infer new related terms that were necessary to find information.

For our present study, the manipulation of complexity was similar to previous works conducted by Dommes et al. (2011) and Monchaux, Amadieu, Chevalier, and Mariné (2015). These authors instructed participants to carry out search problems of varying and increasing in complexity. Complexity depended on the presence or absence of relevant keywords in the instruction, and search questions either had or did not have an answer. Three levels of complexity were designed. The simple questions were designed as the simplest level. The relevant keywords were included in the statement of the simple questions, allowing participants to obtain the correct answers. The intermediate level comprised difficult questions. These questions did not contain the keywords to obtain the correct answers; thus, the participants had to infer new related keywords to complete the searches correctly (e.g., as the word "vegetable" provided in the information question statement did not lead to the correct answer, the participant had to infer "plant"). The more complex level comprised the impossible questions, which contained information that was seemingly believable, but in reality, no answer was possible. Nevertheless, participants were made to believe that answers existed in order to encourage them to formulate many queries. In the Dommes et al.'s (2011) study, younger participants performed better compared to older participants, especially when they dealt with difficult and impossible questions. More precisely, older participants experienced more difficulties compared to younger participants reformulating unsuccessful queries while performing the difficult and impossible questions. Indeed, for simple questions, the authors found that to obtain the targeted answer, all participants formulated mostly a unique query per question that generally contained three keywords. However, when the question complexity increased, age-related differences were observed, specifically, younger participants formulated more queries (means of 4 or 5 queries) and used more keywords (means of 6 or 7 keywords per query) compared to older participants (less than 2 queries and 4 keywords, on average).

3. Research aims and hypotheses

As indicated previously, two major problems seem to impede the information search activity, which are particularly detrimental for older adult users. The first problem pertains to the difficulties in formulating relevant queries and keywords to achieve the search goal when the first query does not provide satisfactory results (Dommes et al., 2011; van Deursen, 2012; van Deursen & Van Dijk, 2009). The second problem concerns difficulties giving up inappropriate searching strategies to adopt better ones (Chin & Fu, 2010; Queen et al., 2012; Stronge et al., 2006).

Concerning the formulation of queries, two prior studies have shown that older adults experienced more difficulties in reformulating unsuccessful queries and generating new keywords compared to their younger counterparts, especially when dealing with complex questions (difficult and impossible ones), which required them to use new keywords (Dommes et al., 2010, 2011). Older adult users also spent longer time exploring the results provided by Google than exploring directly the websites provided by Google. This later behavior is related to poorer performance of older users. These findings corroborated those obtained by Aula et al. (2010) who observed that the participants with poorer performance spent longer time on Google's results compared to participants with greater performance. They also seemed to have trouble modifying unsuccessful strategies to develop a better one. Although this earlier work offers new interesting evidence, to our knowledge, no previous study has examined age-related differences in planning, evaluating, and controlling processes, which seem to be three important components of the search activity.

The present experiment thus aimed to examine the extent to which the difficulties experienced by older adult users as compared with younger ones are related to the strategies implemented as well as with the processes involved in the information search—planning, evaluating, and controlling. This was studied by using tasks (here, questions) of varying and increasing in complexity manipulated through simple, difficult, and impossible questions, as presented below (see Section 4.2). More precisely, seven hypotheses were formulated with regard to dependent variables computed (presented in Section 4.3).

Based on prior studies, which have shown that older adults have difficulties and lower performance while searching for information on the Web (e.g., Czaja et al., 2001; Dommes et al., 2011; Hanson, 2010; Kubeck, Miller-Albrecht, & Murphy, 1999; Morrell, 2005), older participants were expected to exhibit poorer performance (correct answers and search time) compared to their younger counterparts, especially in complex questions (difficult and impossible ones). Therefore, two hypotheses were formulated:

Hypothesis 1: Correct answers. Younger participants should provide a greater number of correct answers compared to their older counterparts (H1a). We expected a decrease in correct answers as the complexity of questions increases, i.e., the fewest number of correct answers for impossible questions followed by difficult questions and simple questions (H1b) with the greatest number of correct answers, especially in the older group (H1c).

Hypothesis 2: Time needed to perform search questions. Older participants should take longer time compared to younger participants (H2a). The time to provide an answer should increase as complexity increases, i.e., more time should be devoted to impossible questions than to difficult ones, which should require more time compared to simple questions (H2b), especially for older participants (H2c).

Accordingly, in line with earlier findings (Dommes et al., 2010, 2011), it was expected that older participants should experience more difficulties compared to younger participants when they have to formulate and reformulate queries, especially for complex questions (difficult and impossible ones). Two hypotheses were formulated:

Hypothesis 3: Queries formulated in Google. Older participants should formulate fewer queries compared to younger participants (H3a). The number of queries should increase as complexity increases, i.e., fewer queries should be formulated for impossible questions than for difficult ones and for simple questions (H3b), which should generate the greatest number of queries, especially in the older group (H3c).

Hypothesis 4: Keywords used. Older participants should use fewer keywords compared to younger participants (H4a). The number of keywords should increase with complexity, i.e., fewer keywords should be generated for impossible questions compared to difficult ones, while simple questions (H4b) should generate the greatest number of keywords, especially in the older group (H4c).

Based on the prior findings, which have shown that older people experience more difficulties in changing strategies to develop better ones compared to younger people (Chin & Fu, 2010; Stronge et al., 2006) and that older people spend longer time examining the results provided by Google than exploring websites provided by Google (Dommes et al., 2011), we formulated two hypotheses:

Hypothesis 5: Time spent on Google vs. websites (i.e., web documents, such as web pages, PDF, word documents). We hypothesized that older adults should spend longer on Google compared to the younger adults (H5a). As we expected to observe more queries as complexity increases (see H3b), the time spent on Google, compared to the time spent on websites, should be longer for impossible questions than for difficult ones and longer for difficult questions than for simple questions (H5b). Age-related differences were expected to increase for impossible and difficult questions (H5c).

Hypothesis 6: Switches between Google and websites. Regarding the time switching between Google and websites, we expected younger participants to switch significantly more compared to the older ones (H6a). The number should also increase with complexity, i.e., more switching with impossible questions than with difficult ones and more switching with difficult than with simple questions (H6b), especially for older participants (H6c).

Finally, older participants should experience more difficulties compared to younger participants in changing strategies, which should affect processes mobilized (planning, evaluating, and controlling).

Hypothesis 7: Involvement of planning, evaluating, and controlling. Older adults should evaluate their activity more often compared to younger adults (H7a), particularly for difficult and impossible questions (H7b). On the contrary, older participants should have trouble planning and controlling their activity compared to older adults (H7c), especially for difficult and impossible questions (H7d).

