



The Future of Learning by Searching the Web: Mobile, Social, and Multimodal

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Abstracts

Recent technological developments related to the World Wide Web including mobile computing, social media, and online videos are shaping the way we learn. As argued in the present commentary, the majority of educational psychological research that has examined how individuals learn by searching the Web, however, has not kept up with this pace. Therefore, the goal of this commentary is to discuss how recent technological developments might affect how learners acquire knowledge through Web search and to provide a respective research agenda. Specifically, we will focus on the use of mobile devices and digital assistants, social networking sites, and online videos, and the opportunities and challenges they present to learners. In addition, we suggest that future research should study the ongoing learning processes during Web search in greater detail. We believe that examining the research questions raised in the present commentary will uniquely contribute to the literature on Web-based searching and learning.

Keywords: Internet; World Wide Web; Web search; learning; new technologies



Introduction

Providing vast amounts of information in various representation formats (e.g., text, pictures, video, audio), the World Wide Web, or shortly the Web, has become a major medium for learning both in formal and informal learning settings. With learning we mean the process of building and refining knowledge structures. Basically, people can learn anything on the Web – and they indeed do so. They search the Web to complete school or university assignments about course-related issues (e.g., Purcell, Heaps, Buchanan, & Friedrichs, 2013) or to inform themselves about socio-scientific issues such as climate change (e.g., Horrigan, 2006), political debates (e.g., Epstein & Robertson, 2015), or health and nutrition issues (e.g., Amante, Hogan, Pagoto, English, & Lapane, 2015), and also to learn procedural skills (e.g., Eickhoff, Teevan, White, & Dumais, 2014).

Individuals no longer do this only at home at their desktop PCs or laptops, but anywhere and anytime (e.g., while travelling) by using mobile devices like smartphones and tablets with ubiquitous Internet access (e.g., Ito, 2009). Moreover, AI (artificial intelligence)-powered digital assistants such as Apple's Siri, Amazon's Alexa, or the Google Assistant even allow to search via voice search and to receive spoken responses. In addition to the use of search engines, people also increasingly inform themselves through social networking sites, for instance, about political (e.g., Smith, 2013) or health issues (e.g., Vance, Howe, & Dellavalle, 2009). These technological developments are about to substantially change the way how users acquire knowledge on the Web. However, the majority of educational psychological research within this field has not kept up with this pace. In the present commentary, we argue that this must change for our research to remain relevant in today's rapidly changing technological society.

Past research on learning by searching the Web

A growing body of quantitative research concerning how individuals in formal or informal learning situations search the Web (for recent overviews, see e.g. García-Rodicio, 2015; Salmerón, Strømsø, Kammerer, Stadtler, & Van den Broek, 2018; Walhout, Oomen, Jarodzka, & Brand-Gruwel, 2017), shows the relevance of this topic in educational sciences. Commonly, learning by searching the Web is described as a sequence of processing steps that unfold in an iterative manner (e.g., Brand-Gruwel, Wopereis, & Walraven, 2009; Gerjets, Kammerer, & Werner, 2011; Kiili et al., 2018; Leu, Kinzer, Coiro, Castek, & Henry, 2013): First, identifying and defining the information need and generating respective search terms; second, locating relevant information resources by evaluating and selecting links from search engine result pages (SERPs); third, scanning and briefly evaluating the information presented in the resources; fourth, thoroughly processing and extracting content from resources identified as useful; and fifth, comparing, integrating, and synthesizing information from several resources to prepare the final task outcome (in the user's mind or externally). A major research goal has been to investigate how individuals select and evaluate potentially useful websites from the innumerable information resources available on the Web in order to construct a coherent mental representation of the issue at hand (cf. Brand-Gruwel et al., 2009; Rouet & Britt, 2011). Increased time spent on relevant and reliable websites and reflections regarding the credibility of information providers have been shown to be positively related to learning outcomes (García-Rodicio, 2015; Goldman et al., 2012; List, Grossnickle, & Alexander, 2016; Mason, Ariasi, & Boldrin, 2011; Wiley et al., 2009). A common finding, however, also is that – especially if prior knowledge about the search topic is low – individuals tend to focus on the first few search results presented by a search engine and mainly evaluate whether or not the search results address the issue they are looking for (e.g., Brand-Gruwel, Kammerer, van



Meeuwen, & Van Gog, 2017; Salmerón, Kammerer, & García-Carrión, 2013; Walhout et al., 2017). Furthermore, particularly younger students (e.g., from grades 5 to 7), seem to rely more on superficial cues such as highlighted keywords when accessing websites rather than on the underlying semantic information contained in the search result descriptions (Keil & Kominsky, 2013; Rouet et al., 2011). Moreover, students of all ages spontaneously tend to pay rather little attention to source features during Web search, that is, to information about who provides the content and for what reason (e.g., Gerjets et al., 2011; Kiili, Laurinen, & Marttunen, 2008; Paul, Macedo-Rouet, Stadtler, & Rouet, 2017; Stadtler & Bromme, 2007; Walraven, Brand-Gruwel, & Boshuizen, 2009; Wiley et al., 2009). Since information published on the Web does not necessarily undergo any quality control, this creates risk for acquiring one-sided, biased, or even false information (cf. Goldman et al., 2012).

