How to support search activity of users without prior domain knowledge when they are solving learning tasks?

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Abstract
This study focused on the impact of prior domain knowledge on the resolution of search tasks. More precisely, the study looked at the effect of procedural and semantic support on search strategies and performances during information search activity comparing different levels of learning tasks. Eighteen students with prior domain knowledge, fourteen unguided students without prior domain knowledge and fifteen guided students without prior domain knowledge had to solve six learning tasks (two "remember" tasks, two "understand" tasks, two "evaluate" tasks) related to psychology. Main results showed that procedural and semantic support improved the navigation of users without prior domain knowledge (i.e. fewer links opened from SERP, less time spent on URL and globally less time to find information, longer queries) and they got close to users having higher prior domain knowledge.

Keywords
Search strategies and performances, learning tasks, prior domain knowledge, support, searching as learning

1. Introduction

Information systems are no longer seen simply as a tool for retrieving content to meet a specific information need but as a tool for acquiring new knowledge in the course of searching, i.e. searching as learning [1]. According to [2], Searching as Learning aims to determine the relationships between the information search activity (e.g., formulation of queries, search strategies, etc.) and learning activities (e.g., reading, note-taking, organizing information collected, etc.). The tasks in SAL can have different levels of learning goals, ranging from simple fact-finding task (i.e remember) to the production of a new set of information (i.e create), [3, 4]. According to [5], search tasks in general can be modulated by other factors, such as prior knowledge related to the search domain, knowledge of the tasks procedures and knowledge in information search. This knowledge have been widely studied, but not in the context of Searching as Learning. Therefore, this study aimed to understand how these types of knowledge could support search activity when users dealt with search tasks of different levels of learning. In particular, we want to know whether users who have no or little knowledge in a domain could get closer to users with a higher level of prior domain knowledge if we provided them with procedural (i.e. regarding the procedure for optimal task solving) and semantic (i.e. regarding the specific vocabulary used in a domain) support. More precisely, when they are solving learning tasks at different levels. In this paper, we present related work on information search, prior domain knowledge and learning search tasks. We review the methodology used to test our hypotheses and then describe our results.

2. Related Work

In the cognitive model of information search, [6] describe the role of cognitive abilities (e.g., verbal and vocabulary abilities, selective attention, etc.) on the three stages of this cyclical activity: (1) during planning and formulating the query stage, (2) the stage of evaluating and selecting the information provided by the search engine, and (3) the stage of deep processing of the information contained in the web pages. Among these abilities, verbal and vocabulary abilities are important on all stages. These ones are directly related to the prior domain knowledge [7]. Users with domain-specific vocabulary knowledge generally construct a more consistent mental representation of the task than users with lower prior domain knowledge, making it easier for them to assess the relevance of the SERP and to select more relevant sources [8]. Specifically, users with a high level of prior domain knowledge are able to focus their attention on relevant elements and inhibit others [9]. With regard to query (re)formulation