4. Method

4.1. Participants

Ten young adults (age range: 21–27 years; $M = 24.6$, $SD = 1.78$) and 10 older adults (age range: 60–68 years; $M = 62.6$, $SD = 2.12$) volunteered to participate in the study. All participants were French native speakers in good health and had normal or corrected-to-normal vision. Education ($M_{younger} = 15.10$ years, $SD_{younger} = 1.52$; $M_{older} = 15.2$ years, $SD_{older} = 1.87$ ($t(18) = -0.29$,

p = n.s.) and familiarity with Internet were controlled. The participants used the Internet for at least five years for information search, mailing, and chatting ($M_{younger}$ = 7.15 years, $SD_{younger}$ = 1.31; M_{older} = 6.70 years, SD_{older} = 1.16; $t(18) = 1.60$, p = n.s.). Older participants were retired or near being retired (in few months), and they worked mainly in education. Older participants were recruited from a city association that offers various activities, such as Internet programs, travel, play board games, and the like.

Younger participants were students (recruited at the University of Paris-Nanterre), or they worked mainly as engineers at the university, teachers, or nurses (recruited from the same association as the older participants).

Participants also completed three paper-and-pencil cognitive ability tests, the letter–letter comparison test, which is considered a good measure of processing speed (Salthouse, 1996), the Trail Making Test (TMT Part B; Spreen & Strauss, 1991) as a measure of flexibility (fluid ability), and the French version of the Raven Mill Hill vocabulary scale (Deltour, 1998). The speed test and flexibility test reflected fluid intelligence while the vocabulary test reflected crystallized intelligence. (1) In the letter–letter test (speed test), stimuli were pairs of 2 letters (X and O) presented in a column. The participant had to check on the same line whether the letters they saw were the same or the different, depending on the stimuli identity. The participants had to complete as many of the items as possible within 30 s. (2) The TMT (part B) test consisted of 25 dots distributed on a sheet of paper. In Part B, the dots included both numbers (from 1 to 13) and letters (from A to L). The participants had to draw lines as quickly as possible to connect the circles in an ascending pattern, alternating between the numbers and letters (i.e. 1-A-2-B-3-C, etc.). (3) The French version of the Raven Mill Hill vocabulary scale comprised two parts. The first one consisted of a series 44 words, and the participants had to define all words. The second one also consisted of a series of 44 words. For each word, the participant had to choose a synonym from a list of six words. In addition to these cognitive ability tests, the participants performed a self-efficacy scale in Information Retrieval on the Web. This scale, developed by Meyer and Rodon (2004; $\alpha_{Cronbach} = 0.84$), is a type of the Generalized Self-efficacy Scale (Schwarzer & Born, 1997) modified to focus on self-efficacy for information searching on Internet (Rodon & Meyer, 2012).

The results obtained corroborated traditional findings, with younger adults ($M = 30$, $SD = 3.13$) showing higher processing speed compared to the older ones on the letter–letter test ($M = 21.5$, $SD = 3.41$; $t(18) = 5.81$, $p < .0001$) as well as the flexibility test ($t(18) = 2.474$, $p < .05$). Older adults ($M = 65.32$, $SD = 25.33$) took longer time compared to younger ones ($M = 102.2$, $SD = 39.75$) while older participants ($M = 72.9$; $SD = 5.53$) outperformed their younger counterparts ($M = 67.2$, $SD = 7.07$; $t(18) = -2.01$, $p < .05$) on the vocabulary test. Concerning the self-efficacy, we observed no significant difference between younger adults ($M = 28.20$, $SD = 3.36$) and older adults ($M = 26.20$, $SD = 6.58$; $t(18) = 0.86$, p = n.s.).

4.2. Material

Participants had to answer 9 search questions (see Table 1), which varied and increased in complexity, as follows:

– The three simple questions (easiest questions) contained the keywords needed to obtain the right answer.
– The three difficult questions (intermediate questions) did not contain the relevant keywords needed to obtain the correct answer. Participants had to generate new related keywords by themselves.
– The three impossible questions (more complex questions) contained elements that made participants believe that an answer could be found in order to encourage participants to reformulate their queries and inferred new keywords (more than for difficult questions). In reality, these questioned could not be answered on the Web.

Table 1
The nine information search questions (translated from French).

Questions	Complexity	Search questions
1	Simple	What is Edith Piaf's date of birth?
2	Simple	What is the height of the "Tower of Pisa"?
3	Simple	What is the duration of gestation of a polar bear?
4	Difficult	What vegetable family does the Nerta belong to?
5	Difficult	How high is the "Mont des Singes"?
6	Difficult	What medical term indicates a jaw deformity?
7	Impossible	How many eggs an armadillo can lay per litter?
8	Impossible	When was the book "Une Vie Rêvée" written by Marc Levy published?
9	Impossible	What is the radio frequency of "Radio Écologie"?

When they found the correct answer, participants were required to underline it using the mouse cursor. They were free to give up if they did not find the information or if they thought that no answer existed by indicating their decision to the experimenter as soon as it was made. They were then asked to write on a sheet of paper either their answer or "give up" or "no answer". While performing the search activity, participants were asked and continuously encouraged to think aloud (see Ericsson & Simon, 1993). The experiment lasted about one and half hour for each participant.

The information search task was performed using a laptop computer, running at 1.4 GHz with 2 GB of RAM, with a 38.1-cm screen and a connected external mouse (the tactile mouse was not allowed). A high-speed Internet connection was used (wireless connection). Internet Explorer 8 was used as a browser, and Google was used as a search engine because all participants reported that they used it, and it is the most widely used search engine in the world (Alexa, 2011, 2014). The search behaviors of the participants (keywords used, web pages visited, etc.) were recorded using free video capture software (CamStudio) and their verbalizations (a functionality of CamStudio allows recording verbalizations). In addition to CamStudio, we used a camera to check the synchronization between verbalizations and actions made with the mouse and keyboard.

4.3. Procedure, dependent variables, and data analysis

First, the participants were instructed to find the correct information to answer the question as quickly as possible. A sample question was provided to familiarize the participants with the search task. The presentation order of the questions was counterbalanced for each participant.

Subsequently, the participants had to complete cognitive ability tests and the self-efficacy scale.

Seven dependent variables (DV) were used. The first four variables assessed information search performance while the remaining three variables assessed information search strategies, as follows:

(1) DV1: Number of correct answers. Giving up the attempt to find an answer or finding incorrect answer was scored 0. A correct answer for simple and difficult questions and reporting that no answer could be found on the Web for impossible questions were scored 1. Thus, the maximum number of correct answers was 9. This total score reflected 3 scores of 3 points each (a score of 3 points for simple question, a score for difficult questions, and a score for impossible questions).
(2) DV2: Search time (in seconds). For each experimental search question, the search time was calculated from the moment participants started the search with Google (i.e., after reading aloud the search question) until they highlighted the answer by clicking the mouse or until they gave up the

search. The mean search time for the three simple, three difficult, and three impossible search questions was calculated for each participant.

