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Does high perceptual load assist in reducing the seductive details effect?

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ABSTRACT

Negative effects of seductive details have been well documented. One current line of research focussed on solutions to reducing the seductive details effect is becoming increasingly promising. Contributing to this line of research, this study investigated whether perceptual load moderated the seductive details effect. The study used a 2×2 factorial design with seductive details (seductive details vs. no seductive details) and perceptual load (high vs. low) as two independent variables. Participants ($N = 123$) were randomly assigned to one of four groups to study materials on atomic structure. The dependent measures were tests of free recall and of conceptual understanding. Results indicated that under high perceptual load, participants performed equally on measures of free recall and conceptual understanding, regardless of the seductive details condition. Under low perceptual load, participants not receiving seductive details outperformed those who received seductive details on both dependent measures. These findings suggest that learners are susceptible to the seductive details effect when perceptual load is low. Theoretical and practical implications are discussed.

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Perpetual load; cognitive load; seductive details; multimedia learning; experiment

Introduction

The rapid advancement of technology has significantly changed the way people access information (Hwang, Kuo, Chen, & Ho, 2014). This made computer-based multimedia learning environments, which use technology to enable learning goals, increasingly common and often predominant. Nowadays, instructors in China may be tempted to seek, modify and include highly entertaining details into their learning materials in an attempt to attract learners' attention due to the easy access to information through modern technology (Gao, Xie, & Liu, 2018) and to current curricular reforms pushing for student-centered approaches to curriculum and pedagogy (see Zhang & Liu, 2014). In a study of secondary school English teachers, Zhang and Liu,

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for example, found that younger teachers, especially those working in the cities, often searched the internet for teaching materials. A number of studies documented a substantially greater use of technology in higher education (e.g., Crook & Gu, 2019; Li, Gao, & Zhang, 2016; Liu, 2010). In reality, however, including highly entertaining details into learning materials, referred to as *seductive details* in the literature, may be interesting but irrelevant, not directly related to the learning objectives of the lesson. Understanding the role that seductive details can play in education in China—where aesthetics has an immense importance (Liu, 2006)—may be of particular importance.

The idea of seductive details, believed to have been first introduced by Garner, Gillingham, and White (1989), has gained much popularity in multimedia learning research. Arguments for incorporating seductive details can be made from a motivational perspective. From this perspective, seductive details are perceived as aesthetically pleasing, which may trigger situational interest and motivate learners to engage in learning (Lin, Holmqvist, Miyoshi, & Ashida, 2017). Indeed, situational interest arising from an immediate reaction to certain features of the learning task, such as novelty or incongruity, has been shown to be an important factor in enhancing student learning (Hidi, 1990; Hidi & Renninger, 2006). Despite of this seemingly undisputable notion, considerable empirical evidence documented the disadvantages of including seductive details as part of learning materials. This well-documented detrimental effect of adding seductive details on recall and problem-solving performance (e.g., Abercrombie, 2013; Harp & Maslich, 2005; Lehman, Schraw, McCrudden, & Hartley, 2007), came to be known as *the seductive details effect.*

The seductive details effect and solutions

The concept of the seductive details effect is grounded in the *cognitive load theory* (CLT; Plass, Moreno, & Brünken, 2010; Sweller, 2010) and in the *cognitive theory of multimedia learning* (CTML; Mayer, 2009, 2014). According to these theories, the processing of seductive details is hypothesised to take some of the learners' limited cognitive processing capacity away from processing task-relevant material. This can produce damaging effects on learning (Rey, 2012). The cognitive load explanation for the seductive details effect has been widely accepted due to a large body of supporting empirical evidence (e.g., Eitel, Bender, & Renkl, 2019; Mayer, Griffith, Jurkowitz, & Rothman, 2008; Park, Moreno, Seufert, & Brünken, 2011; Sung & Mayer, 2012; Yue & Bjork, 2017). For instance, Mayer et al. manipulated the interest level of seductive details and found high-interest details were significantly outperformed by low-interest ones, concluding that highly interesting seductive details sapped working memory capacity away from deeper cognitive processing of the core material during learning. That said, seductive details may also reveal their facilitating effects on learning under certain circumstances. For instance, Wang and Adesope (2016) found that seductive details may have a desirable rather than detrimental effect on transfer for learners with high levels of individual interest. Sanchez and Wiley (2006) found that seductive illustrations led to better performance on the inference verification task for high working memory capacity learners. These findings suggest important learner-related boundary conditions of the seductive details effect, in which seductive details can be potentially beneficial for advanced learners (e.g., those with high individual interest or working memory capacity).

Another fruitful avenue for seductive details research is seeking to eliminate the negative effects of seductive details through task design. For example, Park, Flowerday, and Brünken (2015) presented seductive details under different cognitive load conditions. They found that seductive details were not detrimental under a low extraneous load condition (i.e., narration-textual-seductive details). A more recent study by Wang and Adesope (2017) found that focussed self-explanation, a prompted reflective activity of explaining to self the meanings of materials being studied, minimised extraneous cognitive load and mitigated the deleterious effects of seductive details. However, reducing cognitive load does not necessarily warrant the lessening of the seductive details effect. For example, Abercrombie, Hushman, and Carbonneau (2019) found that prompted use of signalling, a writing technique designed to direct learners' attention while reducing cognitive load, failed to mitigate the seductive details effect.

