What Makes You Feel You Are Learning: Cues to Self-Regulated Learning

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Abstract

While learning in a multitext environment increases with the rise of electronic environments, little is known about what makes learners feel that they should continue learning or already learn enough from one text. The current study aimed at examining what cues learners use to regulate their effort among multiple sources in a multitext environment. By manipulating the amount of new information and conceptual overlap across texts within a topic, we created three types of text environments to generate different trajectories of two cues to perceived learning, new information (measured by rating of perceived new information) and encoding fluency (measured by ratings of reading ease). Results showed that the dominant cue to gauge perceived learning was the perceived amount of new information. The study extended theories in animal foraging and metacognition, and established a novel paradigm to better investigate adult learning in the wild.

Keywords: information foraging, metacognition, self-regulated learning

Introduction

With the availability of information sources is exploding through the development of modern information technologies, learners have to take an active role to manage their learning in contemporary education settings. Since viewing all information is not possible given our limited processing capacity (Simon, 1956), choosing the important information, as well as deciding the amount of effort to allocate to particular sources of information, is necessary for promoting learning. However, how learners determine if they would like to continue or stop learning remains unknown. The current study aimed at investigating the cues learners used to gauge their perceived learning, which would in turn influence when they stop learning.

Research in metacognition has examined the way in which the learner takes an active role to regulate study. Research has suggested that learners allocate their study time according to their perception of how well they are learning the materials (e.g., judgments of learning (JOLs), Dunlosky & Connor, 1997; Metcalfe & Kornell, 2005). Koriat (1997) has argued that learners monitor different sorts of cues in accessing their learning to generate the JOLs. Intrinsic cues are the characteristics of the study items, such as inherent difficulty (e.g., word frequency, familiarity of the items). Extrinsic cues are the conditions of study (e.g., presentation rate or the encoding process available for the learners). Mnemonic cue reflects learners' own assessment of learning, such as the assessment of the outcome of previous recall (e.g., JOLs or recall accuracy from the previous round of study) or the assessment of processing (e.g., ease of processing), which is generated from the experience from participants.

Monitoring for text learning has usually been found to be less accurate than word-pair learning (e.g., Dunlosky, Baker, Rawson & Hertzog, 2006). One sort of metacognitive knowledge that readers often rely on to make judgments about their comprehension performance is processing ease, suggesting that readers who perceive a more fluent reading experience tend to believe that they have better comprehension (e.g., Dunlosky, et al., 2006; Hertzog, Dunlosky, Robinson & Kidder, 2003; Maki, 1998). Processing ease has often been studied as the amount of disruptions in reading. Dunlosky and his colleagues (2006) proposed that processing ease was one of the major cues for readers to judge their subsequent performance on recall or comprehension. However, this cue was often misleading for learners to estimate their learning (Hertzog, et al., 2003).

Information foraging theory also attempts to explain how people manage the acquisition of information in text environments, such as from the internet (Pirolli & Card, 1999). It suggested that information seekers would adapt to the payoff structure (information values and search costs) of the environment to accumulate information gain. Information value is estimated by "information scent" representing a proximal cue of profitability of information (Pirolli & Card, 1999). For example, in the web search, information scent is defined as the semantic relevance between a proximal cue (such as the hyperlinks, titles of the website, or the text snippets of a webpage) and the distal information (such as the linked website).

To answer the question, what makes learners feel they are learning, we adopted theories from both metacognition and information foraging to investigate the cues of perceived learning. Following Koriat (1997), two kinds of proximal cues were examined. First, like information scent of a site (Pirolli & Card, 1999), people may rely on the amount of new information (i.e., new ideas) in the text to determine the amount of knowledge they are able to gain from a text. Accordingly, when individuals perceive that there is more to learn from the texts (an intrinsic cue) and use this as a cue to perceived information gain, they would perceive that they could learn more.