Notably, however, the above cited research has focused mostly on learning from text-based websites that students accessed via search engines on desktop PCs or laptops. Given the technological developments described in the introduction, however, it is of vital importance to now go a step further and investigate how learners select and evaluate information resources when using such new devices and media formats. The goal of the present commentary is to formulate a respective research agenda. Specifically, we will focus on the use of mobile devices and digital assistants, the use of social networking sites, and the use of online videos, and the opportunities and challenges they present to learners. In addition, we argue that future research should study the ongoing learning processes during Web search in greater detail.

1. Searching by using mobile devices and digital assistants – anywhere and anytime

Apart from desktop PCs and laptops, nowadays, individuals increasingly use mobile devices like smartphones and tablets to inform themselves on the Web, for instance when completing school assignments (Purcell, Heaps, Buchanan, & Friedrichs, 2013). Due to the smaller screen size that only allows the simultaneous display of very few search results and also only smaller parts of websites, mobile searches might be even more perfunctory and superficial than searches on desktop computers or laptops. Previous large scale studies indicate that in mobile searches users click on very few results and often seem to only read the information provided in the search results snippets rather than opening the linked web page (e.g., Kamvar & Baluja, 2006). Further descriptive findings by Djamasbi, Hall-Phillips, and Yang (2013) suggest that paid search results (i.e., ads that are presented above the actual search results) might attract more attention on mobile phones than on desktop computers. Kim, Thomas, Sankaranarayana, Gedeon, and Yoon (2015) compared users' search behavior when using a search engine interface presented on a small screen (to simulate the screen of a mobile device) or on a large screen (i.e., a regular computer screen) to conduct simple fact finding tasks. Results showed that participants had greater difficulties to extract information from search results pages on the smaller screens. However, in terms of the accuracy of finding correct answers, no differences between the screen conditions were shown. Yet, it is reasonable to assume that for more complex learning tasks that require comparing and integrating information from various websites rather than finding a single correct answer, the screen size should matter more.

Another upcoming technology is the use of AI-powered digital assistants such as Apple's Siri, Amazon's Alexa, or the Google Assistant. Instead of a list of different search results (that potentially could be evaluated, compared, and integrated), they provide their users only with a single spoken response to their query. This means, that only one result from the SERP is selected and presented to the users, which makes them even more dependent of the search engine algorithm.



Research Agenda

- Future research should investigate how people select and evaluate online information resources for learning purposes when using mobile devices (or small rather than large screens, respectively, cf. Kim et al., 2015). *Possible research questions are:* How many and which websites do they access, how much attention do they pay to source information, and, finally, how complete are their mental representations of the to-be-learned topic as compared to a regular computer screen condition?
- Future research should also investigate how individuals deal with the fact that they receive only one single response, and to which extent they learn from these searches. *Possible research questions are:* To what extent and how do learners try to justify the single knowledge claim they receive (e.g., by checking additional information resources)? To what extent do they evaluate the trustworthiness of the information resource, when source information (i.e., “According to source X, [answer]”) is presented in spoken rather than in written form? What do individuals remember from these spoken responses as compared to conventional search situations where they have to actively select and read written information?

2. Evaluating information encountered on social networking and question-and answering sites

Seeking answers from members of one’s social networks or on social question-and-answering (Q&A) sites has become a fast and popular way to obtain information on various topics. Many individuals trust information from social networking sites (SNS) even more than information provided by search engines (Morris, Teevan, & Panovich, 2010). Yet, how individuals learn from SNS and Q&A sites is still an underexplored topic. Given that the intentional or unintentional spread of misinformation by humans or by social bots is an increasing problem in social media, considering author credibility is crucial when reading messages in SNS and Q&A sites. Studies indicate that both school students and adult users rely more on answers from (self-declared) experts than from non-experts, at least when several alternative messages are provided (Winter & Krämer, 2012; Salmerón, Macedo-Rouet, & Rouet, 2016). However, whereas university students seem to prefer answers from expert authors that refer to an external source of information, primary school students seem to prefer expert messages that report a personal experience (Salmerón et al., 2016). Yet, the actual learning outcomes have not been examined in these studies; neither did study participants have strong opinions on the topics addressed in the task materials.

