Web-Page Reading: Tracing Epistemic Processing by Eye Movements

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Abstract. The present study investigated whether source authoritativeness affects information processing during web-page reading and whether the reading behavior is linked to learning from the Web. We asked undergraduates to read instructional material about the universal validity of the central dogma of molecular biology, which was included in two Web pages differing for authoritativeness. During the reading phase, eye movements were recorded. Following, learning performance was assessed and readers' need for cognition was measured. The results revealed that source authoritativeness influences both immediate and delayed information processing. In addition, a relation between learning performance and eye movement indices was found. Finally, need for cognition played a pivotal role in moderating immediate processing. Altogether, these findings provide new evidence on Web-based information evaluation and learning.

Keywords: Epistemic processing; Internet reading; learning from the Web; need for cognition; mixed models.

Introduction

Students search the Web almost every day to access information for academic assignments. Thus, evaluating the quality of the informational source is a crucial challenge for students, as models of information problem-solving have recently indicated (Walraven, Brand-Gruwel, & Boshuizen, 2009). Only accurate and supported information from reliable sources should be followed up. Yet, students of different grade levels find difficulties in the evaluation of the knowledge accessed on the Web (e.g. Mason & Boldrin, 2008; Wopereis, Brand-Gruwel, & Vermetten, 2008). Information processing that takes into account the source, reliability, and accuracy of information is intended as epistemic (Hofer & Pintrich, 1997). In this study we examined epistemic processing during the reading of Web pages by tracking eye movements. In this regard, the main contribution of eye-tracking methodology is to provide objective data about the time course of cognitive processing during the reading of multi-representational sources (Hyönä, Radach, & Deubel, 2003; Scheiter & van Gog, 2009; van Gog & Scheiter, 2010). A fine-grained analysis of eye movements allows the researcher to distinguish between a more immediate level of processing and a delayed elaboration in the study of comprehension (Hyönä, 2010).

To extend current research on learning from the Web (Bråten & Strømso, 2006; Tsai, 2004), we studied epistemic processing by investigating whether Internet pages are processed differently according to their authoritativeness. We also examined the effect of epistemic processing on learning performance. Furthermore, we investigated epistemic processing in relation to learners' need for cognition (Cacioppo, Petty, Feinstein, & Jarvis, 1996), a dispositional variable that encompasses the tendency towards desire for effortful thinking and understanding, which promotes the interpretation of controversial information (Kardash & Scholes, 1996). Based on the most recent literature, the following research questions guided our study: 1. Do students read information differentially according to the authoritativeness of Web page (epistemic processing)? 2. Is there a link between reading behavior and learning performance? 3. Is the reading behavior influenced by need for cognition?

Method

Participants were twenty-five (13 female and 12 male) undergraduate students from the Faculty of Psychology of a large public university in northern Italy (age: M = 22, SD = 1.7). Participants read two Web pages reporting on the central dogma of molecular biology, which differed for their

authoritativeness. A page was taken from the site of the National Council for Scientific Research (CNR, the high scientific credibility source), whereas a second page from an amateur site (the low scientific credibility source). Within each page, the instructional material was arranged in four areas of interest: text 1, picture 1, text 2, and picture 2. Text 1 and picture 1 comprised argumentation 1, which supported the dogma. In contrast, text 2 and picture 2, comprised argumentation 2, which refuted the dogma. Before participants were presented with the instructional material, prior-knowledge was assessed through two open-ended questions and two multiple-choice questions. During the reading phase, eye movements were recorded. Two indices, *first-pass fixation time* and *look-back fixation time*, which reflect two subsequent stages of processing, automatic (immediate) and strategic (delayed, deeper) respectively, were computed. Following the reading phase, participants' need for cognition and learning performance were assessed.