It should be noted that some plausible solutions for the detrimental seductive details effect found in the literature were to minimise extraneous cognitive load or foster germane cognitive load during the stage of information organisation in working memory. Only a few studies, however, considered overcoming the seductive details at an earlier, selective attention stage. One exception is Peshkam, Mensink, Putnam, and Rapp's (2011) study showing that general irrelevance instructions, a warning by the instructor that learning materials contain irrelevant information, tended to reduce attention to seductive details. Such instructions, however, may not be available to learners in many learning situations, especially when the inductor is the one seeking to enhance his or her presentations with seductive details, a scenario we discussed in the introduction of our paper. An alternative and promising approach to ameliorating the seductive details effect may be to draw upon the inhibitory effects of high perceptual load, which we defined and discussed in the following section.

Perceptual load theory

Multimedia learning environments enable both task-relevant and task-irrelevant information to be presented simultaneously. A key question that has fuelled much research in educational psychology is how and when humans ignore irrelevant information and focus on what is crucial to the task during learning. The *perceptual load theory* (PLT; Lavie, 2005; Lavie & Tsal, 1994), considered to be among most prominent theories of attention, is particularly concerned with selective attention. PLT purports that perceptual capacity is limited and that attention proceeds automatically until that limited perceptual capacity is exhausted. This theory also predicts and differentiates between two scenarios. That is, when a task imposes high perceptual load, perceptual capacity is consumed, leaving little capacity for the perception of task-irrelevant stimuli; on the contrary, when a task imposes low perceptual load, surplus perceptual resources remain to "spill-over" to process any additional, task-irrelevant or distracting stimuli (Murphy & Greene, 2017).

Perceptual load theory has been influential over the last few decades (see Murphy, Groeger, & Greene, 2016). It has generated much evidence suggesting that high perceptual load may indeed eliminate distractor interferences (e.g., Forster & Lavie, 2007, 2008; Greene, Murphy, & Januszewski, 2017; Ro, Friggel, & Lavie, 2009). For example, high perceptual load impaired people's ability to identify peripheral, but not central characters in a video featuring robbery (Greene et al., 2017). Murphy and Dalton (2016) documented failures to detect a tactile stimulus (also known as inattentional blindness/numbness) under a high perceptual load condition. Low perceptual load, on the other hand, was found to be associated with more distractor effects (e.g., more collisions, slower response initiation) in a driving simulation study (Marciano & Yeshurun, 2015). This phenomenon of high (rather than low) perceptual load suppressing the influence of distractors became known in the literature as the inhibitory effect of high perceptual load. As applied to educational settings, the inhibitory effect of high perceptual load would predict that learners would more likely be functionally blind to the presence of task-irrelevant distractors when they are simultaneously engaged in an attention-demanding task (Becklen & Cervone, 1983; Mack & Rock, 1998).

It is worth noting that perceptual load bears some similarities to cognitive load, in that both are modality specific (i.e., auditory and visual modalities; Lavie, 2005) and built upon the idea of limited information processing capacity in humans (Murphy & Greene, 2017). However, it may be more important to note the differences between these two types of load. Perceptual load occurs when selective attentional capacity is being consumed and is directly linked to the amount of information being processed for a given learning task (Macdonald & Lavie, 2011). Cognitive load, on the other hand, occurs when working memory capacity is being consumed and is directly linked to the mental effort invested to accommodate the task's demands (Paas & Van Merriënboer, 1994). Following this rationale, a simple distinction between perceptual load and cognitive load may lie with *when* the load occurs during cognitive processing. The load would be considered perceptual when happening at the early selection stage; the load would be considered cognitive when happening at the late, organisation stage. In terms of their influences on processing distractors, Wang and Duff (2016) argued, "high perceptual load serves as a perceptual barrier that blocks or inhibits distractor processing; whereas high cognitive load reduces executive control capacity, leading to more distractor processing" (p. 592).

Unfortunately, in spite of the great potential of perceptual load theory in terms of explaining the processes of ignoring what is task-irrelevant and focussing on what is task-relevant (selective attention), compared to cognitive load theory, perceptual load theory has received less than adequate attention in its application to multimedia learning. Murphy et al. (2016) pointed out that the level of both perceptual and cognitive loads will determine the efficiency of learning behaviours (e.g., distractor rejection). Therefore, a thorough understanding of multimedia learning requires considering not only cognitive load theory, but also perceptual load theory as multiple representations of information (text, pictures, graphics, audios, videos, animations, etc.) in rich multimedia environments may load perceptual capacity prior to loading working memory capacity.

Figure 1. Screenshots of the reading materials used showing the no-seductive-details-high-load condition (top left), no-seductive-details-low-load condition (top right), seductive-details-high-load condition (lower left), and seductive-details-low-load condition (lower right); original version in Chinese, translated by the authors.