Previous research has shown that individuals’ pre-existing attitudes or opinions about a topic can heavily bias their information retrieval. Individuals seem to preferably access websites that provide attitude-consistent rather than counterattitudinal information (e.g., Frost, Casey, Griffin, Raymundo, Farrell, & Carrigan, 2015; Knobloch-Westerwick, Johnson, & Westerwick, 2015; Schwind & Buder, 2012; Schwind, Buder, Cress & Hesse, 2012), to judge proattitudinal information as more trustworthy (e.g., Bråten, Salmerón, & Strømsø, 2016; Schwind & Buder, 2012; Strømsø, Bråten, & Stenseth, 2017; Van Strien, Kammerer, Brand-Gruwel, & Boshuizen, 2016), and also to better remember it (e.g., Frost et al., 2015; Maier & Richter, 2014; Schwind et al., 2012).

Such predominant exposition to and reliance on attitude-consistent information might be further promoted by personalized web algorithms that present to each user information in line with his or her previous interests, thereby creating so-called “filter bubbles” that isolate users from opposing information (Pariser, 2011). Furthermore, online social networks can create “echo chambers” (e.g., Bakshy, Messing, & Adamic, 2015; Boutyline & Willer, 2017), in which like-minded people share and reinforce their personal



views and spread one-sided or even false information. However, it should also be noted that some recent studies indicate that the problem of echo chambers and filter bubbles on the Internet might be overstated (e.g., Dubois & Blank, 2018; Haim, M., Graefe, A., & Brosius, 2018).

Research Agenda

- Future research should investigate what and how individuals learn from SNS and Q&A sites as compared to traditional websites. *Possible research questions are:* How do people inform themselves (actively or passively) about controversial issues on SNS and Q&A sites, how do they judge the trustworthiness of the encountered information, and what do they finally recall, and which opinions do they form, respectively. Moreover, which roles do their pre-existing attitudes play in these processes?

3. The use of multimodal learning materials and the acquisition of procedural knowledge

The Web is a huge repository for multimodal materials (i.e., a combination of visual and auditory information; such as videos). Adolescents, for instance, frequently use the video-sharing platform YouTube when completing school assignments (Purcell et al., 2013). Apart from conveying declarative knowledge, e.g., in the form of online lectures or documentaries, also a plethora of online tutorials and how-to videos exists on the Web to convey procedural knowledge. Decades of research have shown that this is indeed a very efficient way of learning (Renkl, 2014; Van Gog & Rummel, 2010). Furthermore, research from the field of multimedia learning indicates that particularly for procedural tasks and skill acquisition, the use of visual materials in addition to text might be important for learning (Van Genuchten, Scheiter, & Schüler, 2012). The authors found that the multimedia effect, that is, that individuals learn better from text and pictures than from text alone (cf. Mayer, 2009) was larger in procedural tasks than in conceptual and causal tasks. On the contrary, however, pictures can also be misleading in that they pursue the learner to be less critical about the accompanying text (Isberner, Richter, Maier, Knuth-Herzig, Horz, & Schnotz, 2013; Lenzner, Schnotz, & Mueller, 2013; McCabe, & Castel, 2008; Oegren, Nystroem, & Jarodzka, 2016).

While there exists a lot of research on how individuals learn with single instructional videos (e.g., Merkt, Heier, Weigand, & Schwan, 2011; Merkt & Schwan, 2014) or how they integrate textual and pictorial information within documents (e.g., Eitel, Arndt, & Scheiter, 2013; Schüler, Arndt, & Scheiter, 2015), previous research that examined learning during Web search has mostly focused on textual documents. Only recently, researchers began addressing this topic. For instance, Salmerón, Sampietro, Delgado, Ziegelstein, and Fajardo (2017) examined how primary school students evaluate information from textual websites and personal online videos. Their results indicate that students more critically evaluated the trustworthiness of personal videos than of textual websites and better remembered who provided the information when working with two modalities (i.e., one text-based resource and one video resource) rather than only one (i.e., two texts or two videos). Learners' integration processes across a set of multimodal (i.e., videos) or multimedia (i.e., text and picture) information resources, however, seem to be comparable to integration processes across purely textual information resources, as indicated by recent research by List (in press) and Schüler (in press).

Research Agenda

- Future research should investigate the search for online videos as an important resource for learning, not only for acquiring declarative knowledge but also procedural knowledge. *Possible research questions are:* What criteria do learners use when searching for and selecting online videos for different learning purposes (e.g., for acquiring declarative versus procedural knowledge)? For which learning tasks do they prefer videos over static text-(and-picture)-based websites? To what extent



and how do they evaluate the trustworthiness of information provided in online videos as compared to equivalent textual resources?

