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Deliverable

## D6.3 Evaluation of Proactive Digital Entity Recommender including cost-benefit ratios



**COADAPT**

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## Notices

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## Table of Revisions

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v0.1	10.1.2022	first internal draft	Tung Vuong	1,2,3,4,5,6
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## List of Abbreviations

COADAPT - Adaptive and Conversational Agent Based Systems for Healthy Aging and Workability

D - Deliverable

T - Task

## Definitions

Ageing/older worker	employees aged 50 years or older as agreed in the CO-ADAPT consortium
Younger worker	employees aged below 50 years as agreed in the CO-ADAPT consortium

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# 1 Executive Summary

## Introduction

Intelligent assistants can serve many purposes, including work automation and information management. The role of these assistants is evolving to also support people engaged in work tasks, in workplaces and beyond. Aging workers suffer from low cognitive abilities (processing speed, attention span, working memory) while information for work often is fragmented across computer applications and increasing volume of information make it harder to access previously used resources. Thus, aging workers would benefit from an intelligent agent that supports work tasks in a computer environment. For instance, an assistant (entity recommender) proactively provides task-related information to support user work, such as rapidly locating, discovering useful information (applications, web pages, documents, email messages, contact information, and web search queries) for successfully completing tasks. The system monitors users' interaction with a computer, collects detailed records of users' digital activities and resources (applications and documents) accessed, automatically associates information that could be useful for a task, enables users to access information quickly without the user's explicit feedback, such as manually searching for information.

## Aim of the deliverable

This deliverable is a report of Task 6.3 "Study of Proactive digital entity recommender" that investigates the effects of entity recommendations on task performance, task satisfaction, and memory improvement among young and aging knowledge workers and shift workers. This deliverable presents the main results and evidence on age related differences in the effect of recommendation on everyday digital tasks (between young and aging workers) such as, aging workers find entity recommender more useful than younger workers.

## 2 digit percent improvements on measures

The measure for 2 digit percent improvement is Task Performance, here, the task was to prepare a presentation, so task performance was measured by the quality of presentation content. For that we computed the percentage of correct information and Web documents that were found and used for the content (e.g., the users were asked to find 10 Web documents that they found before). The improvement was achieved as indicated in the results that with the support of the entity recommender, up to 33% (for younger workers) and up to 45% (for older workers) additional correct Web documents were found than without recommendations.

## Results:

*Improved Task performance:* both younger and older adults found the entity recommender was useful, assisting them in performing the tasks.

Users in both age groups performed tasks better when they used the entity recommender, compared to when there was no recommendation available. However, no difference in task performance was found between the two age groups. Interestingly, older users used the entity recommender more, such as they visited/opened more recommended web documents, compared to younger adults. Statistical tests indicate age-related differences in the proportion of clicks to open recommended web documents, however, no age-related

differences in the use of other entities such as Web queries. The results suggest that older adults performed tasks equally well with the younger ones with the assistance of the entity recommender.

*Task Satisfaction:* The majority of the participants (85%) reported high satisfaction with the use of the recommender system. In the interview, participants noted a difference between the experimental conditions (with the recommender system visible) and preferred working with the support of the recommendations. However, some participants (15%) reported an increased effort due to the switch of attention required for the recommender system and the main task.

*Improved Memory:* Older adults could recall more information when using the recommender system. Older adults may hold more information in memory than they can recall: some information is available but not accessible. The recommender system prompted the older users to recall; reminding them of Web queries that were forgotten and relevant for the task.

We found that the younger adults had better memories than the older age group. Before performing the tasks, younger adults could recall more information. For example, in the results, we found that younger users used the recommender system less but still could recall the same amount of information as the older adults who viewed more recommended web pages. In addition, adding time constraints to the tasks negatively affects the ability of older adults to recall. Our results indicated the benefit of recommendation methods that allowed older adults to recall better. The amount of recalled information was associated with how often the older users used the recommended entities. Older users could recall more by using the entity recommender than without it. Perhaps, because the use of the recommended entities was associated with memory and knowledge but not with processing capacity, older adults used and benefited more from the recommended entities than younger adults.