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strategies, those of users having higher prior domain knowledge are often longer (i.e., composed of more words) [10] and these users are faster and perform better [6]. Beyond prior domain knowledge related to vocabulary, other type of knowledge that can impact information search activity is procedural knowledge related to the task [11]. If a task is well known and routine, the resolution procedure is easy to perform; users have less difficulty understanding the structure of the task [12]. According to [13], the interaction of these two types of knowledge (i.e., domain and procedure) supports search activity when users are solving search tasks. In this study, we focus on the resolution of learning tasks at different levels. The first level is "Remember" [3]. It is a simple fact-finding task where the learning objective is unique. The key words provided in the statement are clear, consistent, well-defined, and achievement of the learning objective does not require high cognitive effort [14]. For this tasks, a plateau effect appeared between experts and novices on search performance [7]. The second level is "Understand" [3]. This is a task that will require the understanding and clarification of certain terms in order to access the answer. The statement here is poorly defined because the terms used are not clear but also because they are linked to specific high vocabulary. The production of new search terms is requisite [14]. These tasks can be solved by following a specific procedure (e.g. understanding the definition and terminology of the proposed terms so that inferences can be made to more relevant terms, understanding each search criteria and finding an answer that satisfies them). If users know this procedure, they could solve the task easier and obtain higher performance. For this task, users with a high level of prior domain knowledge formulated more queries than users without prior domain knowledge [7] and had less difficulty adding new search terms [8]. The third level used is "Evaluate" [3]. It requires a comparison of elements as proposed by [15]. These tasks involve text production but vary in structure: "parallel task" and "dependent task". For the parallel task, the elements to be compared are clearly defined and the specific vocabulary to be used to learn new information is provided in the task statement. Semantic support is therefore high. For the dependent task, the elements to be compared are not given in statement and have to be inferred by users during their search. The dependent task requires a higher level of prior knowledge than the parallel task since the semantic support(i.e. specific vocabulary level related to the elements to be compared) is lower in the statement; users have to define and to infer them. These differences are important because in the case of the parallel task, users are supported in their search activity. Based to [3], parallel and dependent tasks have been called "Evaluate" in the present study because the main objective of these tasks is to compare a set of elements. Parallel task corresponds to guided evaluate task and dependent task to unguided evaluate task. In this way,the current study aimed to understand how semantic and procedural support can help users without prior domain knowledge to solve learning tasks compared to users with prior domain knowledge. Specifically, the present study's objective is to determine the effect of knowledge of a resolution procedure ("understand" task) and a specific vocabulary ("evaluate" task) on search activity, with respect to the level of prior domain knowledge (with vs without in psychology).

3. Method

3.1. Hypotheses

- **Hypothesis 1:** Guided users without domain knowledge should spend less time to solve tasks and to have better scores (correct answers) than unguided users without domain knowledge so that the first ones should be close to users with high level of domain knowledge.
- **Hypothesis 2:** Guided users without domain knowledge should formulate more and longer queries than unguided users without domain knowledge so that the first ones should be close to users with high level of domain knowledge.
- **Hypothesis 3:** Guided users without domain knowledge should open fewer links from SERPs and spend less time to explore webpages than unguided users without domain knowledge so that the first ones should be close to users with high level of domain knowledge.

3.2. Independent Variables

- **IV1:** Level of prior domain knowledge as between-subject factor (high/without)
- **IV2:** Level of support as between-subject factor (guided/ unguided) – only for users without prior domain knowledge
- **IV3:** Level of learning task as a within-subject factor (Remember/Understand/Evaluate)

3.3. Dependent Variables

- **DV1: Total time (in sec.) of search session.** For each task (included total time spent on SERP and total time spent on webpages).
- **DV2: Total score in percent.** For remember and understand tasks, when one answer was correct and possible, scores are "1" (correct) and "0" (wrong). For evaluate tasks, which were open-ended tasks (several answers were acceptable but

specific elements had to be found), 1 point was assigned for each expected element contained in the answer with a score varying from 0 to 9 by task.

- **DV3: Queries (number and length).** For each search task, the total number of queries submitted to the search engine per search session was computed. The mean length of queries per search corresponds to the total sum of keywords number used during a search session divided by the number of total queries submitted to the system during this search session.
- **DV4: Number of links opened up from SERP.** For each search task, total number of selected and opened links by users from the search results pages.
- **DV5: Total spent time (in sec.) on webpages.** For each task during the search session.

3.4. Participants

Eighteen users with high level of domain knowledge aged from 22 to 30 years old (M = 24.6 SD = 2.20), fifteen guided users without domain knowledge aged from 22 to 28 years old (M = 24 SD = 1.77) and fourteen unguided users without domain knowledge aged from 22 to 27 years old (M = 24.1 SD = 1.44) took part in the experiment. All of them were French native speakers. The sample was composed of 12 males and 35 females, all in master degree (16 females with psychology knowledge, 8 guided and 11 unguided females without psychology knowledge). Concerning the self-assessment scale of psychology knowledge (4-p Likert scale), scores were significantly different ($t(45) = 7.69$, $p > .001$) between users with domain knowledge (M = 3.39 SD = 0.5) and users without (M = 1.86 SD = 0.74). In addition, the scores obtained through the multiple-choice test in Psychology domain were significant ($t(45) = 7.71$, $p < .001$). Users with domain knowledge had better scores (M = 8.94 SD = 2.46) than users without (M = 3.34 SD = 2.39).