The current study

Building on prior research, the current study sought to investigate the seductive details effect under high and low perceptual load conditions. The study is novel because, to the best of our knowledge, no studies yet have directly examined the relationship between seductive details and perceptual load. To fill the gap, we manipulated perceptual load in a chemistry (atomic structure) learning task. Specifically, the study differentiated between high perceptual load (imposed by a larger amount of textual information per screen) and low perceptual load (imposed by a smaller amount of textual information per screen; see Figure 1).

This approach to material manipulation is grounded in the idea that high perceptual load is imposed by a central task (learning from informational text, in our case) that involves a substantial amount of processing of stimuli at the perception level (amount of textual input ± seductive detail on the screen, in our case; see Koivisto & Revonsuo, 2009). According to reading comprehension literature (Goldman et al., 2016; Graesser & McNamara, 2011), learning from a single text involves readers constructing at least three layers of memory representations capturing different aspects of the text, namely, (a) *the surface level*, "an unanalyzed verbatim representation of the text string (e.g., the words)" created through decoding (Goldman et al., 2016, p. 222), (b) *the textbase/meaning level*, converting words into sets of propositions representing the content of the text, and (c) *the situation/interpreted level*, a coherent representation of the entire text, elaborated with relevant background knowledge on the topic. Our approach to material manipulation targets text representation at the surface level by increasing the amount of decodable text to process.

This approach is also consistent with the first of the two theoretically proposed operationalizations of perceptual load, namely, "increased perceptual load means that either the number of different-identity items that need to be perceived is increased, or that for the same number of items perceptual identification is more demanding on attention" (Lavie, 2005, p. 75). Although in current perceptual load literature, to our knowledge, there are no experiments in which materials are developed for learning specific disciplinary subject matter, our perceptual load operationalisation is common for discrete skills performance tasks such as relevant search task (manipulation of numbers of items in visual sets of letters and shapes; Lavie & Cox, 1997) or simulated driving to avoid collisions (manipulation of the number and spacing of items, such as cars, pedestrians, etc.; Marciano & Yeshurun, 2015). In light of lacking relevant examples for disciplinary content learning, we attempted to develop and manipulate learning materials in a way they fit the operational definition of perceptual load. For other examples altering perceptual load by varying the number of items (number of words and sentences, in our study) on display for the learner see Murphy et al. (2016). In other words, our material manipulation is at the surface level of text representation (Goldman et al., 2016) and is consistent with perceptual load theory research altering perceptual load by varying the number of items (number of words and sentences per screen, in our study) on display for the learner (see Murphy et al., 2016).

In sum, the current study investigated assumptions derived from perceptual load theory with a focus on the effectiveness of perceptual load that could reduce the negative effects of seductive details. To this end, the current study conducted an experiment that varied the seductive details condition (presence vs. absence) and perceptual load condition (high level vs. low level), forming four different conditions altogether. Based on perceptual load theory and previous seductive details research, the primary hypotheses of the current study were as follows:

Hypothesis 1: For high perceptual load conditions, the seductive details group will not differ from the no seductive details group on free recall and conceptual understanding.

Hypothesis 2: For low perceptual load conditions, the no seductive details group will outperform the seductive details group on free recall and conceptual understanding.

Hypothesis 3: For seductive details conditions, the high perceptual load group will identify seductive details with less accuracy as compared with the low perceptual load group.

Method

Participants and design

One hundred and twenty-three undergraduate students (67% female; $M_{age} = 19.13$ years, $SD = 1.56$) majoring in education from a large Chinese university participated in this study. They were randomly assigned to one of four learning conditions in a 2 by 2 between-subjects factorial design. Seductive details (sds vs. no-sds) and perceptual load (high level vs. low level) were varied in this factorial design, leading to four learning conditions: (1) sds-high-load ($n = 29$); (2) sds-low-load ($n = 30$); (3) no-sds-high-load ($n = 31$); and (4) no-sds-low-load ($n = 33$). Participants were paid $5 for their participation upon completing the experimental session.

Materials

The multimedia lesson was delivered through Qualtrics, an online survey software. The learning materials used in the present study pertained to the atomic structure. The objective of the learning task was to understand the complex structure and attributes of an atom and subatomic particles. This objective was explicitly stated during the introductory portion of the survey that was common to all treatment conditions. The learning materials were presented on 4 or 10 discrete screens, depending on the perceptual load condition. For the low-perceptual-load conditions, the instruction contained 4 screens, each with written text of about 240 words (968 words across all screens combined); for the high-perceptual-load conditions, the instruction contained 10 screens, each with written text of about 100 words (968 words across all screens combined) . The text did or did not include seductive (interesting but irrelevant) images, depending on the particular condition. For the seductive details conditions, the text was accompanied by 10 seductive images selected from online sources, all of which dealt with the topic of chemical particles on a surface level (not targeting the learning objective and only tangentially related to the key content). For the no seductive details condition, the text was not accompanied by any seductive images. Figure 1 shows a sample of screenshots for the four conditions. All of the screens were designed by the first author.