### **Ethical evaluation**

This research poses important ethical issues both in conducting user studies and in developing technologies that can potentially be exploited against the user. Our study adhered to strict ethical standards and received ethical approval. However, we also see the opportunity raised by this work to support personal data management and related research to empower individuals by improving their right to self-determination regarding their personal data and providing tools to manage it.

### **Conclusion and relevance**

Our study for the evaluation of entity recommender, demonstrated the success of having entity recommendation as an intervention that aimed at supporting older users' every digital work. Our results demonstrated the benefit of recommendation methods that allow older adults to better perform digital work tasks while minimizing processing demands and search costs (e.g., by reducing the number of clicks and the need to remember hierarchical link structures). Results have important implications for design of recommendation systems that better fit the needs and limits of older users.

## 2 Introduction

Cognitive development (the process of which people explore information and learn to solve problems) has different trajectories across our lifespan [Devine & Maselli 2017]. Processing capacity consisting of processing speed, attention span, and working memory often declines while aging [Riddle 2007, Roda & Nabeth 2008]. This limitation imposes extra difficulties on aging users such as, in moving the mouse, tracking cursor, navigating between folders (or hyperlinks), remembering browsing and interaction history [Michael 2016]. These may be the reasons why aging users are often believed to be less efficient in searching for information, thus affecting users' workability and their wellbeing. This has been shown in the previous studies in that aging users tended to browse less information and spend more time extracting information, while giving up searching earlier than younger users [Jessie 2012]. In addition, early research works suggested that an increase in time pressure would lead to dramatically decreased working memory, negatively affecting task performance, and causing more anxiety in aging workers [Julie 2004].

Because of limited processing capacity, aging users would benefit more from a recommendation system that provides direct links to information (e.g., documents, applications, files, webpages, and other entities) than a hierarchical system where information could be accessed only under certain predefined routes determined by the layers of directories dictated by the designer [Pound et al. 2010]. It is possible that recommendations lower the search cost, for example, reducing the number of clicks between folders and links [Fisk 2004]. Aging users may be able to access relevant information more efficiently to meet their needs, which leads to improved workability [Jessie 2012].

In the COADAPT project, UH studied the effect of entity recommendation on the users' everyday digital work. In particular, our focus is on how older and younger users may use the recommendations differently, how these differences may influence user workability, learning, and how the differences may lead to age-sensitive system designs.



### **3 Objectives**

This deliverable is a report of Task 6.3 “Study of Proactive digital entity recommender” that investigates the usefulness and effectiveness of entity recommendations on the task performance and memory between young workers and older workers. The overall aim is to demonstrate that the entity recommender system is more useful for older workers, compared to the younger ones. This deliverable 6.3 utilizes output presented in D2.2 “Participatory design for Entity Recommender” and D3.1. “Implementation of Entity Recommender”. The results of the Task 6.3 will be disseminated through WP7 on dissemination, communication and exploitation.

## 4 Work done and main achievements

### 4.1 Ethics

The use of digital activity monitoring on personal computers to conduct research for T6.3 involves ethical concerns and we are aware of the privacy implications of the data as such. We have taken active steps to protect the participants. In particular, to safeguard participant privacy during the experiment, the participants' logged data were encrypted, stored locally on participants' laptops during monitoring, and never exposed to anyone except the participants. Upon completing the experiment, we only archived interaction logs during the lab study for evaluation, but we removed all personally identifiable information and any user-level metadata. We followed the ethical guidelines of the University of Helsinki and principles of data anonymization and minimization at every stage of the data processing. The logs were archived and stored in a server protected by authentication mechanisms and firewalls. This work received ethical approval from the University of Helsinki in Finland.