Alternatively, as demonstrated in the literature in metacognition (Dunlosky et al., 2006), people may rely on encoding fluency (i.e., ease of processing, a mnemonic cue) to determine the amount of knowledge they are able to acquire from a text. Individuals who perceive that they have less difficulty learning information from the texts will perceive they learn more. Therefore, either one or both of the cues, the perceived amount of new information and

Table 1. Three types of text patches

	New Information	Encoding Fluency
The HI-LCO condition. High information and low conceptual overlap	High	Low
The HI-HCO condition. High information and high conceptual overlap	High	High
The LI-HCO condition. Low information and high conceptual overlap	Low	Very High

perceived encoding fluency may contribute to the perceived learning. Hence, the current study used three kinds of multitext environments to operationalize the availability of these proximal cues. By using the analogy of "food patches" in foraging theories, a collection of articles under a topic was operationalized as a text patch in the study.

Specifically, the manipulation focused on the relationship across articles on a topic (which operationalized the "text patch") to induce different trajectories of fluency and availability of new information to examine their relative contributions to perceived learning. To create three patch types varying in the amount of new information and the stimulation of perceived encoding fluency, the current study followed Kintsch's theory on how information is encoded from texts (Kintsch 1994). Kintsch and his colleagues (1975) suggested that although introducing new concepts in a sentence creates demands for comprehending, introducing new propositions (i.e., ideas) about the same concepts is less effortful relative to introducing new ideas that contain new concepts. In other words, while introducing more new ideas (propositions), there was a way to mitigate the effort of encoding by using the same concepts to build up new relationships among old concepts. They demonstrated this empirically by showing that while controlling the number of propositions and sentence length in the short sentences, learners spent longer time and recalled less for the items with more new concepts than the items with fewer new concepts. This finding suggested a way to differentially foster encoding fluency while increasing the equivalent amount of new information (ideas) in text, through the repeated usage of concepts across articles, called conceptual overlap. By manipulating the amount of new information and conceptual overlap across articles, the three conditions were summarized in Table 1.

In the HI-LCO condition (high information and low conceptual overlap), there were more and more new ideas and more new concepts introduced as participants read the articles in a topic. As shown in Figure 1a, participants would be expected to experience an increasing amount of new information if they continued to exploit this text patch. In addition, because the conceptual overlap among articles was low in this condition, participants would be expected to experience low encoding fluency across articles (as in Figure 1b). In the HI-HCO condition (high information and high conceptual overlap), there were more and more new ideas but few new concepts introduced as participants read the articles in a patch. The conceptual overlap among articles would be expected to increase coherence across articles even though the information load was high. Therefore, as shown in Figure 1a and 1b, participants would be expected to experience high information gain, but also high encoding fluency over the articles in this condition. In the LI-HCO condition (low information and high conceptual overlap), texts introduced virtually no new information and were, of course, high in conceptual overlap. As shown in Figure 1a, participants would be expected to perceive little new information because the content of articles was repetitive. At the same time, because of the use of paraphrase, participants would have high encoding fluency (Figure 1b).

The differential patterns of change in these cues across the articles in three conditions allowed us to test how these cues affect perceived learning in three conditions (Figure 1c and 1d). By investigating the functions of perceived learning in the three conditions, we were able to differentiate the cues learners use to estimate their perceived learning.