Measures

Prior knowledge

As a control measure, prior knowledge was assessed with a test (Cronbach's $a = .78$) that included five multiple-choice questions on atomic structure (e.g., "In a neutral atom, which of the following two quantities will always be equal?"). One point was assigned for each correct answer, resulting in a possible score ranging from 0 to 5 points.

Situational interest

Situational interest was measured by a scale (Cronbach's $a = .93$) that included five items that were adopted from a study by Wang and Adesope (2016). The situational interest scale was applied for manipulation check to ensure that our experimental manipulation of seductive details was successful. Learners rated on a 5-point Likert scale (1 = *strongly disagree*, 5 = *strongly agree*) their level of agreement with each statement gauging their spontaneous attention and affective reactions to the materials presented (e.g., "I thought the topic was fascinating;" "I got caught-up in the topic").

Extraneous cognitive load

Extraneous cognitive load was measured by a scale that included two items (Cronbach's $a = .77$) adopted from Park et al. (2015). Learners rated on a 5-point Likert scale (1 = *very easy*, 5 = *very difficult*) their responses to the following items: "How easy or difficult was it for you to differentiate between relevant and irrelevant information?" and "How easy or difficult was it for you to collect all information you needed?" Because this scale focuses more on the instructional design instead of the content, this scale is assumed to be a measure of extraneous rather than intrinsic cognitive load (associated with the complexity of the task) or germane load (associated with learning-conducive effort of learners; Cierniak, Scheiter, & Gerjets, 2009).

Identification accuracy of seductive images

Image identification accuracy was assessed with eight questions that asked if the image appeared in the text the learner just read. Four of the questions presented images that were part of the learning materials; the remaining four questions presented images that were not part of the learning materials. One point was assigned for each correct answer, yielding a possible score ranging from 0 to 8 points.

Learning performance

Learning was assessed with one free-recall task and 15 multiple-choice questions. For the free-recall task, learners were required to write down everything they could remember from the text. One point was assigned for each of the facts presented in the text that each learner correctly included in their response. Two independent raters scored each response and reached a high level of agreement (interrater reliability coefficient of.89).

The multiple-choice questions gauged conceptual understandings of the learning content (e.g., ''If the number of electrons in a stable atom is 12, what is the number of the protons?"). Each question had only one correct answer for which one point was assigned yielding a possible score ranging from 0 to 15 points. The reliability analysis of the multiple-choice subtest yielded a *Cronbach's alpha* of .74. These questions were not identical to the 5-item prior knowledge test described above.

Procedure

The experiment was administered through a Qualtrics link accessed in a laboratory where each learner was seated in front of a computer. Before the experiment started, participants who volunteered to participate signed a consent form and were randomly assigned to one of four Qualtrics links representing the four experimental conditions. The experimental session started when learners clicked on the link. Prior to the session, learners were asked to read a passage carefully and that they would be posttested on their learning.

The learners in the no seductive details group went through five phases. They were required to complete: (1) demographic survey, (2) prior knowledge test, (3) reading task, (4) interest and cognitive load scales, and (5) learning performance test. The learners in the seductive details group also went through these same phases, plus one

Table 1. Descriptive statistics (means and standard deviations) for the dependent variables across the four experimental groups.

	No-SDS-low-load		SDS-low-load		No-SDS-high-load		SDS-high-load	
	$n = 33$		$n = 30$		$n = 31$		$n = 29$	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Prior knowledge	2.70	1.15	2.32	1.47	2.70	1.18	2.21	1.34
Situational interest	2.75	1.01	4.21	1.05	2.93	.80	3.28	.68
Extraneous cognitive load	2.28	.74	1.80	.71	2.63	1.01	2.11	.91
Image identification	n/a	n/a	6.25	1.38	n/a	n/a	6.21	.83
Free recall	2.97	1.89	1.18	1.54	1.97	1.25	1.75	1.46
Conceptual understanding	8.35	2.91	5.68	2.97	7.53	2.71	6.21	1.88

more phase. That is, after completing the interest and cognitive load scales, they were required to answer the seductive images identification questions. The entire experiment lasted about 40 min and was self-paced, meaning that learners were able to decide when to move forward to the next page. Learners were thanked for their participation and dismissed when they reached the last page of the online survey. Learners' response data were automatically collected and stored in Qualtrics to be later exported to SPSS files ready for subsequent analyses.

Results

Family-wise type I error rate was set at the .05 level. We used partial η^2 or Cohen's *d* as the effect size index. Accordingly, .01, .06, and .14 are considered as the η^2 values for small, medium, and large effect sizes, and .20, .50, and .80 are considered as the d values for small, medium, and large effect sizes (Cohen, 1988). Table 1 shows the means and standard deviations for each dependent measure across the four treatment conditions.

Preliminary analyses

A one-way analysis of variance (ANOVA) was conducted and the results revealed that there were no significant group differences in prior knowledge, $F(3,\ 119) = 1.20$, $MSE = 1.966$, $p = .313$, $\eta^2 = .03$. Since there were no differences in learners' prior knowledge of the atomic structure, a decision was made not to consider the pre-test score as a covariate in subsequent analyses.