### 4.2 User Study

#### *Experimental Design*

A 2X2X2 mixed factor experimental design was conducted. One between-subject variable is Age (young/old) and two within-subject variables are Recommendation (visible/not visible) and Time pressure. For within-subject variables, we designed the study with the following four system configurations:

- Condition 1: Control condition with no time constraint and the recommender system running in the background but not visible for the user.
- Condition 2: Experimental condition with no time constraint and the recommender system visible for the user.
- Condition 3: Experimental condition with time constraint (5 minutes to complete a task) and the recommender system running in the background but not visible for the user.
- Condition 4: Experiment condition with time constraint (5 minutes to complete a task) and the recommender system visible for the user.

In four conditions, participants could use any application running on their laptops, as they would normally do, with the only differences being the availability of interactive recommendations and time pressure in the experimental condition. The input to the recommender system is the user's digital activities, such as applications are being used, documents are being opened, and the content that are being examined and produced on the computer screen.

#### *Participants*

Twenty participants were recruited. 10 younger users (2 shift workers) mean age = 20.7 and 10 older adults (3 shift workers) (50 years old and above; mean age = 58.5) were invited to this study. There were no main effects of gender on search behavior. All participants had higher education. All the younger adults had bachelor degrees. All older adults had at least a high school degree. All participants were highly

experienced in using computers and they used computers as a daily basis.

### ***Research questions***

We defined the following research questions to understand the usefulness of entity recommendation (differences between the experimental and control conditions) and whether older workers find entity recommender more useful compared to the younger ones:

- RQ1: Does the entity recommendation provide useful information beyond what the user can find without it?
- RQ2: Are the entity recommendations more useful for older workers compared to the younger workers?

### ***Entity recommender***

The recommender system is a system that continuously monitors a person's digital context, such as applications being used or documents being opened and proactively present information that may be useful without any explicit action required on the part of the user. It is similar to Apple Siri or Google Assistant which recommend entities (applications and documents) mostly based on the frequency of usage and routines. Contrary to these systems which extract file names, applications, and email addresses through operating system calls, entity recommender operates entity extraction in processing on all text available in a given active window. The practical implementation of the system consists of three main components. A digital activity monitoring module extracts entities across application boundaries. An online machine learning method learns about user interests in real time based on digital activity monitoring data. A user interface presents the list of recommended entities.

Figure 1 below illustrates the entity recommender system's user interface. It implements three specific features: 1) showing the entities being recommended by the system, 2) presenting information in a non-intrusive manner - showing entities at the bottom of the screen, and 3) allowing direct action on entities when relevant - quick access to entities by simply clicking on recommendations. In the Figure, the user is performing a writing task, while the entity recommender proactively suggests useful documents and other entities to support the task. The user can quickly access a document that is related to the current task, without having to look for it or navigate to it

