J. Comput. Educ. (2018) 5(2):243–257
https://doi.org/10.1007/s40692-018-0106-0

Attention please! Enhanced attention control abilities compensate for instructional impairments in multimedia learning

Maria Wirzberger[1] · **Günter Daniel Rey**[1]

Received: 17 April 2018 / Accepted: 17 May 2018 / Published online: 26 May 2018

Abstract Learners exposed to multimedia learning contexts have to deal with a variety of visual stimuli, demanding a conducive design of learning material to maintain limitations in attentional resources. Within the current study, effects and constraints arising from two selected impairing features are investigated in more detail within a computer-based learning task on factor analysis. A sample of 53 students received a combination of textual and pictorial elements that explained the topic, while impaired attention was systematically induced in a 2 × 2 factorial between-subjects design by interrupting system-notifications (with vs. without) and seductive text passages (with vs. without). Learners' ability for controlled attention was assessed with a standardized psychological attention inventory. Approaching the results, learners receiving seductive text passages spent significantly more time on the learning material. In addition, a moderation effect of attention control abilities on the relationship between interruptions and retention performance resulted. Explanations for the obtained findings are discussed referring to mechanisms of compensation, load, and activation.

Keywords Multimedia learning · Controlled attention · Interruptions · Seductive details · Learning performance

Introduction

In multimedia learning contexts, learners usually have to deal with a mass of visual stimuli from different multimedia contents, for instance complex animations in virtual learning environments being accompanied by textual explanations or

✉ Maria Wirzberger
maria.wirzberger@phil.tu-chemnitz.de

[1] Psychology of Learning with Digital Media, Institute for Media Research, Faculty of Humanities, TU Chemnitz, Straße der Nationen 12, 09111 Chemnitz, Germany

interactive agents. The arising requirement to deal with distracting and irrelevant material puts high demands on attentional resources that play a crucial role in capturing, processing, and reproducing information.

Approaching the attention construct itself, Styles (1997) already outlined the difficulty to seize its complexity due to the multifaceted nature. Besides of selectivity and alertness, a key feature consists in the limited capacity of attentional resources (Posner and Boies 1971). Whereas mental alertness can be described as ability to develop and maintain an optimal sensitivity to external stimulation, in particular the capacity aspect demands to control the focus of the available resources. Following this point of view, Kane et al. (2001) take into account the selectivity and capacity facet and describe attention as the ability to either maintain stimulus, goal or context information in an effective manner when facing interference, inhibit goal-irrelevant stimuli or responses, or both. This allows flexibility in response to demands of the respective environmental context, whether a person has to keep many representations or just one simple goal active, or is expected to inhibit irrelevant representations or responses.

However, not all visual content increases demands on cognitive control abilities, but might require only enhanced effort in perceptual resources. According to Lavie et al. (2004), increasing perceptual load is realized by adding more items to the same task, or a more demanding perceptual task for the same number of items. In contrast, load related to cognitive control makes use of functions responsible for cognitive control processes like working memory. Lavie (2010) states that distractor interference should grow with declining perceptual load, as people are less engaged in perceiving relevant stimuli, but it should rise with increasing load related to cognitive control, as distraction puts additional demands on information processing. Such distinction receives confirmation by more recent work from Konstantinou et al. (2014) that refines the role of working memory in terms of visual maintenance versus cognitive control.

Attention in instructional design

When adapting these evidences to instructional scenarios, a conducive design of learning material becomes an essential prerequisite to ensure that learners' limited resources are not overstrained. The rich literature on design effects in instructional media deals with a variety of facilities to sustain task-related attention and thus support optimal learning performance (Mayer 2014). Amongst other aspects, the elimination of interesting but irrelevant details is recommended, as they are prone to distract attention from relevant learning content (Harp and Mayer 1998). Such "seductive details" affect in particular people with low ability to control attention (Sanchez and Wiley 2006; Rey 2014), according to Conway and Kane (2001) directly corresponding with lower working memory capacity. Above that, they cause greater impairment in learning performance and evoke extended learning times when forcing deeper processing, being the case for irrelevant text passages compared to pictures (Rey 2011). Differences in processing textual and pictorial elements are confirmed as well on a neurophysiological level (Gerě and Jaušovec 1999). Following the dual-channel assumption of the Cognitive Theory of

Multimedia Learning (CTML; Mayer 2014), seductive details presented on the same information channel as relevant learning content, like irrelevant text passages inserted in a learning text, restrain learners from compensating additional demands by using alternative perceptual resources.