Situational interest

A two-way ANOVA was conducted. The results indicated that there was a significant main effect of perceptual load, $F(1,\ 119) = 5.15$, $MSE = 4.229$, $p = .025 < .05$, $\eta^2 = .041$ (small-to-medium effect), a significant main effect of seductive details, $F(1,\ 119) = 29.971$, $MSE = 24.613$, $p < .001$, $\eta^2 = .201$ (large effect), and a significant interaction between these two variables, $F(1,\ 119) = 11.396$, $MSE = 9.358$, $p = .001 < .05$, $\eta^2 = .087$ (medium-to-large effect), on situational interest. The statistically significant mean differences in the manipulation check demonstrated that our experimental

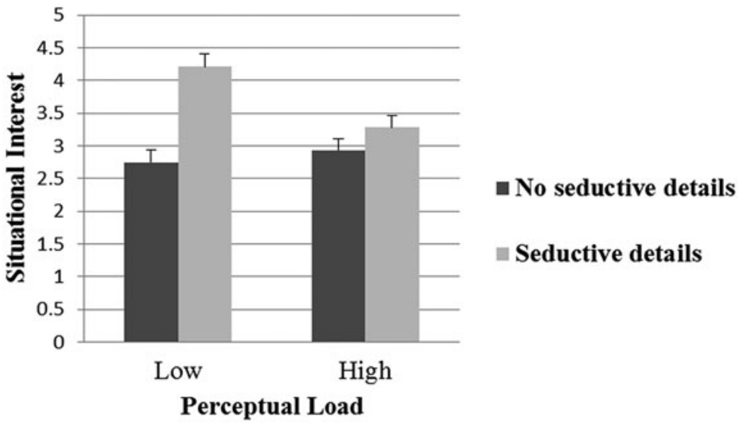

Figure 2. Situational interest by seductive details and perceptual load (error bars represent standard errors of the means).

manipulation of seductive details was successful, as learners in the seductive details groups (combined) rated much higher on situational interest than those in the no seductive details groups. Post hoc tests (Bonferroni-adjusted multiple comparisons) revealed that the *sds-low-load* group found the learning content more interesting than the other three groups: *sds-high-load* ($d = 1.05$, $p = .001$); *no-sds-low-load* ($d = 1.42$, $p = <.001$); and *no-sds-high-load* ($d = 1.37$, $p = <.001$). There were no significant differences found for other comparisons (see Figure 2).

Extraneous cognitive load

A two-way ANOVA analysis indicated that there was a significant main effect of perceptual load, $F(1, 119) = 4.527$, $MSE = 3.237$, $p = .035 < .05$, $\eta^2 = .037$ (small-to-medium effect), and a significant main effect of seductive details, $F(1, 119) = 10.749$, $MSE = 7.685$, $p = .001 < .05$, $\eta^2 = .083$ (medium-to-large effect), on cognitive load. However, the seductive details × perceptual load interaction was not significant, $F(1, 119) = .022$, $MSE = .016$, $p = .881 > .05$, $\eta^2 = .000$. The significant main effects indicated that the high perceptual load groups reported experiencing higher extraneous cognitive load than did the low perceptual load groups. The no seductive details groups reported experiencing higher extraneous cognitive load than did the seductive details groups. Bonferroni-adjusted multiple comparisons revealed that the *sds-low-load* group experienced lower extraneous cognitive load than the *no-sds-high-load* group ($d = -.95$, $p = .002 < .05$). There were no significant differences found for the other comparisons (see Figure 3).

Identification accuracy of seductive images

A *t*-test was conducted on identification accuracy of seductive images and the results revealed that there was no significant difference between the two seductive details groups (i.e., *sds-low-load* and *sds-high-load*), $t(57) = .117$, $p = .907 > .05$.

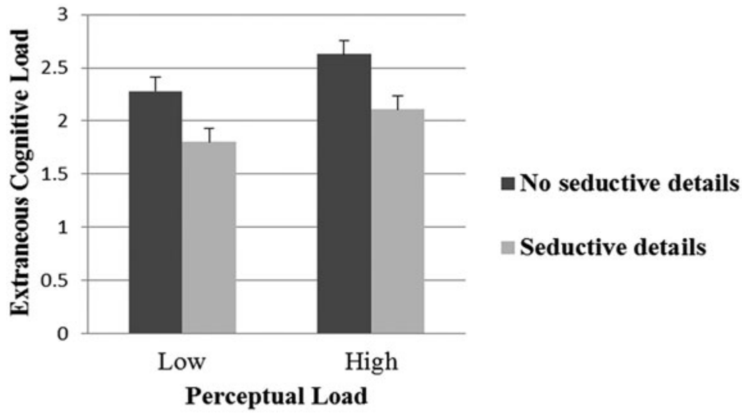

Figure 3. Extraneous cognitive load by seductive details and perceptual load (error bars represent standard errors of the means).