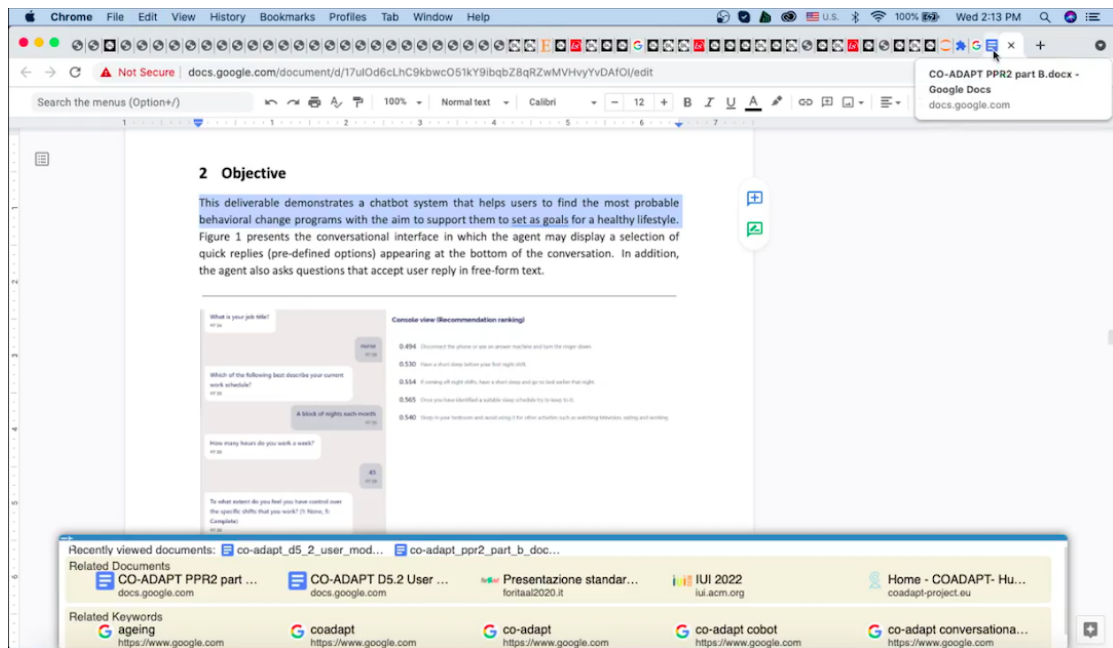


Figure 1. Entity Recommender.

## Procedure

There were two phases of the experimental procedure (ref. Figure 2). The first phase in which participants were assigned 4 essay tasks with different topics (health, history, culture, technology), followed by two-week digital activity monitoring in which digital activity monitoring software was installed on the participants' laptops to continuously collect digital activity logs which were encrypted and stored. The second phase was a lab study in which participants came back to our lab to evaluate the recommender system. The lab study included system setup, a training task, four tasks assigned under four conditions in random order (a Control condition where no time pressure and recommendations are not visible; an Experimental condition where there was no time pressure and recommendations are visible; an Experimental condition with time pressure and recommendations are not visible; and an Experimental condition with time pressure and recommendations are visible). Participants were asked to prepare presentations for the topic of each task, interviews were conducted to collect direct comments and impressions from participants following task performance, and lastly relevance assessment on the recommended entities.

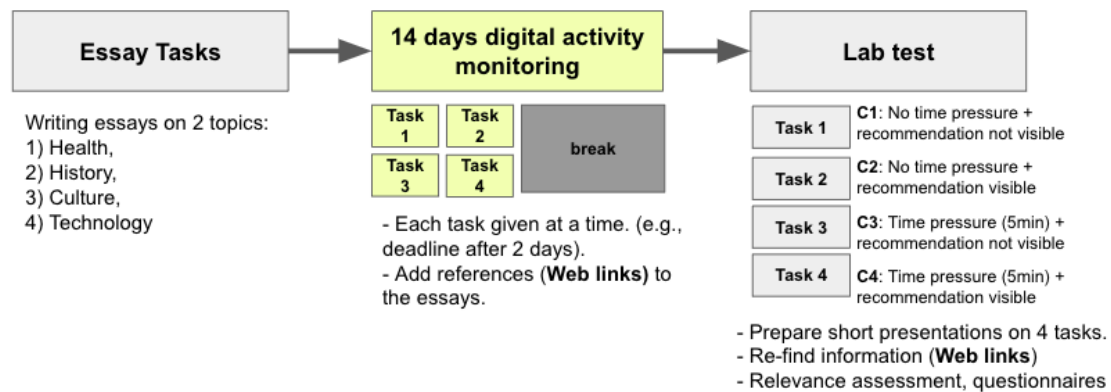


Figure 2. Procedure of the experiment

### Tasks

Here is an example of a writing task:

*More than 80% of adults have low back pain at some time in their life. While back pain is usually acute (short-term), back pain can often be chronic. For those with chronic back pain, this might be caused by other physical problems.*

- Find out the connections between back pain and other bone diseases, such as osteoporosis, arthritis, osteoarthritis, etc.
- Find out the connections between back pain and health problems except bone diseases.
- Provide some methods to relieve back pain.

*Answer the questions and find 10 reference links to support your answer.*

For preparing a short presentation task, participants were asked to:

*Prepare the content for presentation and find again reference links (Web documents) that were used before in the essay. If that was not possible, find new references.*

### Measures

**Utilization of recommendations** was measured as the number of correct entities (reference web documents/links and web queries) that were clicked on the user interface and used for the presentation. Only unique entities were counted. The rationale was that in order for the system to assist the user in performing the task more effectively, the system should recommend entities that are actually used by the user in the task.