(3) DV3: The number of queries that each participant formulated and entered in the search engine text box. We computed the first query and the others ones after unsuccessful results or in order to further information search. The mean number of queries for the three simple, three difficult, and three impossible search questions was calculated for each participant.

(4) DV4: The number of different keywords used in the Google box. If the same keyword was used several times, we counted it once. The mean number of keywords was calculated for each participant for the three simple, three difficult, and three impossible search questions.

(5) DV5: The percentage of the total search time that the user devoted to the Google search engine's pages to type keywords in the text box and to examine the link results provided by Google relative to the search time spent inspecting web documents within websites given because of the Google search (web pages, PDF, word documents, etc.). The mean percentage of the search time spent on Google for the three simple, three difficult, and three impossible questions was computed for each participant.

(6) DV6: The number of switches between results provided by Google on the one hand and opening websites (or documents) provided by Google on the other hand. The mean switches for the three simple, three difficult, and three impossible questions was computed for each participant.

(7) DV7: The percentage of the participant's verbalization sequences assigned to each of the three processes: evaluating, planning, and controlling. The mean percentage of the sequences for the three cognitive processes was computed for three difficult and three impossible questions for each participant.

As just indicated, verbalization data were recorded and transcribed. Two people analyzed the protocols to identify the distribution of planning, controlling, and evaluating processes during search activity. When the two judges differed in their evaluations, they discussed them until they reached an agreement. The degree of agreement obtained was greater than .94. The verbalizations for which no agreement could be reached were removed from the analyses.

We utilized a mixed factorial design with age as a between-subject factor (2 levels: young, old) and a complexity as within-subject factor (3 levels: simple, difficult, impossible). For DV 5 and 7, the ANOVA also included repeated measures conducted with time spent on Google vs. websites (2 levels) for DV5 and planning, evaluating, and controlling for verbalizations for DV7.

For all ANOVAs, the LSD-Fisher test was used for post-hoc pairwise comparisons. Partial η^2 was used as an index of the relative effect size.

To examine the role of strategies and cognitive abilities in performance, a binary logistic regression was computed.

5. Results

5.1. Correct answers

As expected (H1a), ANOVAs revealed a significant effect of age ($F(1,18) = 12.52$, $p < .005$, $\eta_p^2 = .41$) on the number of correct answers, with the older adults providing fewer correct answers ($M = 1.7$; $SD = 0.34$) compared to the younger adults ($M = 2.1$; $SD = 0.44$). Complexity also had a significant effect, partially in line with H1b ($F(2,36) = 51.10$, $p < .0001$, $\eta_p^2 = .74$). Indeed, post-hoc analyses revealed that simple questions ($M = 2.95$, $SD = 0.22$) generated a greater number of correct answers compared to the difficult ($M = 0.95$, $SD = 0.94$) ($p < .0001$) and impossible questions ($M = 1.95$, $SD = 0.81$) ($p < .005$); however, difficult questions generated fewer correct answers compared to the impossible ones ($p < .0001$). As hypothesized (H1c), the age × complexity interaction was significant ($F(2,36) = 3.72$, $p < .05$, $\eta_p^2 = .17$), with younger participants providing more correct answers compared to their older counterparts for the difficult ($p < .005$) and impossible questions ($p < .005$) but not for the simple ones (p = n.s.; see Table 2 for means and standard deviations).

5.2. Search time (in seconds)

Contrary to H2a, age had no significant effect on search time ($F(1,18) = 0.05$, p = n.s.). A significant effect of complexity ($F(2,36) = 47.37$, $p < .00001$, $\eta_p^2 = 0.72$) was observed, partially in line with H2b. Simple questions ($M = 50.10$ s, $SD = 38.35$) were processed faster compared to the difficult ($M = 397.20$ s, $SD = 180.79$) ($p < .001$) and impossible ($M = 286.45$ s, $SD = 118.79$) ($p < .001$) questions; however, contrary to H2b, impossible questions were processed more quickly compared to the difficult ones ($p < .05$). Age × complexity interaction was non-significant ($F(2,36) = 1.35$, p = n.s.), contrary to H2c (see Table 2 for means and standard deviations).

5.3. Queries formulated

As expected (H3a), younger participants formulated more queries compared to the older ones ($F(1,18) = 12.02$, $p < .01$, $\eta_p^2 = .40$), with the mean of 4.12 ($SD = 1.48$) for younger participants and 2.28 ($SD = 0.79$) for older participants. The complexity also had a significant main effect ($F(2,36) = 22.38$, $p < .00001$, $\eta_p^2 = 0.55$). Simple questions ($M = 1.18$, $SD = 0.25$) generated fewer queries compared to the difficult ($M = 4.42$, $SD = 2.79$) ($p < .0001$) and impossible ($M = 4$, $SD = 2.28$) ($p < .0001$) questions while no significant difference was observed between the difficult and impossible questions (p = n.s.), partially confirming H3b. The age × complexity interaction was significant ($F(2,36) = 3.82$, $p < .05$, $\eta_p^2 = .18$). Younger participants formulated more queries compared to the older participants for difficult questions ($p < .005$) and impossible questions ($p < .01$) but not for simple ones (p = n.s.), as expected (H3c) (see Table 2 for means and standard deviations).

5.4. Keywords

In accordance with H4a, younger participants formulated more keywords ($M = 5.26$; $SD = 1.27$) compared to the older participants ($M = 4.09$; $SD = 1.20$), and this difference was significant ($F(1,18) = 4.41$, $p = .05$, $\eta_p^2 = .20$). Complexity also had a significant effect ($F(2,36) = 10.69$, $p < .001$, $\eta_p^2 = .37$; H4b), with simple questions ($M = 3.33$, $SD = 0.67$) generating fewer keywords compared to the difficult ones ($M = 5.60$, $SD = 2.65$) ($p < .005$) and the impossible ones ($M = 5.08$, $SD = 1.81$) ($p < .0001$). No significant difference emerged between the difficult and impossible questions (p = n.s.), which is partially consistent with H4b. The age × complexity interaction was not significant ($F(2,36) = 1.27$, p = n.s.), contrary to H4c.

5.5. Search time spent on Google vs. websites[2]

All participants spent more time on Google (58.08% of time) rather than on websites (41.12%), and this difference was

[2] We used "websites" to refer to all web documents opened up by participants (as defined in Section 4.3, DV6).