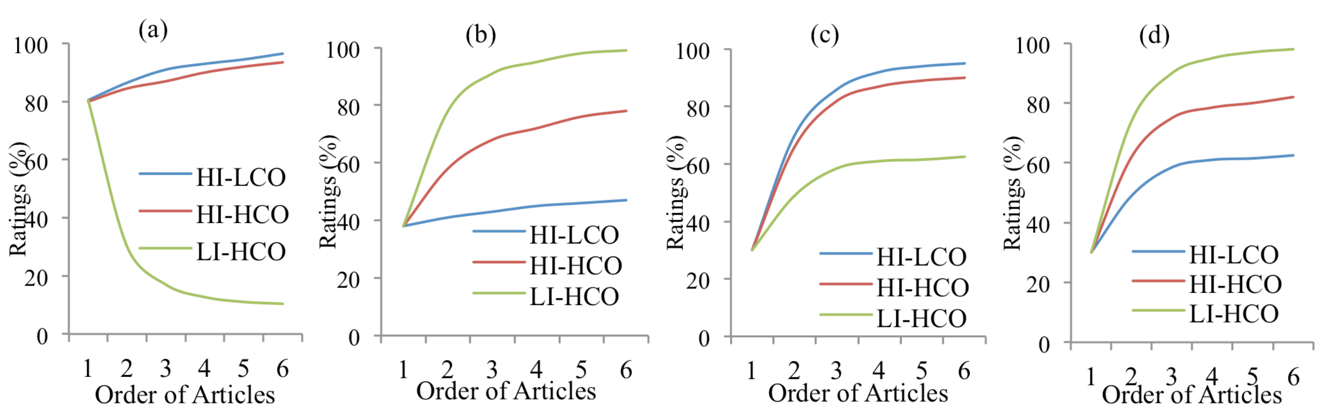


Figure 1. The expected (a) perceived amount of new inforamtion and (b) reading ease as a function of the sequence of articles in each condition; The expected perceived learning if adults adopt the cue of (c) the perceived amount of new information or (d) reading ease as a function of the sequence of articles in each condition

Method

Participants

Seventy-nine participants were recruited from Amazon Mechanical Turk. Data from 27 people were excluded due to technical problems. Data from the remaining fifty-two participants (Mean age =38.9, *SD*=10.9, age range=23-69; 46% female) were used in the analysis. Most (60%) of the participants completed college (Mean years of education =15.3, *SD*=1.9, range=12-20).

Table 2. Descriptive statistics of the text properties among three conditions

	HI-LCO	HI-HCO	LI-HCO
Number of words	220.28 (3.06)	220.56 (3.06)	220.28 (3.06)
Number of sentences	13.22 (0.43)	13.39 (0.43)	12.61 (0.43)
Sentence length	16.91 (0.50)	16.69 (0.50)	17.75 (0.50)
Log word frequency (WF)	2.88 (0.03)	2.90 (0.03)	2.91 (0.03)
WF of the content words	2.01 (0.03)	2.03 (0.03)	1.99 (0.03)
Flesch-Kincaid grade level	10.07 (0.22)	10.19 (0.22)	9.50 (0.22)
Number of unique concepts in all the articles	172~190	100~106	56~80

Materials

In the study, adults were asked to learn about "Transplantation and Donation" by reading a set of short articles about three topics, Bone Grafts, Blood Donation and Corneal Transplants. These text materials were adapted from articles extracted from dozens of health information websites with good credibility, such as MedlinePlus, WebMD, Mayo Clinic and others. For each topic, three sets of six sequential articles were created, with the three sets constituting the primary manipulation of the experiments, such that sets varied in the amount of new information and degree of conceptual overlap across articles (i.e., repeated use of the same concepts in multiple articles). *New information* in an article was operationalized as the ideas (propositions) that had not appeared in any of the previous articles under the same topic. *Conceptual overlap* was operationalized as the proportion of the same content words that were appeared in the consecutive articles. This measure was obtained from Coh-Metrix, a text analysis database developed by Grasser and his colleagues (Graesser, McNamara, Louwerse & Cai, 2004).

The first article for each topic was always an introductory article to provide an overview of the topic and was the same across the three sets. Subsequent articles in each set were constructed as follows.

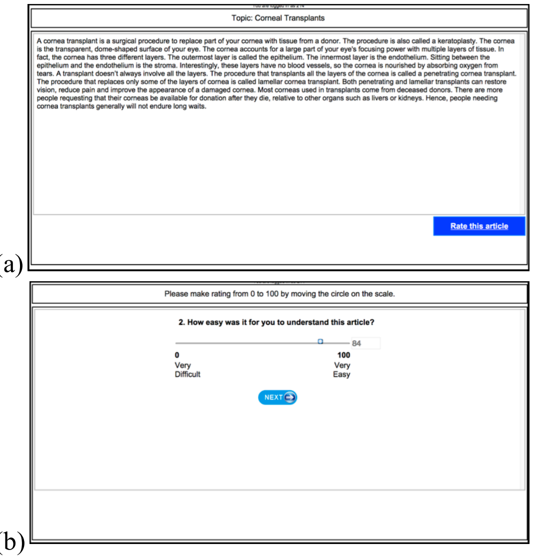
(a)
(b)