**Task performance** was measured as the number of references (web documents/links) that the users successfully re-find or recall (either recall by the users themselves or by opening the recommended Web documents). The rationale was that in order for the system to assist the user in performing the task more effectively, the recommendations should help the users to recall correct information.

**Subjective user experience** with the entity recommender was investigated by using a semi-structured interview (open-ended questions). The interview explored aspects related to the participants' impression that the system had influenced the task,

including the quality of the experience of use, and the overall experience of relevance of the entities displayed.

### **Significance test procedure**

We applied two-way ANOVA to determine whether there are significant differences in performance between Experimental and Control conditions, and between the age groups. To test the significance levels, we used the number of clicks on entities and number of reference Web documents that the participants successfully found again as dependent variables; conditions and age groups as independent variables. Tukey post-hoc tests were also conducted for pairwise comparisons.

### **Results: Age difference in search behavior**

Table 1 presents the results for search behavior and corresponding performance in two conditions (an Experimental condition with time pressure and recommendations are not visible and the Control condition). The results indicate that with time pressure there was significant difference in search behavior measured by the number of successfully recalled Web queries between the age groups. This suggests that adding time pressure to the task may lead to reductions in working memory capacity for aging workers. In the interview, 6 users in the older group also reported that it was difficult (when the recommender system was not visible) to recall the same Web queries that they used before (during the monitoring phase). However, there was no significant difference in task performance measured by the number of successfully recalled reference Web documents between the age groups and between the conditions. This suggests both young and older users performed tasks equally well with or without time pressure. This also suggests that younger users in the time pressure condition queried at a significantly higher rate, compared to the older users.

*Table 1. Search behavior (when the entity recommender is not visible) measured by number of Web queries and corresponding task performance measure by the reference Web documents that were successfully recalled between the age groups*

	50+ group	<50 group	p
<b>No Time Pressure (Control condition)</b>			
Number of successful recalled reference Web documents used before	2.38	1.83	0.2
Number of successful recalled reference Web queries used before	1.5	1.33	0.6
<b>Time Pressure</b>			
Number of successful recalled reference Web documents used before	1.5	1.17	0.6
Number of successful recalled reference Web queries used before	<b>1</b>	<b>2.5</b>	<b>0.005</b>

**Results: Cost-benefit ratios**

Answer **RQ1**: Figure 3 and 4 illustrate the recall of relevant web documents in the Control and the Experimental conditions during the lab study. With recommendation visible and there was no time pressure, for the aging group (50+), on average, the participants were able to find 4.25 (4 to 5 Web documents), while an average of 2.3 Web documents (2 to 3) were found by the participants themselves without the recommendation visible. Similarly, when there was time pressure and recommendations were visible, on average, older participants were able to find 2.88 (3 Web documents), while only 1.62 Web documents (1 to 2) were found by the participants themselves without the recommendation visible. A significant difference was found in the number of Web documents successfully re-found between the Experimental conditions (with/without time pressure) and the Control condition for this age group ( $p=0.02$ ). This indicates that the system was able to help the older workers to find more reference Web documents compared to when recommendation was not visible (up to 45% more reference Web documents were successfully recalled by the users with the support of the entity recommender).

A similar finding can also be seen for the younger group (<50). The younger users were able to find more reference Web documents that they used for the essays using the support of the entity recommender in time pressure condition and also in no time pressure condition. Younger users managed to find 3 to 4 reference Web documents that they used before in Experimental conditions with/without time constraint, while an average of 1 reference Web document was re-found successfully in Control condition. The difference between Experimental and Control conditions for the younger group was also significant ( $p=0.02$ ). Up to 33% additional reference Web documents were successfully found by younger users when the recommender was visible. Overall, the results indicate that the entity recommendation provided useful information beyond what the user can find without it.