Table 2
Means and *SD* of correct answers, search time (seconds), queries and keywords, as a function of age and complexity of the questions.

	Age groups	Simple questions		Difficult questions		Impossible questions		Total	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Correct answers (number)	Young	2.90	0.32	1.40	0.70	2.70	0.48	*2.15*	*0.41*
	Older	3.00	0.00	0.50	0.97	1.90	0.74	*2.00*	*0.49*
	Total	*2.95*	*0.22*	*0.95*	*0.94*	*2.30*	*0.73*	*1.95*	*0.48*
Search time (seconds)	Young	48.13	22.44	361.33	207.58	310.27	162.67	*239.91*	*108.33*
	Older	52.07	50.92	433.07	151.84	262.63	45.49	*249.26*	*56.23*
	Total	*50.10*	*38.35*	*397.20*	*180.79*	*286.45*	*118.79*	*244.58*	*84.14*
Queries (number)	Young	1.27	0.26	5.77	3.12	5.33	2.35	*4.12*	*1.48*
	Older	1.10	0.22	3.07	1.62	2.67	1.25	*2.28*	*0.79*
	Total	*1.18*	*0.25*	*4.42*	*2.79*	*4.00*	*2.28*	*3.20*	*1.50*
Keywords (number)	Young	3.50	0.70	6.20	2.75	6.07	1.85	*5.26*	*1.28*
	Older	3.17	0.63	5.00	2.54	4.10	1.16	*4.09*	*1.20*
	Total	*3.33*	*0.68*	*5.60*	*2.66*	*5.08*	*1.82*	*4.67*	*1.35*

significant ($F(1,18) = 11.73$, $p < .005$, $\eta_p^2 = .39$). The interaction between age and Google-website time was significant ($F(1,18) = 8.31$, $p < .005$, $\eta_p^2 = .32$). The younger participants ($M = 47.94\%$) spent longer on websites compared to the older participants ($M = 35.89\%$) ($p < .05$) while the reverse was observed for the time spent on Google, as proposed in H5a ($M_{young} = 52.06\%$ vs. $M_{old} = 64.11\%$). The interaction between Complexity and Google-websites time was significant ($F(2,36) = 24.85$, $p < .0001$, $\eta_p^2 = .58$). Participants spent longer on Google than on other websites when they performed simple ($M_{Google} = 73.81\%$ vs. $M_{websites} = 26.11\%$; $p < .0001$) and difficult search ($M_{Google} = 57.65\%$ vs. $M_{websites} = 42.35\%$; $p < .01$), whereas no significant difference appeared for impossible questions ($M_{Google} = 42.69\%$ and $M_{websites} = 57.31$; p = n.s.). These results partially confirm H5b.

The age × Google-website time × complexity interaction was not significant ($F(2,36) = 2.79$, $p = .07$). Post-hoc comparisons showed that younger participants spent longer time on websites compared to older participants when they performed impossible questions ($p < .01$). No significant age difference emerged for simple questions (p = n.s.) or for the difficult ones (p = n.s.). These results partially confirm H5c (for detailed results, see Fig. 1).

5.6. Switches between Google and websites

In accordance with H6a, younger participants ($M = 4.48$, $SD = 0.8$) exhibited more switches compared to older participants ($M = 3.75$, $SD = 0.47$) ($F(1,18) = 5.91$, $p < .05$, $\eta_p^2 = .25$). The complexity also had a significant effect ($F(2,36) = 77.76$, $p < .0001$, $\eta_p^2 = .81$), with fewer switches in simple questions ($M = 1.63$, $SD = 0.41$) than in difficult ($M = 5.8$, $SD = 2.03$) ($p < .005$) and impossible questions ($M = 5.27$, $SD = 1.69$) ($p < .005$). Difficult and impossible questions did not differ significantly, contrary to H6b. The interaction between age and complexity was significant ($F(2,36) = 7.85$, $p < .005$, $\eta_p^2 = .30$). The younger participants did more switches compared to the older participants only when they performed impossible questions ($p < .001$), which was partially in accordance with H6c (see Fig. 2 for the means and standard

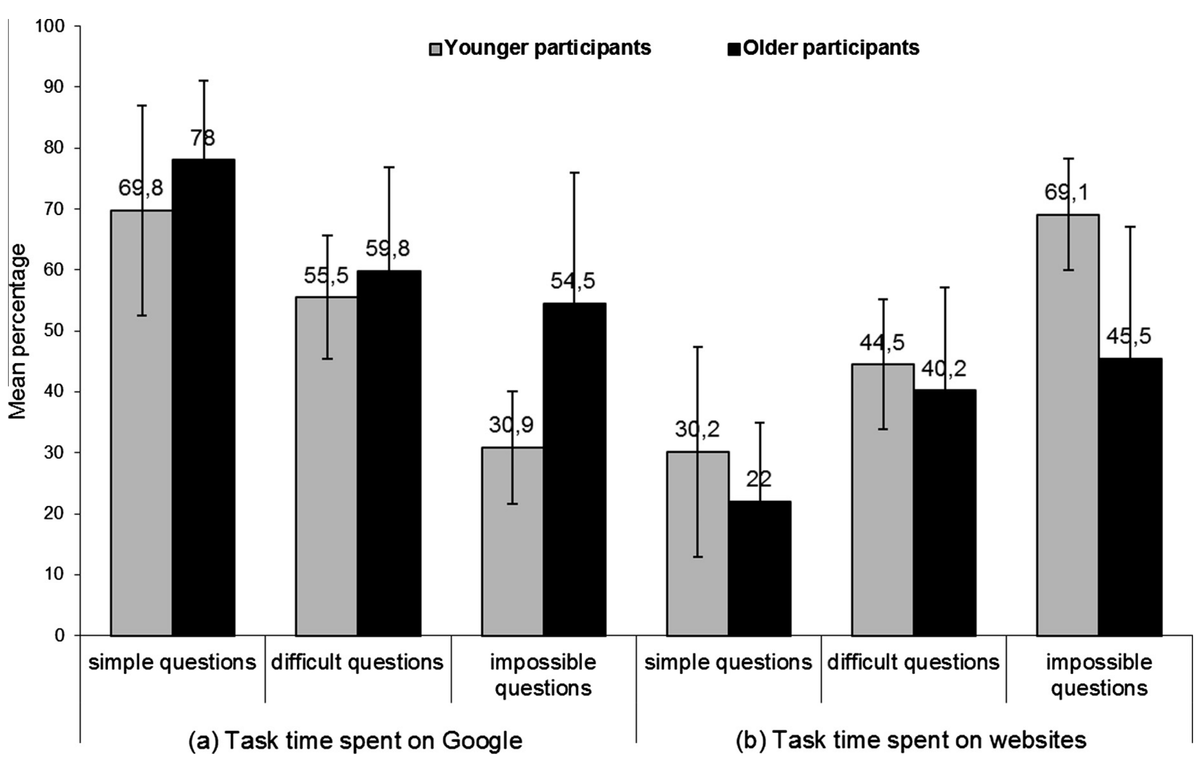

Fig. 1. Mean (*SD*) percentage of search time spent on Google vs. on websites with regard to age and question complexity.