In order to test our hypotheses, a mixed-effect multiple regression model was fitted for both eye-movement indices computed for each area of interest. A mixed-effect model incorporates both fixed-effect terms and random-effect terms. This model provides a statistical tool to control for the large inter-individual variability, such as in the eye-movement measures (Kuperman, Schreuder, Bertram, & Baayen, 2009). In this respect, the models used in the present study included random intercepts for *participants*, the *type of page* as fixed-effect factor, and *by-participant random slopes for type of page*. Moreover, four covariates were inserted into the model. *Need for cognition* and *learning performance* were studied as covariates of interest, while *prior-knowledge* and *reading time* were control variables.

Results

Epistemic Processing

The picture which refutes the dogma (picture 2) was fixated for a longer time during the first-pass reading for the amateur page than for the CNR (37.14 sec, $p = .0001$, Table 1). In contrast, the argumentation which supports the dogma (argumentation 1) was fixated for a longer time during the second-pass reading within the authoritative page than within the amateur page (-18.85 sec, $p = .05$)[1].

Table 1: Fixed effects of the model for first-pass fixation time on picture 2

Variable	Estimate	MCMC *M*	HPD95lower	HPD95upper	*p*MCMC	*pr*(> |*t*|)
Intercept	-47225.6604	-47233.4872	-70114.1616	-24553.3869	0.0002	0.0002
TypePage	37140.2180	37032.3032	20926.4261	55136.9407	0.0001	0.0001
ReadingTime	0.0014	0.0018	-0.0343	0.0369	0.9194	0.9346
Prior-knowledge	-334.7886	-329.2155	-1468.2819	812.1175	0.5618	0.5402
NeedCog	738.6227	739.5096	357.7332	1113.9733	0.0002	0.0005
Learning	-316.2605	-319.8491	-2379.7079	1826.6785	0.7698	0.7650
TypePage:NeedCog	-628.4755	-626.6160	-917.3162	-344.0163	0.0001	0.0001
TypePage:Learning	-6731.1604	-6662.4338	-11104.5947	-2358.8298	0.0028	0.0028

Note. Estimates are in milliseconds; MCMC = Monte Carlo Markov chain; HPD95lower = lower boundary of the 95% highest posterior density interval; HPD95upper = upper boundary of the 95% highest posterior density interval; *p*MCMC = *p* values estimated by the MCMC method using 10.000 simulations; *pr*(>|*t*|) = *p* values obtained with *t*-test using the difference between the number of observations and the number of fixed-effects as the upper bound for the degrees of freedom.

Epistemic Processing and Learning Performance

When considering the picture refuting the dogma (picture 2) within the CNR page, participants who spent a longer time during the first-pass reading showed a higher learning performance (-6.73 sec, $p =$

[1] For the sake of brevity, for argumentation 1 we only present the effect sizes and the corresponding statistical significances. Full specification of the model has been inserted only for picture 2 (Table 1).

.003, Table 1). Similarly, participants who spent a longer fixation time during the second-pass reading on the argumentation supporting the dogma (argumentation 1) within the amateur page, learned more (7.95 sec, $p = .011$).

Epistemic Processing and Need for Cognition

When considering the picture refuting the dogma (picture 2) within the CNR page, participants with a higher need for cognition showed a longer fixation time during the first-pass reading (-628.48 msec, $p = .0001$, Table 1).

Discussion

These findings provided further evidence for a kind of processing that can be considered epistemic: while reading the Internet, individuals processed information differently, depending on source authoritativeness (Mason & Ariasi, in press). For example, the processing of the picture that confuted the central dogma of molecular biology within the amateur page was automatic, requiring more efforts within the institutional source. In addition, the relationship between epistemic processing and Web-based learning was documented. In this respect, students who were able to overcome the effect of such a processing learned more than students who were not: students who deeply processed an alternative information (picture 2) within the institutional source (CNR), as revealed by the analysis of eye movements, achieved a better learning performance. Finally, need for cognition revealed to moderate the effect of epistemic processing. In particular, the higher the need for cognition, the longer the fixation time on the picture confuting the dogma within the institutional page. Therefore, a high desire for effortful thinking and understanding seems to induce students to take into account the refutational information even in a high scientific credibility source.

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