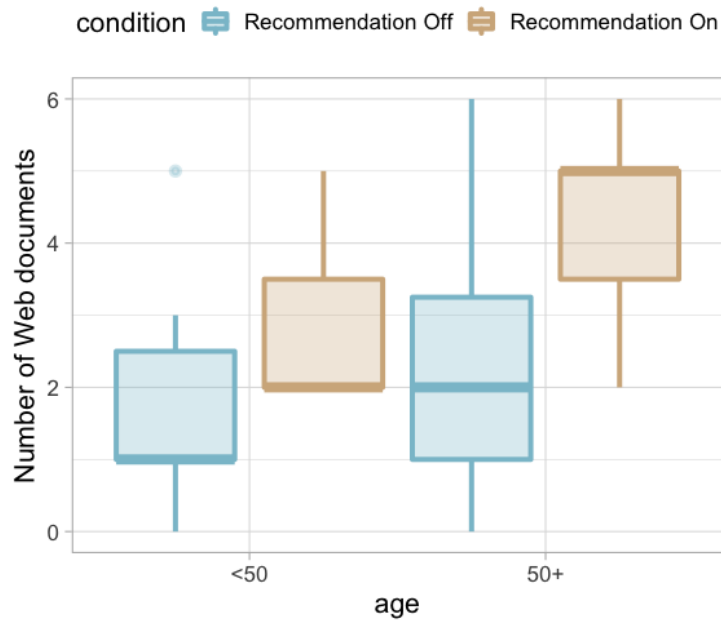


Figure 3. Results for Task performance in which there was No Time Pressure. Number of References (Web documents) that the users successfully recalled in 2 conditions (with and without entity recommendation)

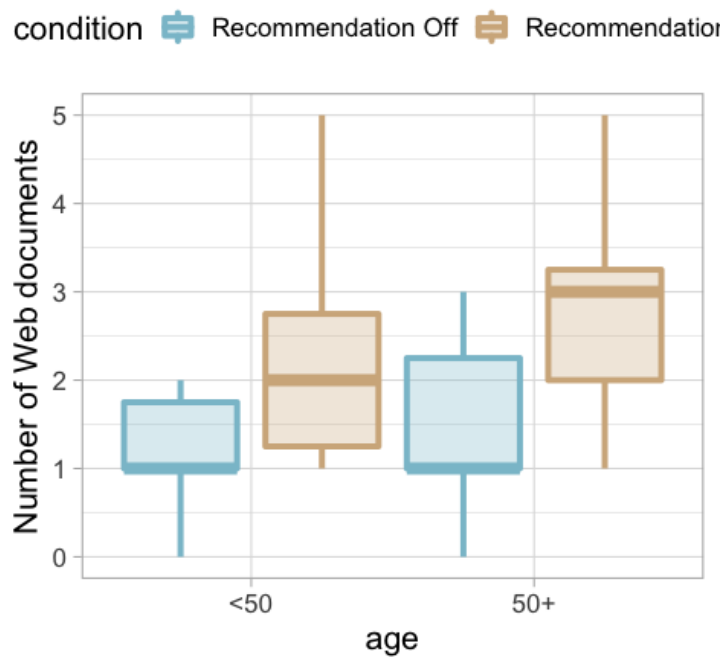


Figure 4. Results for Task performance in which there was Time Pressure. Number of References (Web documents) that the users successfully recalled in 2 conditions (with and without entity recommendation)



Subjective user experience with the entity recommender indicates high satisfaction from the participants. Overall, the users in both age groups reported a positive experience with the system (N=17): *“I enjoyed it... I was surprised that it recommended things that I just intended for”* (P01).

All participants found the entities recommended by the system relevant:

*“They were right on the spot”* (P04).

*“They were surprisingly relevant, with various kinds of applications and various kinds of materials... I had for example this task manager, various files... they were really relevant for the subject... so it was quite good in that sense”* (P07).

*“They were mostly very good. I think there were maybe a couple of them... they weren’t relevant, but mostly it had picked up the right side”* (P03).