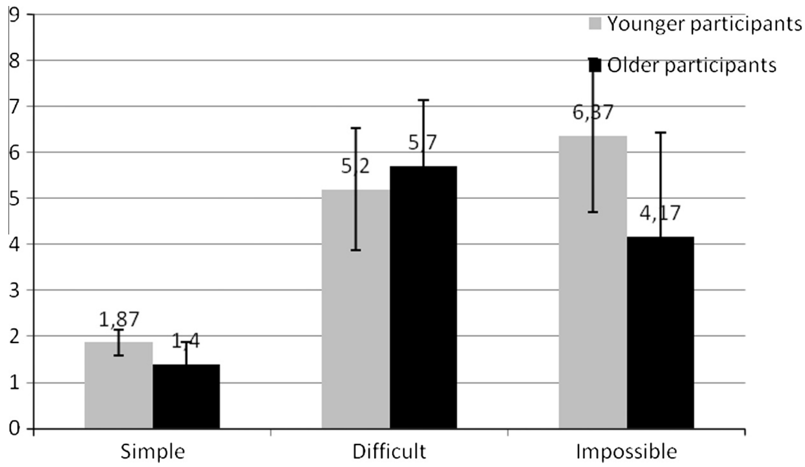

Fig. 2. Mean (*SD*) number of switches between Google and websites with regard to age and question complexity.

deviations). Other comparisons were not significant. For detailed results, see Fig. 2.

5.7. Distribution of the planning, evaluating, controlling processes

Only interactions involving cognitive processes make sense and are presented here (see Fig. 3).

The age × processes interaction was significant ($F(2,36) = 18.77$, $p < .0001$, $\eta_p^2 = .51$). As expected (H7a), the older participants evaluated ($M = 41.62\%$, $SD = 19.3$) more often than the younger participants ($M = 17.6$, $SD = 16.38$) ($p < .0001$), whereas the younger participants planned ($M = 44.74\%$, $SD = 35.45$) ($p < .005$) and controlled ($M = 37.65$, $SD = 28.1$) their search activity more often ($p < .05$) compared to the older ones ($M_{planning} = 29.43$, $SD = 25.34$; $M_{controlling} = 29.94$, $SD = 14.18$). The age × processes × complexity interaction was also significant ($F(4,72) = 5.54$, $p < .0001$, $\eta_p^2 = .24$). Post-hoc tests indicated that the older participants evaluated all types of questions, simple questions ($p < .01$), difficult questions ($p < .001$), and impossible ones ($p < .0005$), more often compared to the younger participants (see Fig. 3 for detailed descriptive results). The younger participants planned their activities more compared to the older participants when responding to all types of questions ($ps < .0001$). Finally, the younger participants controlled more often their search activities compared to the older ones when they performed the difficult and impossible questions only ($ps < .0001$). The reverse was observed for simple questions, since the older participants controlled their activity more often compared to the younger participants ($p < .0001$) (see Fig. 3 for detailed descriptive results).

5.8. Logistic regression analyses

To further assess the performance determinants, a logistic regression was computed on correct answers (0: incorrect answer

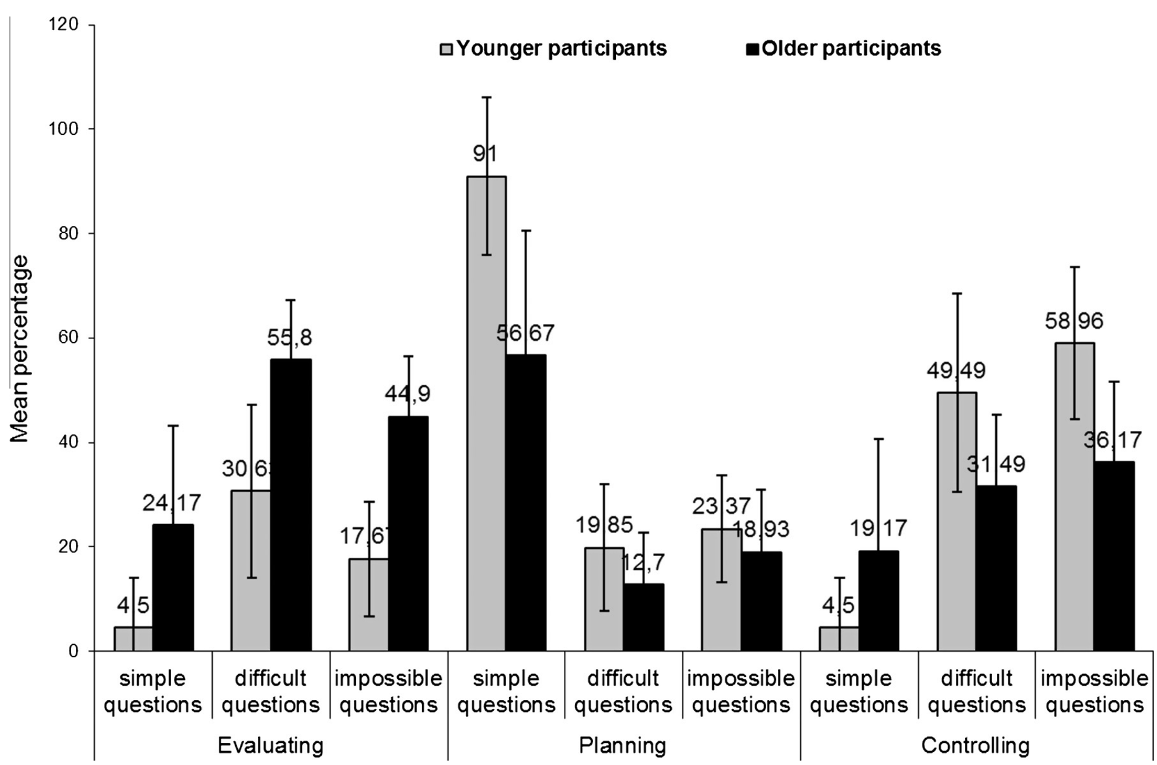

Fig. 3. Mean percentage of time (*SD*) devoted to evaluating, planning, and controlling with regard to age and question complexity.

or giving up; 1: correct answer, 9 answers × 20 participants = 180 data) as a function of age (young vs. old), the strategies used (search time; number of queries; number of keywords; percentage of time devoted to the Google search engine's page; number of switches between Google and websites; and percentage of participant's verbalizations assigned to the evaluating, planning and controlling processes), and cognitive abilities (vocabulary; speed of processing; flexibility; self-efficacy score).