3.5. Material

All participants used a Dell Latitude 5590 (17 inch) with Windows 10 Pro, Intel Core i7 8th Gen processor and external mouse. To record data, we used an ad-hoc software, which recorded time, clicks, visited SERPs and documents. To test our hypotheses, we created six search tasks in guided and unguided version, all related to psychology:

Remember task: What was the name of Chomsky, the author of generative theory?

Understand task - unguided: As part of his researches, Lionel conducts observations in various circumstances that he extrapolates to make previsions. In your view, what is the research method used by Lionel?

Understand task - guided: As part of [...] by Lionel? To solve this task, you have to produce new keywords and it is necessary that research method integrates the set of given criteria.

Evaluate task - unguided: You have an interest about social psychology domain and you want to write an article about social perceptions, in particular on ones which contribute to discrimination. To do that, you have to know what are the elements included in social perceptions, how they work, how they build themselves, what the sub-processes are and how they influence the discrimination. Specifically, you have to carry out these following activities: 1) to retrieve information about social perception elements, which contribute to discrimination. 2) To select three elements on which you are going to concentrate in this article. You want to present their specific characteristics which encourage you to select them among others elements. 3) To compare their functioning at the level of sub-processes.

Evaluate task - guided: You have [...] discrimination. You want to focus on three elements about social perception, which allow explaining the functioning of discrimination. These three elements are: 1) social categorization, 2) Stereotypes, 3) Prejudices. You wish to describe the set of these three elements, particularly: to present their functioning, how they build themselves, the sub-processes and how they influence discrimination. You have to integrate in the article the completeness of three descriptions, which correspond to the set of analysis criteria.

Understand and evaluate tasks test the support variable. In the unguided version, participants saw only the task statement. In the guided condition, the procedural support (Understand) took the form of an additional instruction that informed the participant about the procedure to follow to succeed in the task. The semantic support (Evaluate) informed participants on the items to compare. For evaluate task non-guided, the items on which to perform evaluation and comparison work were not indicated in the statement. For the remember tasks, no support was provided because these were control tasks where the literature does not show any significant difference in their resolution.

3.6. Procedure

The study took place at the University of Toulouse. Before starting search sessions, participants had to complete four online questionnaires: demographic information; habits with internet, self-efficacy scale in information search (10 items), MCQ of psychology knowledge (16 questions). Once the pre-questionnaires were completed, the main instructions were presented and participants started to perform the six search tasks in randomized order. Participants had to provide a written response. Users with domain knowledge and a part of users without domain knowledge saw the unguided tasks and the other part of users without domain knowledge performed the tasks in their guided version.

4. Results

For all the dependent variables, we carried out ANOVA (repeated measures) on two independent variables and contrasts to identify if the support helps non-experts. We mixed the "level of prior domain knowledge" (IV1) and the "support" (IV2) to obtain the independent variable "Group" with three modalities (with domain knowledge unguided, without domain knowledge guided and unguided).The independent variable "level of learning task" stayed the same.

Regarding the total time on search session, statistical analyzes did not reveal any significant effect of support ($F(2, 44) = 1.10$, $p > .05$). Nevertheless, contrasts indicated that users with domain knowledge ($M = 340$ $SD = 60.16$) need less time to solve tasks than unguided users without domain knowledge ($M = 464.58$ $SD = 68.42$) with $F(3, 42) = 9995106$, $p < .001$. No significant difference was obtained between users with knowledge and guided users without ($p > .05$) nor between the two groups of users without knowledge ($p > .05$). This part of hypothesis 1 was only partially verified.

Concerning the scores of correct answers, ANOVA did not show any significant effect of the support with $F(2, 44) = 2.76$, $p > .05$. Contrasts indicated that users with knowledge ($M = 0.53$ $SD = 0.02$) have better scores than guided users without ($M = 0.49$ $SD = 0.03$) with $F(2, 43) = 487.71$, $p < .001$.No significant differences were observed between users with knowledge and unguided users without, nor between the two groups of users without knowledge ($p > .05$). The second part of hypothesis 1 was not confirmed.