4. Analysis of the learning sequence and learning increment during Web search

A final issue that we would like to address is a methodological one. Most research on learning during Web search measures some kind of learning outcome, in the form of a knowledge test (and respective knowledge gains from pre- to post-test) or an essay, for which the number of arguments raised or the breadth and depth of topic coverage are analyzed (cf. Wilson & Wilson, 2013). In addition, process measures during the search process are increasingly investigated by means of navigation logs, eye-tracking data, or verbal protocols (see e.g., Argelagós, Brand-Gruwel, Jarodzka, & Pifarré, 2018). Typical measures are the number and type of search results selected from a SERP or the time spent on relevant or reliable over irrelevant or unreliable websites (e.g., García-Rodicio, 2015; Goldman et al., 2012; Kammerer & Gerjets, 2014; Mason, Junyent, & Tornatora, 2014; Wiley et al., 2009), the number and type of search results fixated on a SERP or the respective total fixation time on search results (e.g., Brand-Gruwel et al., 2017; Hautala, Kiili, Kammerer, Loberg, Hokkanen, & Leppänen, 2018; Kammerer & Gerjets, 2012; Walhout et al., 2017), the order in which the search results are visually inspected (e.g., Kammerer & Gerjets, 2014; Şendurur, & Yildirim, 2015), or the number and kind of verbal utterances (e.g., about the type or credibility of sources) mentioned by the individuals during search results selection or while reading the websites (e.g., Anmarkrud et al., 2014; Bråten, Ferguson, Strømsø, & Anmarkrud, 2014; Gerjets et al., 2011; Greene, Copeland, Deekens, & Seung, 2018; Kammerer, Bråten, Gerjets, & Strømsø, 2013; Greene, Yu, & Copeland, 2014; Mason, Boldrin, & Ariasi, 2010a, 2010b, 2011; Walraven et al., 2009). However, how the navigation sequence (or the navigation path) in which certain kinds of websites are accessed affects the learning outcome has hardly been examined yet. Research on learning with instructional hypertext-based learning environments has shown that the navigation path, that is, the order in which pages of the hypertext system are accessed, indeed affects learning outcomes. For instance, a coherent navigation path (i.e., subsequently accessing web pages that are semantically related) is beneficial for learning, particularly when prior knowledge about the topic is low (e.g., Salmerón, Cañas, Kintsch, & Fajardo, 2005; Salmerón, Kintsch, & Cañas, 2006).

Furthermore, previous educational psychological research has hardly investigated how learning increases during Web search and how this in turn influences the subsequent search behavior. First empirical evidence from the field of Web and data science indicates that the knowledge users gain during a search session constantly affects their ongoing search and evaluation processes, such as, their use of query terms and their selection and evaluation of websites (Eickhoff et al., 2014; Gadiraju, Yu, Dietze, & Holtz, 2018). Eickhoff et al. (2014), for instance, examined, both for declarative and procedural searches, how query complexity and the time spent reading a website increased during the time course of a search. Moreover, Westerwick, Kleinman, and Knobloch-Westerwick (2013) showed that prior attitudes differently affected the selection of attitude-consistent and attitude-inconsistent websites during the course of users' Web search. Thus, future educational psychological research should also use more fine-grained analyses, e.g., by splitting up the search session into several time intervals.

Research Agenda

- Future research should examine the sequence of the learning path taken during Web search. *Possible research questions are:* How do the navigation paths of more and less successful learners differ?



Can certain navigation paths be identified that are more or less beneficial for learning, depending on specific learner characteristics, such as learners' prior topic knowledge or reading skills?

- Future research should also investigate how individuals' topic knowledge changes throughout the search session and how this in turn influences subsequent selection and evaluation processes. *Possible research questions are:* How is new information incorporated into existing schemata, how do these influence further search and evaluation behavior, and how could this be captured with process-tracing measures?

Conclusion

In sum, we argue that with the proposed research agenda our research can keep pace with recent technological developments such as mobile computing and digital assistants, social networking sites, and instructional online videos. To empirically examine how they shape learners' search and evaluation behavior on the Web is vitally important for educational psychological research. We believe that examining the research questions raised in the present commentary will uniquely contribute to the literature on Web-based searching and learning. Moreover, they can give educational insights into how to foster students' Web search practices, which are essential skills for twenty-first century learning (e.g., Kiili et al., 2018; Van de Oudeweetering, & Voogt, 2018). For instance, research might provide insights regarding which digital tools and formats are particularly suited for specific learning purposes and specific types of learners. Moreover, with technology increasingly doing the thinking for the users, from an educational perspective it is of great importance to make students aware of how the technology and the underlying algorithms work and how to use digital media and tools in a meaningful, reflective, and self-regulated way.

Keypoints

- Recent technological developments are influencing the way how users search and learn on the Web
- We provide a research agenda for future research on learning by searching the Web
- Specifically, we address the use of mobile devices and digital assistants, social networking sites, and online videos
- The ongoing learning processes during Web search need to be studied in greater detail

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