Figure 2. Example layouts: (a) article page, (b) rating page

The HI-LCO condition was the high information - low conceptual overlap condition. Following the introduction, the subsequent articles were constructed so that each subsequent article $Article_N$ contained relatively more new information (i.e., propositions) and new concepts than $Article_{N-1}$. This was accomplished by elaborating on five different areas (subtopics) of the topic to create the five subsequent articles. In this condition, new ideas as well as new concepts were consistently introduced across the six articles in a topic.

The HI-HCO condition was the high information - high conceptual overlap condition. Subsequent articles were created by introducing new ideas using about the concepts that had been introduced in prior articles within the same topic. There was always more new information but few new concepts in $Article_N$ relative to $Article_{N-1}$ in this condition. Subsequent articles were constructed by elaborating on existing concepts with new ideas. For example, for the topic of "bone graft," the first article briefly introduced concepts such as allografts and autografts, as well as more basic concepts related to donors, locations of grafts (hips, spines), tissue banks, materials, procedures, and so forth; subsequent articles elaborated, for example, on allografts and autografts, in part by grounding the explanation in these more basic concepts.

The LI-HCO condition was the low information - high conceptual overlap condition. This was a paraphrase condition that introduced minimal new ideas or concepts across the five subsequent articles. There was almost no new information or new concepts in $Article_N$ relative to $Article_{N-1}$. In this condition, the information in the first article was paraphrased in the five subsequent articles without adding new concepts or new ideas. (Because it was not practically feasible to have the low information - low conceptual overlap condition in which introducing no new information with new concepts, there were three conditions in the study).

To verify the differences in conceptual overlap across conditions, CohMetrix (Graesser et al., 2004) was used. Conceptual overlap was defined as the proportion of content words that occurred in the current article and any of the previous articles on the same topic ($M_{HI\text{-}LCO}$=0.28, $SE_{HI\text{-}LCO}$=0.01; $M_{HI\text{-}HCO}$=0.47, $SE_{HI\text{-}HCO}$=0.01, $M_{LI\text{-}HCO}$=0.70, $SE_{LI\text{-}HCO}$=0.01). ANOVA was conducted to examine the effects of condition on conceptual overlap. There was a significant effect of condition on conceptual overlap ($F(2,42)=367.20$, $p<.0001$). Post-hoc tests further confirmed that conceptual overlap in the HI-LCO condition was lower than the HI-HCO condition ($d=-0.18$, $p<.001$) and the LI-HCO condition ($d=-0.42$, $p<.001$) and the conceptual overlap in the HI-HCO condition was lower than the LI-HCO condition ($d=-0.23$, $p<.001$).

Despite the fact that conceptual overlap was different across conditions, all other linguistic properties of the texts in three conditions were carefully controlled, including the number of words, number of sentences, sentence length, word frequency (Balota, et al., 2007) and readability (descriptive statistics in Table 2). There were no differences in the number of words ($F(2,51)=0.003$, $p=0.99$), number of sentences ($F(2,51)=0.93$, $p=0.40$), sentence length ($F(2,51)=1.27$, $p=0.29$), average log word frequency ($F(2,51)=0.23$, $p=0.80$), log word frequency of all content words ($F(2,51)=0.50$, $p=0.61$) and Flesch-Kincaid grade levels ($F(2,51)=2.95$, $p=0.6$) across three conditions. Therefore, except the differences in new propositions and conceptual overlap, the texts used in three conditions were largely equivalent.

Experimental Design

The study followed a within-subject design with condition being the within-subject variable (The HI-LCO condition, HI-HCO condition and LI-HCO condition). The order of condition was counterbalanced. Participants would answer three multiple-choice questions about the shared contents across three conditions (the first article) at the end of the each topic. The purpose was to motivate participants to pay attention to the study, and make sure that participants read and understood the main ideas in each topic.