Concerning the effect of support, the ANOVA did not show any significant difference on the total number of queries ($F(2, 44) = 0.62$, $p > .05$). Contrasts showed that users with knowledge ($M = 7.12$ $SD = 1.05$) produce fewer queries than unguided users without ($M = 7.83$ $SD = 1.20$) with $F(2, 43) = 5657.23$, $p < .001$. No significant differences were obtained between users with knowledge guided users without ($p > .05$), nor between the two groups of users without knowledge ($p > .05$). The first part of H2 was not validated.

The ANOVA did not reveal a significant effect of the support on queries length ($F(2, 44) = 1.78$, $p > .05$). Contrast indicated that users with knowledge ($M = 4.09$ $SD = 0.35$) produced longer queries than unguided users without ($M = 3.75$ $SD = 0.38$) with $F(2, 43) = 6031.29$, $p < .001$. No significant differences were obtained between users with knowledge and guided users without, nor between the two groups of users without knowledge ($p > .05$). The second part of H2 was not completely verified.

No significant effect of support appeared for links opened up from SERPs ($F(2, 44) = 0.45$, $p > .05$).Contrasts indicated a significant difference between users with knowledge ($M = 8.85$ $SD = 1.49$) and unguided users without ($M = 10.76$ $SD = 1.7$), with $F(2, 43) = 19232.32$, $p < .001$. Users with knowledge opened fewer links from SERPs. A significant difference appeared between guided ($M = 9.96$ $SD = 1.64$) and unguided users without knowledge ($F(2, 43) = 1543.31$, $p < .001$). Guided opened fewer links from SERPs. No significant differences were obtained between users with knowledge and guided users without ($p > .05$). This part of hypothesis 3 was validated.

Regarding the total time spent on web pages, ANOVA did not show any significant effect of support ($F(2, 44) = 1.20$, $p > .05$). Contrasts indicated that users with knowledge ($M = 316$ $SD = 58.47$) spent less time on web pages than unguided without ($M = 441.72$ $SD = 66.26$) with $F(3, 42) = 11520492$, $p < .001$. Guided users without ($M = 347.64$ $SD = 64.02$) spent less time than unguided without ($F(3, 42) = 585671.6$, $p < .001$). No significant difference between users with knowledge and guided without appeared.The second part of hypothesis 3 was confirmed.

5. Conclusion

Users with knowledge and guided users without opened up fewer links and spent less time on web pages than unguided users without knowledge. These results suggest that support used was able to allow users without knowledge who benefited from it to focus more on the relevant information contained in the SERPs and web pages. Users with knowledge scored better than guided users without. This result may in part raise questions about the relevance of the support used. First, for the understand task, procedural support had to help users when they were formulating queries. However, although this instruction was handled by the participants, guided users may have experienced difficulties completing this activity and understanding the information from the web content. As for the semantic support for the evaluate tasks, it made the task more closed than the non-guided version. Guided users had to compare specific items, while the other two groups had more freedom in the items to be selected. To further understand the correct answer scores, qualitative analysis of the answers would be interesting in order to determine if the semantic level of the final productions (level of specificity of the terms used) as well as their structure (copy/paste, paraphrase, reformulation...) are different between users with knowledge and users without. With regard to the length of queries and the total search time for users having prior domain knowledge, they produced longer queries and needed less time to complete the search than the unguided without knowledge. While the guided users were close to users with a high level of knowledge, their performance was not sufficient to outperform the unguided users without knowledge in terms of correct answers. For the queries, further analyses are currently in progress in collaboration with natural language processing researchers. The objective is to evaluate the specificity of the terms used in queries in order to know if the support has had an impact on this variable. Regarding the total number of queries generated, users with knowledge generated fewer queries than unguided users without knowledge. One possible explanation was that unguided users without knowledge had to search for more information, such as definitions of specific terms provided in task statement for example. While the users with prior domain knowledge were familiar with the specific psychological terms provided in the task statement, they started their search directly. This hypothesis would be interesting to test in future studies on Searching as Learning. Indeed, a search engine should be able to adapt to different user backgrounds. Users with prior domain knowledge and users without cannot follow the same search and learning sub-objectives. The first ones can start their search at a higher learning level than the others who might need to access certain definitions and terminology to elaborate a mental representation of the task closer to ones of users having a high prior domain knowledge.

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