However, some participants (N=3) specified that it took a while for them to get relevant results:

*“At first they didn't have much to do with what I was doing... but after that I felt, like, relevance got a lot higher over time, so in the end, they were pretty good”* (P11).

While many participants did not notice issues with using the recommender system, some participants (N=3) in both age groups reported some minimal effort due to the switch of attention between the task and looking at the recommendations:

*“I switched my attention sometime to the tool where I saw the various suggestions... it could be even not so good if I had all time switched attention.”* (P03)

Answer to **RQ2**:

Table 2 provides a quantitative indication of how the information provided by the entity recommender was used for the user tasks with/without time constraint. More specifically, when there was no time pressure, the number of recommended Web documents that older participants used in their task (only after they were recommended) was significantly higher than the number of Web documents used by younger participants ( $p=0.02$ ). Older participants used (clicked on) 2.62 Web documents while younger participants clicked only on 1 Web document. Surprisingly, there was no significant difference in the task performance between the age groups. Older participants performed tasks equally well as younger participants. This result indicates that the recommended entities were used more by older participants in the task because participants saw them useful while younger participants managed to re-find reference Web documents by themselves (using Web queries) with less use of the entity recommender. No significant differences were found in task performance and search behavior between the age groups in Experimental conditions with time pressure.

Table 2. Use of recommended entities (when the entity recommender is visible) and corresponding task performance measured by number of reference Web documents and Web queries that were successfully recalled between the age groups with/without time pressure

	50+ group	<50 group	p
<b>No Time Pressure</b>			
<b>Use of Recommended Entities</b>			
Number of Opened Reference Web documents (by clicking on the recommended documents)	2.62	1	0.02
Number of Used Web Queries (by clicking on the recommended Web queries)	2.38	1.83	0.3
<b>Task Performance</b>			
Number of successful recalled reference Web documents used before	4.25	2.98	0.1
<b>Search behavior</b>			
Number of successful recalled reference Web queries used before	2.88	3	0.9
<b>Time Pressure</b>			
<b>Use of Recommended Entities</b>			
Number of Opened Reference Web documents (by clicking on the recommended documents)	1.62	1.17	0.3
Number of Used Web Queries (by clicking on the recommended Web queries)	1.88	2	0.6
<b>Task Performance</b>			
Number of successful recalled reference Web documents used before	2.88	2.33	0.7
<b>Search behavior</b>			
Number of successful recalled reference Web queries used before	2.12	3.33	0.4

Furthermore, Figure 4 shows the task performance (when there was no time pressure) of participants in both age groups (measured as the number of Web documents that the participants managed to re-find). The older participants in Experimental condition and Control start from roughly the same level of task performance with the younger participants. Performance was low at the beginning, but, after six minutes the older participants in the Control and Experimental conditions performed better with higher task performance. The reason was because

the older participants were a bit slower than younger participants and they did not manage to re-find as many documents for the task at first, compared to the younger participants. After ten minutes, the task performance of older participants consistently improved and was higher than task performance of younger participants over time. With the recommender system, the older participants managed to re-find more reference Web documents already within three minutes. The results indicate that a majority of reference Web documents can be re-found within three minute after the older participants start to interact with the computer. On another hand, younger participants were very fast at first, achieving high task performance within five minutes from the beginning, but the performance was not improved further after that.