Procedure

When a participant logged into Mechanical Turk, s/he was presented with a consent form, and then completed a demographic questionnaire. For the main task, participants were asked to learn health information from multiple texts, with the goal to learn as much as possible about topics related to Donation and Medical Transplants. All participants were asked to read 18 articles, six articles in each of the three conditions. The assignment of condition to each topic was counterbalanced.

To begin, participants viewed a button corresponding to one of the topics, Bone Grafts, Blood Donation or Corneal Transplants. Once clicking on the topic button, the first article was presented (Figure 2a). After reading each article, participants pressed a button, which initiated the presentation of three rating scales (Figure 2b) to operationalize perceived encoding fluency, the perceived amount of new information and perceived learning. The perceived amount of new information was assessed with the item, “Taking into account the other articles that you have read today about this topic, how much new information was in this article?” which participants rated on a scale of 0 to 100, where 0 meant that this article did not have any new information, and 100 meant that this article had completely new information. Encoding fluency was assessed with the item, “How easy was it for you to understand this article?” which participants rated on a scale of 0 to 100, where 0 meant that it was very difficult to learn from this article, and 100 meant that it was very easy to learn from this article. In addition to the hypothesized proximal cues used to determine information gain, perceived learning was assessed by the item, “Taking in to account the other articles that you have read today about this topic, how much new information did you learn from this article?” which participants rated on a scale of 0 to 100, where 0 meant that they did not learn anything new from this article, and 100 meant that they learned everything from this article.

After providing these ratings for the article, participants pressed the “NEXT” button to read the subsequent article. After reading all six articles about one topic, participants were directed to a new topic and continued in the same way. Articles within a topic were presented sequentially. After reading one topic, participants answered three multiple-choice questions about the main concepts in the introductory article. Lastly, participants completed two cognitive tasks. Reading time on each page was recorded.

Table 3. Descriptive statistics for ratings of perceived reading ease, the perceived amount of new information, perceived learning and comprehension in three conditions

	HI-LCO	HI-HCO	LI-HCO
Reading ease	79.64 (2.75)	81.89 (2.40)	84.33 (2.13)
The perceived amount of new information	84.29 (1.97)	76.85 (1.92)	34.93 (2.96)
Perceived learning	81.35 (2.01)	75.76 (1.84)	38.51 (3.38)
Comprehension (Accuracy scores)	0.83 (0.04)	0.82 (0.04)	0.94 (0.03)

Results

The analysis focused on answering two questions; (a) whether participant’s ratings of new information and ease of processing varied across conditions as predicted, and (b) to what extent did learners use these cues to judge their perceived learning across the articles.

The Effects of Condition on Monitoring

Table 3 summarizes the descriptive statistics for ratings of perceived ease of processing, the perceived amount of new information, and perceived learning; and for accuracy scores of the comprehension questions in the three conditions. Repeated measures ANOVA was used to examine the effects of condition on encoding fluency showing a significant main effect of condition ($F(2,51)=3.88$, $p<.05$). Post-hoc tests suggested that adults thought articles in the HI-LCO condition were more difficult than articles in the HI-HCO condition ($d=-2.25$, $SE=1.15$, $p=0.05$) and the LI-HCO condition ($d=-4.69$, $SE=1.92$, $p<.05$). However, $SE=3.61$, $p<.001$).

Finally, there was a significant effect of condition on comprehension performance ($F(2,36)=3.66$, $p<.05$). Adults tended to perform better in the LI-HCO condition than the HI-HCO condition ($d=0.12$, $SE=0.05$, $p<.05$) and the HI-LCO condition ($d=0.11$, $SE=0.04$, $p<.01$), in part because of the repetition of ideas across articles. There was no difference in performance between the HI-LCO condition and the HI-HCO condition ($d=0.01$, $SE=0.05$, $p=0.87$).