Learning performance

Table 1 shows the means and standard deviations for each dependent measure across the four treatment conditions. A 2×2 between-subjects multivariate analysis of variance (MANOVA) was conducted with seductive details (presence vs. absence) and perceptual load (high level vs. low level) as the independent variables and free recall and conceptual understanding scores as the dependent variables. There was a significant main effect for seductive details, Hotelling's Trace = .144, $F = 8.488$, $p < .001$, $\eta^2 = .126$ (large effect) and the seductive details × perceptual load interaction, Hotelling's Trace = .078, $F = 3.074$, $p = .037 < .05$, $\eta^2 = .086$ (medium-to-large effect). However, the main effect for perceptual load was not significant, Hotelling's Trace = .004, $F = .235$, $p = .791 > .05$, $\eta^2 = .004$.

Univariate tests were conducted to examine if there were significant effects for recall and conceptual understanding. The results revealed a statistically significant effect of seductive details on free recall, $F(1, 119) = 10.052$, $MSE = 30.688$, $p = .002 < .001$, $\eta^2 = .078$ (medium-to-large effect), and conceptual understanding, $F(1, 119) = 120.911$, $MSE = 14.946$, $p < .001$, $\eta^2 = .112$ (medium-to-large effect). The results also revealed a statistically significant effect of the seductive details × perceptual load interaction on free recall, $F(1,\ 119) = 6.187$, $MSE = 18.888$, $p = .014 < .05$, $\eta^2 = .049$ (small-to-medium effect), and conceptual understanding, $F(1, 119) = 4.668$, $MSE = 37.764$, $p = .033 < .05$, $\eta^2 = .038$ (small-to-medium effect).

The first set of follow up ANOVAs was performed on free recall. Performance results by seductive details and perceptual load are presented in Figure 4. The results showed a significant main effect of seductive details, $F(1,\ 119) = 10.052$, $MSE = 30.688$, $p = .002 < .001$, $\eta^2 = .078$ (medium-to-large effect), and a significant interaction effect of seductive details × perceptual load, $F(1,\ 119) = 6.187$, $MSE = 18.888$, $p = .014 < .05$, $\eta^2 = .049$ (small-to-medium effect). Overall, the no seductive details groups significantly outperformed the seductive details groups on free recall. Bonferroni-adjusted multiple comparisons were performed and found that the *no-sds-low-load* group significantly outperformed the *sds-high-load* group ($d = .72$, $p = .036$) and the *sds-low-load* group ($d = 1.04$, $p < .001$). There were no significant differences between the other comparisons.

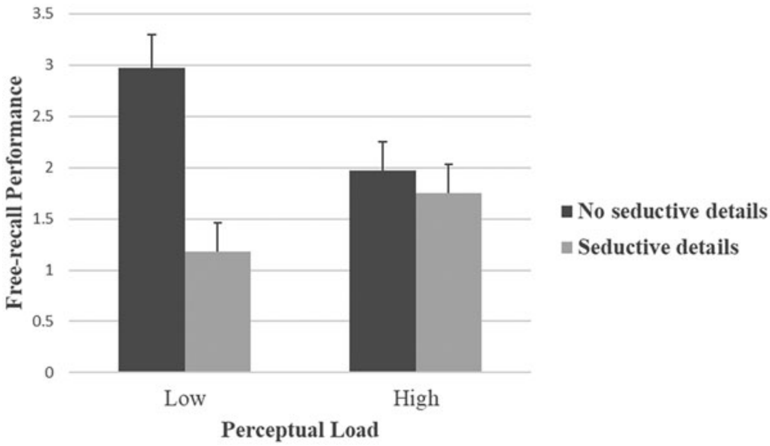

Figure 4. Number of correct answers included in free recall by seductive details and perceptual load (error bars represent standard errors of the means).

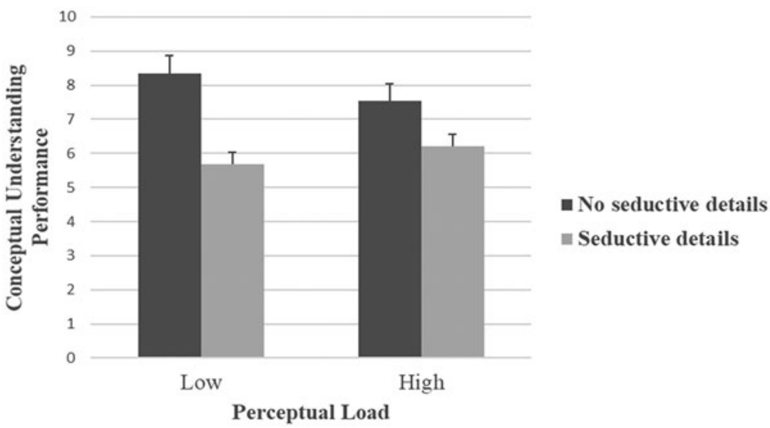

Figure 5. Conceptual understanding performance by seductive details and perceptual load (error bars represent standard errors of the means).