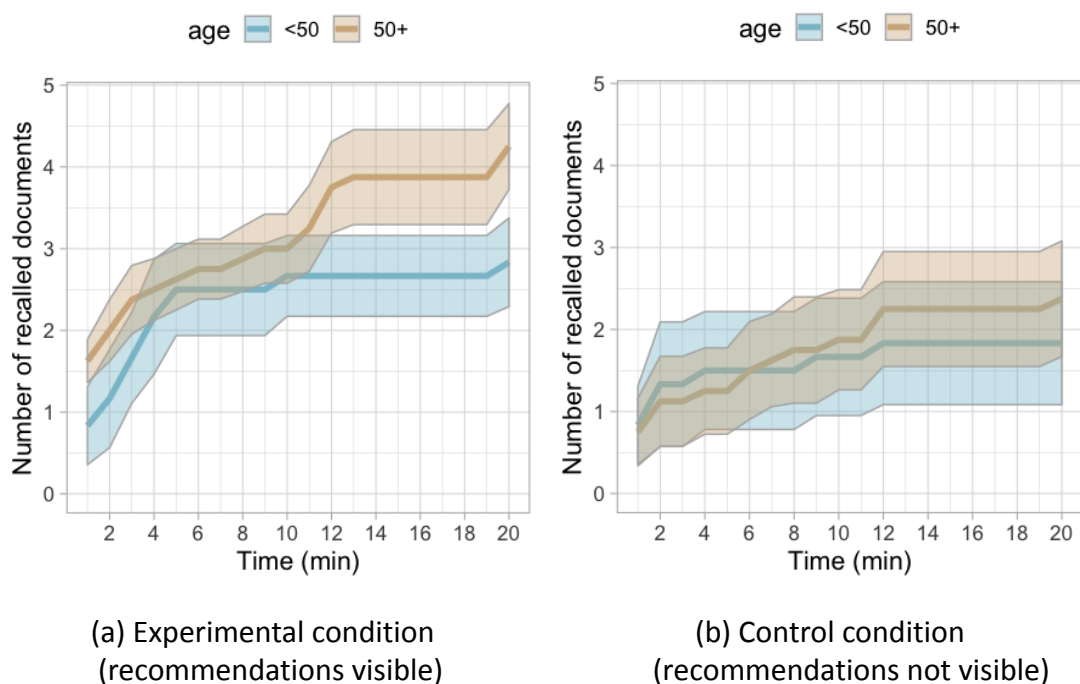


Figure 4. Results for Information Recall when there was no time pressure. Number of reference Web documents that were successfully recalled over time

### 4.3 Publication

Part of the results of this work has been published in ACM Transactions on Computer Human Interaction (TOCHI) [Giulio et al. 2021].

## 5 Summary and conclusions

This deliverable shows the usefulness of the entity recommender in the user's digital tasks including the recommendations resulted in 33-45% improved task performance for both young and older workers. The between-subject study investigating the age-group differences showed that the older workers found entity recommendations more useful than the younger ones. Although older participants used the recommendations more than younger participants, there are no significant differences in task performance between the age groups.

The overall aim of the task and this deliverable was to demonstrate the support of the entity recommender for aging workers. We concluded that based on the research and the results of this study conducted as part of CO-ADAPT project, the entity recommender can positively affect users working in their everyday digital tasks. The entity recommendation approach in particular, as implemented in the system, had several benefits including effective access to entities (web documents, applications, web queries). An advantage of automatically predicting and presenting users with potentially useful information in advance is that when users decide to search for it, the information might be readily available without users needing to formulate queries. This was often observed in our study. Because people typically need to retrieve information in support of a primary task, they prefer to do it in the most automatic ways that take less attention away from their primary tasks. While searching or managing information in hierarchy structures (folders, web links) requires effort, novel approaches should support users in concentrating on creative tasks while automating the rest. With our approach, recommendations were automatically computed in the background without requiring users to formulate queries, thus requiring less mental effort for aging workers. Additionally, our entity recommendation approach provided visual cues that iteratively guided users toward the desired information by following familiar elements, similar to the events in web/folder navigation scenarios. Our future work is to look into the limitations of recommender systems for search and recommendation. For instance, recommendations do not always arrive in the same order, making them less consistent than navigating through well-known structures.

## 6 Deviations

Number of participants was planned to be 30, but the results and data were collected only from 20 individuals, also delayed in delivering the report. A reason for this deviation is that the study was conducted with in-person meeting with participants in the lab and covid situation with a new variant of the virus made it harder to recruit participants. In order for completion of the deliverable quicker with no further delays, we concluded the results with less number of participants. However, there is no impact on the results and it didn't affect the achievement of the overall objective of the study.

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