Table 4. Estimates of parameters of the mixed effects models - effects of condition on ratings (reading ease, perceived amount of new information, perceived learning) across order of articles

	Reading Ease		New Information		Perceived Learning	
	Estimate (*SE*)	*t*	Estimate (*SE*)	*t*	Estimate (*SE*)	*t*
Intercept	78.72 (2.50)	31.51*	72.35 (3.05)	23.71*	69.56 (2.95)	23.62*
Order	0.91 (0.34)	2.65*	-8.95 (0.72)	-12.5*	-7.20 (0.65)	-11.01*
Con 1	1.10 (1.09)	1.01	7.33 (2.27)	3.23*	7.24 (2.07)	3.49*
Con 2	1.37 (0.97)	1.41	-2.46 (2.01)	-1.22	-3.42 (1.84)	-1.86†
Con 1 x Order	-0.86 (0.28)	-3.05*	4.99 (0.58)	8.56*	4.06 (0.53)	7.62*
Con 2 x Order	-0.11 (0.25)	-0.44	-0.13 (0.52)	-0.25	0.34 (0.47)	0.72

Note. Contrast coding was used to test the effects of conditions on ratings across the order of articles. Con 1 was to examine the differences between high information (averaging HI-LCO and HI-HCO) and low information (LI-HCO); Con 2 was to examine the effects of conceptual overlap in high-information conditions (HI-LCO and HI-HCO).

* $p<.05$; † $p<0.10$

articles in the HI-HCO condition were equivalent with articles in the LI-HCO condition in terms of encoding fluency ($d=2.44$, SE=1.87, $p=0.20$). There was also a significant effect of condition on the perceived amount of new information ($F(2,51)=123.45$, $p<.001$). Post-hoc tests further showed that participants thought there was more new information in the HI-LCO condition than the HI-HCO condition ($d=7.44$, $SE=2.00$, $p<.001$) and the LI-HCO condition ($d=49.36$, $SE=4.12$, $p<.001$). Adults also rated that there was more new information in the HI-HCO condition than the LI-HCO condition ($d=41.92$, $SE=3.66$, $p<.001$). Condition also had an effect on perceived learning ($F(2,51)=96.69$, $p<.001$). Post-hoc tests further showed that participants thought that they learned more in the HI-LCO condition than the HI-HCO condition ($d=5.59$, $SE=1.96$, $p<.01$) and the LI-HCO condition ($d=42.84$, $SE=4.10$, $p<.001$), and adults thought that they learned more in the HI-HCO condition than the LI-HCO condition ($d=37.25$,

The Effects of Condition on the Changes in Monitoring

Mixed effects models (PROC MIXED in SAS) were used to analyze how the ratings changed across articles in three conditions article by article (Estimates of parameters are in Table 4). The same contrast coding was used to examine the effects of condition.

Results showed that reading ease increased across articles in the LI-HCO condition more than in the other two conditions ($t=-3.05$, $p<.01$). However, there was no difference in the changes in reading ease between the HI-LCO and HI-HCO conditions ($t=-0.44$, $p=0.66$) (See Figure 3a for the average ratings of encoding fluency as a function of articles in three conditions). On the other hand, the perceived amount of new information decreased across articles more in the LI-HCO condition than the other two conditions ($t=8.56$, $p<.001$). There was also no difference in the changes of the perceived amount of new information

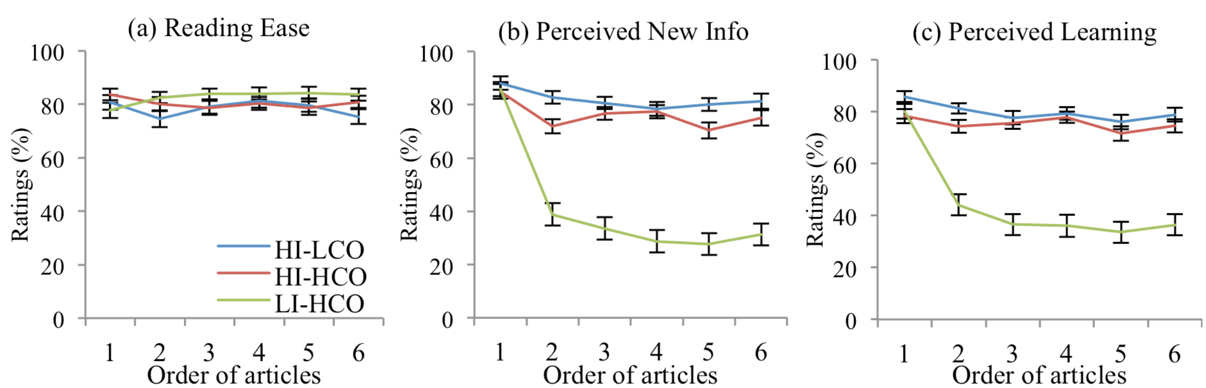


Figure 3. (a) Perceived ease, (b) the perceived amount of new information, (c) perceived learning from articles on the same topic, as a function of condition