The second set of follow up ANOVAs was conducted on conceptual understanding. Figure 5 shows the conceptual understanding performance results by seductive details and perceptual load. As in the free-recall test, the results also demonstrated a significant main effect of seductive details, $F(1,\ 119) = 120.911$, $MSE = 14.946$, $p < .001$, $\eta^2 = .112$ (medium-to-large effect), and significant interaction effect of seductive details × perceptual load, $F(1,\ 119) = 4.668$, $MSE = 37.764$, $p = .033 < .05$, $\eta^2 = .038$ (small-to-medium effect). Overall, the no seductive details groups significantly outperformed the seductive details groups on conceptual understanding. Bonferroni-adjusted multiple comparisons revealed that the *no-sds-low-load* group significantly outperformed the *sds-high-load* group ($d = .87$, $p = .020$) and the *sds-low-load* group ($d = .91$, $p = .002$). There were no significant differences between the other comparisons.

Discussion

The aim of the present study was to investigate the impacts of perceptual load on reducing the seductive details effect among university students. The significant interactions detected between seductive details and perceptual load on both recall and conceptual understanding indicate that the seductive details effect has a boundary condition, which is learners' experienced perceptual load. Simply put, whether or not seductive details affect learning depends on the level of perceptual load. Specifically, one of the major findings from this study is that, as predicted by Hypothesis 1, under high perceptual load, there were no statistically significant differences between the seductive details and no seductive details groups on both free recall and conceptual understanding posttests. As predicted by Hypothesis 2, the results show that when perceptual load is low, the no seductive details group significantly outperformed the seductive details group on both posttests, suggesting a deleterious seductive details effect. These results are in line with perceptual load theory. Taken together, these results suggested that learners were less attentive to task-irrelevant information (seductive details) when attention was more fully engaged in a high-load task; this resulted in the learning content processing level similar to that of participants not presented with seductive details. However, when presented within a low-load task context, seductive details also entered awareness as there were sufficient attentional resources available for processing additional stimuli. This might result in simultaneous processing of both stimuli (i.e., informational text and seductive details) and thus overload the limited working memory capacity. These results are consistent with prior research that compared learning from high- versus low-perceptual-load tasks (Caparos & Linnell, 2010; Cartwright-Finch & Lavie, 2007; Murphy & Greene, 2016). Caparos and Linnell (2010), for example, found that high perceptual load narrowed the scope of attentional selection, impairing detection of peripheral, but not central stimuli.

The results also indicated that the no seductive details low perceptual load group significantly outperformed the seductive- details high perceptual load group. This finding is somewhat unexpected, as high perceptual load was found to focus learners' attention on the learning of the central content thus rendering them less susceptible to the seductive details effect. While surprising, it is possible that perceptual load itself might play a role in influencing learning outcomes. Breaking the text into smaller chunks (4 versus 10 screen segments in the present study) may be considered as a variation of a segmenting technique, known to reduce information processing demands (e.g., Mayer, Dow, & Mayer, 2003; Moreno, 2007; Singh, Marcus, & Ayres, 2012). Therefore, participants in the seductive details high perceptual load group, even though they did not pay attention to the seductive details, might have experienced information processing overload caused by the high-load text, which might in turn have hindered their learning relative to those who studied the low-load text without seductive details. Contrary to Hypothesis 3, there were no statistically significant differences between the low- and high-load groups' seductive images identification scores, which suggests that perceptual load did not influence the extent to which learners accurately identified and recalled seductive images. This result surprisingly contrasts with our findings that the high perceptual load groups performed the same on posttests in spite of seductive details, which we attributed to high perceptual load impairing the detection of seductive details. This may be due to a measurement issue, as our identification measure allowed for guessing, thereby compromising the validity of the findings. Alternatively, it may be that learners under high perceptual load may still pay some, but limited, attention to the seductive images due to their appeal. There is some evidence showing that some stimuli may escape inattentional blindness due to their salience (e.g., a happy face icon, participant's names) and can be easily detected even when performing attention demanding tasks (Mack, Pappas, Silverman, & Gay, 2002; Mack & Rock, 1998). It is important to note that such limited attention to seductive images might not proceed to a further cognitive processing stage, but may be sufficient for learners to correctly identify seductive images.

Another surprising finding relates to the extraneous cognitive load learners experienced during learning. According to the cognitive load theory, extraneous cognitive load is caused by inappropriate instructional designs and detrimental to knowledge acquisition (Paas & Sweller, 2014; Sweller, 2010; Sweller, van Merrienboer, & Paas, 1998). Based on these premises, the *sds-low-load* group should have experienced higher extraneous cognitive load than the other groups as it was outperformed by the *no-sds-low-load* group (recall: $d = -1.04$; conceptual understanding: $d = -.91$), the *sds-high-load* group (recall: $d = -.38$; conceptual understanding: $d = -.21$), and the *no-sds-high-load* group (recall: $d = -.56$; conceptual understanding: $d = -.65$). However, the *sds-low-load* group was found to experience the lowest level of extraneous cognitive load, relative to the other groups. The inconsistency between this result and the cognitive load theory predictions could plausibly be attributed to the extraneous cognitive load's inability to account for variations in learning outcomes just by itself. It is quite unexpected that the seductive details groups rated the extraneous cognitive load lower than the no seductive details groups. One possibility is that high situational interest may mitigate the negative effects of extraneous load caused by seductive details, which is in part in line with the cognitive-affective theory of learning with media (CATLM; Moreno, 2005, 2006) predicting that motivational factors would mediate learning via cognitive engagement. Another possibility is that the traditional aesthetics of Chinese learners may mitigate the negative effects of extraneous load caused by seductive details. That is, unlike the cognitive-rational Western aesthetics separating objects (objective reality) from their perceptions (subjective reality), Chinese practical-emotional aesthetics may lead to a greater perceived harmony between the objective and the subjective (i.e., conceiving of the object-perception relationship as being more intrinsic in nature; Qingping, 2006), predicting that aesthetics may mediate learning via differences in perception.