The model was significant, $\chi^2(11) = 48.95$, $p < .001$, Nagelkerke's $R^2 = .33$. The Hosmer–Lemeshow goodness-of-fit statistics showed that the model adequately describes the data (p = n.s.). The probability to provide a good answer was significantly associated with both the number of switches between Google and websites (Wald statistic = 14.56, $p < .001$) and the planning processes (Wald statistic = 6.36, $p < .05$). Participants who switched less often performed significantly better (odds ratio = 0.71) compared to participants who switched often between the results provided by Google and opening websites (or documents). Participants who frequently planned their activities performed significantly better (odds ratio = 1.026) compared to participants planned their activities less frequently. Flexibility abilities were close to the significance level (Wald statistic = 3.16, $p = .076$). Participants with higher flexibility scores performed significantly better (odds ratio = 1.032) compared to participants with lower flexibility scores. Age was not significant (Wald statistic = 0.21, p = n.s.).

6. Discussion

This study aimed to determine the effect of the users' age and search questions complexity on performance and strategies when using a search engine (in this case Google).

The results obtained confirmed several established age-related differences in web search performance (e.g., fewer correct answers, fewer queries, fewer keywords), which were particularly notable with increased question complexity (see also Dommes et al., 2010, 2011; Stronge et al., 2006). Indeed, although younger and older participants took about the same time to perform search questions, older participants found fewer correct answers, especially for difficult and impossible questions. Moreover, although they had higher vocabulary knowledge, they formulated fewer queries and used fewer keywords compared to younger participants when they processed difficult and impossible questions. Older people globally experienced more difficulties in getting out of impasses. These age-related differences may be due to unsuccessful strategies that older participants use and to difficulties in modifying these strategies when they are not well suited. Indeed, older participants spent longer time to explore Google results, opened up and explored fewer websites, and thus switched between Google and websites less frequently compared to younger participants, especially when responding to impossible questions. These results suggest that older people tend to use the same strategy regardless of search question complexity, as previously observed by Chin and Fu (2010) in a navigational task (navigation into a precise website without using any search engine). The strategy developed by older participants in the present experiment may be compared to the so-called top-down knowledge-driven strategy defined by Chin et al. (2009). Indeed, in the top-down knowledge-driven strategy, participants took longer time before clicking on a new link and visited few links (Chin et al., 2009). In the present study, older participants spent longer viewing the Google results and opened up few links provided by Google. In line with the results obtained by Chin et al. (2009), this strategy, utilized mainly by older people, is inefficient to perform specific complex fact-finding searches, and all questions in our experiment involved fact-finding searches.

At the beginning, we hypothesized that impossible rather than difficult questions should decrease performance since no answer existed on the Web, although the questions appeared to have an answer. However, the main results showed either no significant difference between these two categories of questions or slightly better performance on impossible compared to difficult questions. These results may be explained by the fact that participants became aware quickly that no answer could be found and then gave up their searches (as we can see with shorter time devoted to searching for impossible question compared to difficult ones).

Though verbalizations obtained were very time consuming in terms of coding and interpretation, the qualitative analyses of verbalizations recorded while the participants performed the search questions proved to be very useful for specifying age-related differences in such search activities. These qualitative analyses revealed age-related differences in evaluating, planning, and controlling processes. Indeed, younger participants planned their search activities more frequently compared to older participants and, inversely, older participants evaluated their activities more frequently compared to younger participants, regardless of the question complexity. Concerning the controlling process, we observed a significant interaction between age and question complexity: younger participants controlled their activity more often compared to older participants when they had to answer difficult and impossible questions. Thus, when faced with difficult and impossible questions, which led them to impasses, older participants experienced more difficulties in changing unsuccessful strategies for better ones compared to their younger counterparts. In contrast, older participants evaluated more thoroughly the relevance of the results provided by the search engine before making a decision about which link to open and visit, as revealed by the longer time spent on Google and fewer switches they made between Google and websites. Based on the work of Aula et al. (2005) and Aula et al. (2010), such behavior seems to be the hallmark of an exhaustive evaluation, which is observed more frequently in less advanced users and associated with fewer successful tasks. The reverse is true for an economic evaluation for which users scan at most half of the results displayed by the search engine before undertaking their first action. In the present study, older participants could have exhibited an exhaustive evaluation whereas younger users could have developed an economic evaluation. The economic strategy led younger participants to achieve higher performance compared to older participants. These findings may also be the consequences of the cognitive difficulties that older adults experience in controlling their search activity and in modifying their search strategies with an aim to select those that are more efficient, as shown by Mata and Nunes (2010). More precisely, these authors found that compared to young people, older people spent longer time searching for information (on matrix in their experiment) but used less information to make their choices. These results can be related to ours, since older participants spent longer time evaluating Google results before choosing a link to be opened up, and they evaluated information more often compared to younger participants. The top-down strategy (as defined by Chin et al. (2009)) with the exhaustive evaluation used by the older web users was associated with decreased performance when searching for information on the Web: fewer correct answers, fewer queries, fewer keywords, longer time to evaluate, longer time on Google (to evaluate results and not to reformulate queries, since older participants generated fewer queries compared to the younger participants), and less time to control their activity. In a more general way, the difficulties that older adults experienced may be related to general cognitive declines, as shown previously (e.g., Dommes et al., 2011; Pak & Price, 2008; etc.). These declines in fluid abilities are not always compensated by crystallized abilities (in this study, vocabulary abilities). Logistic regression results support this claim, since we have shown that decline in flexibility and planning had a negative influence on performance (correct answers provided) and that the higher vocabulary level of older adults did not allow overcoming the declines in fluid ability. These results support those obtained by Czaja, Sharit, Hernadez, Nair, and Loewenstein (2010), which have shown that older adults with higher reasoning abilities performed better compared to older adults with lower score.

7. Conclusion: implications and limitations

This study was designed to examine age-related differences in search performance and strategies as a function of search question complexity. The results obtained showed that older web users not only exhibited poorer performance, but also selected fewer efficient strategies compared to younger web users. These age-related differences may be explained, at least partially, by the difficulties that older people experience in planning and controlling their search activity, especially when dealing with difficult and impossible questions. Planning requires knowing various search strategies while controlling is a high demanding cognitive process. These difficulties are also related to age-related declines, or as in the present study, to cognitive flexibility, since participants with lower flexibility scores gave fewer correct answers. The observed higher level of vocabulary of older participants did not enable them to use Google more efficiently, since they formulated fewer queries and used fewer keywords compared to younger participants (see also Dommes et al., 2011).