between the HI-LCO condition and HI-HCO condition (t=-0.25, p=0.80) (See Figure 3a for the average ratings of the perceived amount of new information with progression through the articles in the three conditions). Similarly, perceived learning also decreased across the articles more in the LI-HCO condition than the other two conditions (t=7.62, p<.001). The changes in perceived learning did not differ in the HI-LCO condition and HI-HCO condition (t=0.72, p=0.47) (See Figure 3a for the average ratings of perceived learning as a function of articles in three conditions). So generally it appeared that perceived learning tracked the changes in new information and not fluency (as measured by reading ease).

The Cues to Perceived Learning

To further investigate the cues used to judge perceived learning, an analysis was done to test how changes in reading ease and the perceived amount of new information related to the changes in perceived learning article-by-article using the linear mixed effects models. Results showed that the perceived amount of new information was the dominant cue used to judge perceived learning (Est=0.78, SE=0.01, t=61.48, p<.0001), but that reading ease was not (Est=-0.04, SE=0.03, t=-1.24, p=0.21).

Discussion

Our findings successfully validated the text manipulation in three conditions such that adults perceived that the LI-HCO condition had less new information than the HI-HCO and HI-LCO conditions did. Also, averaging ratings from six articles in one condition, adults tended to perceive that the LI-HCO and HI-HCO conditions were easier than the HI-LCO condition. Interestingly, averaging six articles, adults even rated articles in the HI-HCO condition overall as easy as those in the LI-HCO condition. Even if there was much more new information in the HI-HCO condition than the LI-HCO condition, conceptual overlap induced encoding fluency for learners to comprehend information in the HI-HCO condition and the LI-HCO condition equivalently. Therefore, as expected, when manipulating the amount of new information and conceptual overlap across articles, adults perceived more new information and lower encoding fluency in the HI-LCO condition; more new information and higher encoding fluency in the HI-HCO condition, and less new information and higher encoding fluency in the LI-HCO condition. Results also suggested that amount of new information was more central for learners to judge how much they were learning than fluency.

Some previous studies have shown that learners relate encoding fluency to their judgments of learning, although encoding fluency is a misleading cue for estimating actual learning performance (Dunlosky et al., 2006; Rawson et al., 2002). Interestingly, in our study, although some learners did relate encoding fluency to their learning to a modest degree, the dominant cue to perceived learning was not encoding fluency. Encoding fluency did not contribute to perceived learning alone. It appears that encoding fluency is only a meaningful cue for adult learners to gauge their learning when they also perceive new information is available. The dominant cue for judging perceived learning in this study, which has been neglected in the previous literature, is the perceived amount of new information available. Therefore, the main contribution of the current study was to provide the evidence that the perceived amount of new information has accounted for most of the variance in perceived learning relative to encoding fluency. However, regarding the probes we used to measure the cues and perceived learning, there were similar phrases used in the probes for both the perceived amount of new information and perceived learning, follow-up studies would avoid using similar terms across probes for cues and perceived learning.

In addition to the use of different probes for the cues and perceived learning, follow-up studies would use this paradigm to examine how learners use these cues to regulate their study and their actual learning outcome. Given that the goal of the study was to understand what makes learners feel that they are learning, we did not measure the learning outcome deliberately. The multiple-choice questions used in the study were mainly used to ensure that participants captured the major ideas in the topic (with the accuracy scores exceeding 80%), instead of to measure the individual differences in learning outcome. Hence, follow-up studies would focus on how learners use these cues to regulate their study for optimizing their learning in the multitext environments.

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