The lack of statistically significant differences in extraneous cognitive load ratings between the seductive details and no seductive details groups, across both low and high perceptual load conditions, suggests that the seductive details effect may be due not to the increased extraneous cognitive load, but to the decreased ability to control attention and ignore irrelevant information (caused by the high perceptual load in the present study). Although this finding runs counter to the cognitive overload hypothesis, it is consistent with other results in the seductive details literature. For example, Sanchez and Wiley (2006) found that the decreased ability to control attention (due to low working memory in their study) may render individuals vulnerable to the seductive details effect. That said, even though the cognitive overload hypothesis may have failed to account for our study's outcomes, this hypothesis should not be ruled out in future research. One reason for our study's results may be that the added static seductive images used in the present study may have served as attention distractors without creating a significant extraneous cognitive load source.

The overall findings of the present study provide insight into a novel way of interpreting the seductive details effect by revealing its previously unexplored boundary condition.

Implications

Theoretical implications

This study extends perceptual load theory research beyond comparing low versus high perceptual load tasks' impacts on learners' ability to detect central and peripheral stimuli. This study used an expository text and seductive detail images as the reading material and assessed recall and conceptual understanding as learning outcomes, making findings more meaningful and informative for the field of multimedia learning. Also, unlike prior research on seductive details, the present study examined the seductive details effect from a novel, perceptual load theory perspective thus contributing to the very limited literature examining the seductive details effect at an earlier stage of cognitive processing in the memory system. This approach could significantly deepen our understandings of the seductive details effect and provide an insight into its potential boundary conditions.

Practical implications

The results of this study demonstrate the interaction between perceptual load and seductive details. A closer examination of the interaction reveals that the seductive details effect only occurs under low perceptual load. On the basis of these overall results, instructional designers should consider not including interesting, but task-irrelevant details in low perceptual load lessons. On the other hand, such details may be safely added to more perceptually demanding lessons for the purpose of arousing and/or maintaining learners' interest without diverting their attention away from key information. Nevertheless, instructional designers should keep in mind that given that a less-demanding lesson without seductive details would be superior to a more-demanding lesson with seductive details, adding seductive details may only be recommended when it is not an option to reduce the demanding level of the lesson.

It is important to note, however, that our recommendations may not be applicable to all individuals (e.g., high performing students) or settings (e.g., cultures, schooling experiences, courses). With regard to individuals, we recommend that future studies seeking to replicate our results consider demographic characteristics such as academic levels, SES, and gender, among other possible confounders. With regard to settings, replications across cultural/linguistic contexts may be particularly important given that orthography is a basic constituent of word reading (Perfetti & Liu, 2005) and may affect text processing at the surface level (Goldman et al., 2016). In particular, literature highlights several differences between character and alphabetic orthographies that may pose additional burdens on processing. First, Chinese characters consist of stroke patterns that need to be visually and spatially processed from two dimensions, left-to-right and top-to-bottom (Yang, 2018), to generate the "verbatim representation of the text string (e.g., the words)" (Goldman et al., 2016, p. 222). Second, Yang (2018) notes, some differences between strokes may be very subtle (e.g., lengths of the horizontal lines are the only distinguishing characteristic between '未' and '末'). Finally, unlike with alphabetic languages, where spelling suggests how the word should be pronounced (which allows for subsequent meaning mapping), Chinese characters are usually morphemes (i.e., visual forms mapping directly onto the meaning rather than onto the sound (Wang, McBride, Zhou, Malatesha Joshi, & Farver, 2018).

Limitations and future directions

Regardless of theoretical and practical contributions of this study may, there are still some limitations that should be acknowledged. First, this study did not directly measure the perceptual load level across conditions. One could argue that it may not always be the case that a screen containing more words would cause high perceptual load relative to one containing less words. Future research could develop a valid tool to assess learners' perceptual load throughout a learning task.

Second, the seductive details in the present study were presented in the form of images rather than text. According to Schnotz (2014), text and images are two different kinds of external representations (i.e., descriptive and depictive, respectively). Such external representation differences may also impact internal (i.e., mental) representations, which may affect both learning processes and outcomes. For example, as compared to words, images may be more easily identified and recalled due to their non-abstract nature. On this account, future research is needed to replicate our study with other external representations of seductive details (e.g., seductive text and audio).

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