While the present study provides new evidence-based results, several limitations need further investigation. The sample size was quite small, which may have challenged the statistical analyses (e.g., the logistic regression analysis), and it did not allow for the inclusion of covariates. Moreover, older adults were quite young (60–68 years). Therefore, our results need to be interpreted with caution when determining whether age is driving the observed declining performance in older web users or their cognitive abilities. In this study, we controlled the level of familiarity with the Internet (see Section 4.1) to compare older (less than 70 years old) and younger people. However, it would relevant to include older people (more than 70 years old). Indeed, given the increasing adoption of technologies by older people, future studies will be able to include more older people and consider several age groups within the older adults' cohort with similar or with various Internet experiences and skill levels. Further empirical studies should also be carried out to determine more precisely the role of planning, evaluating, and controlling processes in the information search activity in relations to age-related declines in cognitive abilities, especially executive functioning, since aging impairs executive functioning (see e.g., Salthouse, Atkinson, & Berish, 2003). Future studies should also address the role of prior domain knowledge in information search activity with regard to age. In the present study, we used questions related to general domain knowledge shared by everyone (e.g., what is the height of the "Tower of Pisa"?). However, prior studies reported that age-related differences in the amount of information searched diminished when familiarity with the task context increased (e.g., Johnson & Drungle, 2000). Therefore, it would be very interesting to address the relationship among age, planning-evaluating-controlling processes, and the level of knowledge in the information domain.

The results we obtained highlight the importance of designing training methods that would be better suited to the specific needs of older users and help them implement more efficient search strategies when navigating on the Web. For instance, it would be relevant to:

- Present various strategies to formulate queries and support them to plan in advance their search activity.
- Support older adults in evaluating in a more efficient way information in order to make better decisions and to open up more links provided by search engine.
- Train older adults to use their vocabulary abilities and use new question-related keywords.

In addition to developing training programs for older people, it is important to design search engine tools to reflect age-related differences. For instance, search engine tools could suggest relevant query-related keywords (in a semantic way) to help older adults infer new keywords and use their vocabulary abilities.

Older adults are one of the fastest growing groups of web users, so web designers must consider their specificities if they want that older people use the Web in an efficient way and profit from all range of services. Moreover, increasing the number of older users and supporting them in navigating the Web is a challenge, not only for the expansion of the Internet, but also for their well-being. Indeed, a recent study conducted over a six-year period has for example shown that older adults who use computers and the Internet had better attention and memory capacities (Slegers et al., 2014). Therefore, using the Internet could help reduce some age-related cognitive declines.

References

Alexa (2011, 2014). *Top 500 global sites*. <http://www.alexa.com/topsites> Retrieved 16.01.11 and 08.07.14.

Arguello, J. (2014). Predicting search task difficulty. In M. de Rijke, T. Kenter, A. de Vries, C. Zhai, F. de Jong, K. Radinsky, & K. Hofmann (Eds.), *Proceedings of the 36th european conference in information retrieval (ECIR'14)* (pp. 88–99). Amsterdam: Springer.

Aula, A. (2005). User study on older adults' use of Web and search engines. *Universal Access in the Information Society, 4*(1–2), 67–81.

Aula, A., Majaranta, P., & Räihä, K.-J. (2005). Eye-tracking reveals the personal styles for search result evaluation. In *Paper in proceedings of INTERACT 2005* (pp. 1058–1061).

Aula, A., Khan, R., & Guan, Z. (2010). How does search behavior change as search becomes more difficult? In *Paper in proceedings of CHI'2010* (pp. 25–44).

Barsky, E., & Bar-Ilan, J. (2012). The impact of task phrasing on the choice of search keywords and on the search process and success. *Journal of the American Society for Information Science and Technology, 63*(10), 1987–2005.

Campbell, D. J. (1988). Task complexity: A review and analysis. *Academy of Management Review, 13*(1), 40–52.

Chevalier, A., & Chevalier, N. (2009). Influence of proficiency level and constraints on viewpoint switching: A study in web design. *Applied Cognitive Psychology, 23*, 126–137.

Chevalier, A., Dommes, A., & Martins, D. (2013). The effects of ageing and website ergonomic quality on internet information searching. *Ageing & Society, 33*(6), 1009–1035.

Chevalier, A., Maury, A.-C., & Fouquereau, N. (2014). The influence of the search complexity and the familiarity with the website on the subjective appraisal of aesthetics, mental effort and usability satisfaction. *Behaviour & Information Technology, 33*(2), 116–131.

Chi, M. T. H., & Glaser, R. (1985). Problem solving ability. In R. J. Sternberg (Ed.), *Human abilities: An information processing approach* (pp. 227–250). New York: Freeman.

Chin, J., & Fu, W.-T. (2010). Interactive effects of age and interface differences on search strategies and performance. In *Paper in proceedings of the 28th ACM conference on human factors in computing systems CHI'10*. Atlanta, GA: ACM Press.

Chin, J., Fu, W.-T., & Kannampallil, T. (2009). Adaptive information search: Age-dependent interactions between cognitive profiles and strategies. In *Paper in proceedings of the 27th annual conference of ACM computer human interaciton (CHI) conference. Boston, MA.*

Crabb, M., & Hanson, V. L. (2014). The use of age, technology usage, and cognitive characteristics in relation to user perceived disorientation. In *Proceeding of 16th international ACM SIGACCESS conference on computers & accessibility* (pp. 193–200).

Czaja, S. J., Sharit, J., Hernadez, M. A., Nair, S., & Loewenstein, D. (2010). Variability among older adults in Internet health information seeking performance. *Gerontechnology, 9*(1), 46–55.

Czaja, S. J., Sharit, J., Ownby, R., Roth, D., & Nair, S. (2001). Examining age differences in performance in a complex information search and retrieval task. *Psychology and Aging, 16*, 564–579.

Deltour, J. J. 1998. Echelle de vocabulaire Mill Hill de J.-C. Raven, French Version. Paris: Editions et Applications Psychologiques.
Dinet, J., Chevalier, A., & Tricot, A. (2012). Information search activity: An overview. *European Review of Applied Psychology/Revue Européenne de Psychologie Appliquée, 62*(2), 49–62.
Dommes, A., Chevalier, A., & Lia, S. (2011). The role of cognitive flexibility and vocabulary abilities of younger and older users in searching for information on the Web. *Applied Cognitive Psychology, 25*, 717–726.
Dommes, A., Chevalier, A., & Rossetti, M. (2010). Searching for information on the Web with a search engine tool: A pilot study about the differences between young and older adults. *Psychological Reports, 106*(2), 1–9.
Ericsson, K. A., & Simon, H. A. (1993). *Protocol analysis: Verbal reports as data* (Revised ed.). Cambridge: MIT Press.
Eslinger, P. J., & Grattan, L. M. (1993). Frontal lobe and frontal-striatal substrates for different forms of human cognitive flexibility. *Neuropsychologia, 31*, 17–28.
Etcheverry, I., Baccino, T., Terrier, P., Marquié, J. C., & Mojahid, M. (2012). Age differences in information finding tasks: Performance and visual exploration strategy with different web page layouts. *Computers in Human Behavior, 28*, 1670–1680.
Gatto, S. L., & Tak, S. H. (2008). Computer, Internet, and E-mail use among older adults: Benefits and barriers. *Educational Gerontology, 34*(9), 800–811. 2008.
Hanson, V. L. (2010). Influencing technology adoption by older adults. *Interacting with Computers, 22*(6), 502–509.
Hardt, H., & Hollis-Sawyer, L. (2007). Older adults seeking healthcare information on the Internet. *Educational Gerontology, 33*(7), 561–572.
Johnson, M. M. S., & Drungle, S. C. (2000). Purchasing over-the-counter medications: The impact of age differences in information processing. *Experimental Aging Research, 26*, 245–261.
Klöckner, K., Wirschum, N., & Jameson, A. (2004). Depthand breadth-first processing of search result lists. In *Paper in Proceedings of CHI '04 extended abstracts* (pp. 1539–1539).
Kubeck, J. E., Miller-Albrecht, S. A., & Murphy, M. (1999). Finding information on the World Wide Web: Exploring older adults' exploration. *Educational Gerontology, 25*(2), 167–183.
Lorigo, L., Pan, B., Hembrooke, H., Joachims, T., Granka, L., & Gay, G. (2006). The influence of task and gender on search and evaluation behaviour using Google. *Information Processing and Management, 42*(4), 1123–1131.
Marchionini, G. (1989). Information-seeking strategies of novices using a full-text electronic encyclopedia. *Journal of the American Society for Information Science, 40*(1), 54–66.
Mata, R., & Nunes, L. (2010). When less is enough: Cognitive aging, information search, and decision quality in consumer choice. *Psychology and Aging, 25*, 289–298.
Matsuda, Y., Uwano, H., Ohira, M., & Matsumoto, K. (2009). An analysis of eye movements during browsing multiple search results pages. In J. A. Jacko (Ed.), *Proceedings of the 13th international conference on human-computer interaction, Part I: New trends* (pp. 121–130). San Diego, CA, Berlin, Heidelberg: Springer-Verlag.
Mellor, D., Firth, L., & Moore, K. (2008). Can the Internet improve the well-being of the elderly? *Aging International, 31*(1), 25–42.
Meyer, T., & Rodon, C. (2004). Trouver sur Internet une réponse à une question: auto-efficacité et illusion de compétence [Finding an answer to a question using the Web: Self-efficacy and illusion of competence]. In J. Perriault (Ed.), *HERMES–Cognition, communication, politique: Pour une critique de la raison numérique Cognition, communication, politics:acriticalapproachofthedigital mind]* (pp. 27–34). Paris: CNRS Editions.
Monchaux, S., Amadieu, F., Chevalier, A., & Mariné, C. (2015). Query strategies during information searching: Effects of prior domain knowledge and complexity of the information problems to be solved. *Information Processing and Management, 51*(5), 557–569.
Morrell, R. W. (2005). The process of construction and revision in the development of a model web site for use by older adults. *Universal Access in the Information Society, 4*(1), 24–38.
Pak, R., & Price, M. M. (2008). Designing an information search interface for younger and older adults. *Human Factors, 50*(4), 614–628.
Queen, T. L., Hess, T. M., Ennis, G. E., Dowd, K., & Grühn, D. (2012). Information search and decision making: Effects of age and complexity on strategy use. *Psychology and Aging, 27*(4), 817–824.
Rodon, C., & Meyer, T. (2012). Searching information on the Web and planning fallacy: A pilot investigation of pessimistic forecasts. *European Review of Applied Psychology/Revue Européenne de Psychologie Appliquée, 62*, 103–109.
Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review, 103*(3), 403–428.
Salthouse, T. A., Atkinson, T. M., & Berish, D. E. (2003). Executive functioning as a potential mediator of age-related cognitive decline in normal adults. *Journal of Experimental Psychology: General, 132*(4), 566–594.
Schwarzer, R., & Born, A. (1997). Optimistic self-beliefs: Assessment of general perceived self-efficacy in thirteen cultures. *World Psychology, 3*, 177–190.
Sharit, J., Hernandez, M. A., Czaja, S. J., & Pirolli, P. L. (2008). Investigating the roles of knowledge and cognitive abilities in older adult information seeking on the Web. *ACM Transactions on Computer-Human Interaction, 15*(1), 1–15.
Sihvonen, A., & Vakkari, P. (2004). Subject knowledge improves interactive query expansion assisted by a thesaurus. *Journal of Documentation, 60*(6), 673–690.
Slegers, K., van Boxtel, M. P. J., & Jolles, J. (2014). Computer use in older adults: Determinants and the relationship with cognitive change over a 6 year episode. *Computers in Human Behaviors, 28*, 1–10.
Spreen, O., & Strauss, E. (1991). *A compendium of neuropsychological tests: Administration, norms, and commentary*. New York: Oxford University Press.
Stronge, A. J., Rogers, W. A., & Fisk, A. D. (2006). Web-based information search and retrieval: Effects of strategy use and age on search success. *Human Factors, 48*(3), 434–446.
Sum, S., Mathews, R. M., Hughes, I., & Campbell, A. (2008). Internet use and loneliness in older adults. *CyberPsychology & Behavior, 11*(2), 208–211.
Tabatabai, D., & Shore, B. M. (2005). How experts and novices search the Web. *Library & Information Science Research, 27*, 222–248.
van Deursen, A. J. A. M. (2012). Internet skill-related problems in accessing online health information. *International Journal of Medical Informatics, 81*, 61–72.
van Deursen, A. J. A. M., & Van Dijk, J. A. G. M. (2009). Using the Internet: Skill related problems in users' online behavior. *Interacting with Computers, 21*, 393–402.
Wagner, N., Hassanein, K., & Head, M. (2014). The impact of age on website usability. *Computers in Human Behavior, 37*, 270–282.
White, R. W., & Drucker, S. M. (2007). Investigating behavioral variability in web search. In *Proceedings of the 16th international conference on World Wide Web* (pp. 21–30).