In addition to distractions being inherent in the learning task, learners often face distractions arising from situational aspects (Wickens et al. 2013), for instance system-induced interruptions while working in a computational environment or notifications received from social networks like Twitter or Facebook. They impair attentional resources as well and disable a concentrated focus on the respective learning goal. Since multimedia-based learning scenarios itself are usually embedded in computer-based settings, these issues are of essential relevance for instructional research and design.

Present study and hypotheses

Within the presented study, new insights into the maintenance of attentional resource demands in multimedia learning contexts were gained by systematically inducing potential distractors while presenting relevant learning material. For this purpose, seductive text passages were embedded within the offered instructional content and as interrupting system-notifications were presented repeatedly over the task. To tie in with the results of Sanchez and Wiley (2006) and Rey (2014), learners' ability to control their attentional focus was assessed with a standardized psychological attention inventory in advance. Following the common practice in multimedia learning research, when assessing the learning outcome, a distinction between retention and transfer performance was employed (Rey 2012).

Based on the outlined theoretical background on attention processes, cognitive control and multimedia learning, the following hypotheses were postulated:

H1 Inserting seductive details into multimedia learning content impairs retention and transfer performance and increases learning times.

H2 Inducing system-related interruptions within a multimedia learning task results in lower retention and transfer performance and increased learning times.

For both hypotheses, in line with evidence by Sanchez and Wiley (2006) and Rey (2014), influences of learners' attentional control abilities were inspected. In addition, from these results, the following interaction hypothesis emerges:

H3 Already impaired attention due to system-induced interruptions intensifies the negative effect of seductive details on retention and transfer performance and further increases learning times.

Methods

Participants

A total of 53 university students, on average aged 37.83 years (SD = 11.43, range: 20–67), completed the learning task on factor analysis. Most of them were enrolled within an undergraduate distant-study course in Psychology (94.1%). Nearly half of the participants were in lower terms (45.3%) and nearly two-third were part-time students (67.9%). By means of gender, the sample was rather homogeneous with about 79% female participants. All students received course credits according to their curriculum to compensate for participation.

Design

Hypothesis was tested within a 2 × 2 factorial, multivariate design with interrupting system-notifications and seductive details as independent variables, and retention performance, transfer performance and learning time as dependent variables. Attention control abilities and previous knowledge were recorded as control variables. People were randomly assigned to the four experimental conditions with nearly equal distribution (see Table 1).

Independent variables

The operationalization of seductive details followed Rey (2014) via inserting additional text passages with a total of 584 words (*M* = 64.8 additional words per page, SD = 19.2, range: 35–95). They were presented on nine pages at different positions within the learning text and consisted of information slightly related to the

Table 1 Descriptive statistical values of previous knowledge, attention control abilities, retention and transfer performance and learning times within the manipulated trials (with vs. without seductive details, with vs. without interrupting system-notifications)

Group			Type of test											
IV1	IV2	*N*	Previous knowledge		Attention control		Retention performance		Transfer performance		LT_{sed}		LT_{int}	
			M	SD	*M*	SD	*M*	SD	*M*	SD	*M*	SD	*M*	SD
–	–	13	0.46	0.78	6.58	0.91	25.15	4.53	13.85	2.94	1.55	0.71	1.87	1.00
+	–	13	0.85	0.90	5.78	1.16	25.85	4.78	12.54	2.54	1.87	0.59	2.00	0.75
–	+	14	0.86	1.61	5.87	0.82	23.36	3.61	13.43	2.88	1.54	0.54	1.96	0.74
+	+	13	1.77	2.35	6.70	0.82	27.00	5.90	14.62	4.21	1.83	0.42	2.12	0.51

IV1 presence of seductive details; *IV2* presence of interrupting system-notifications; LT_{sed} learning times in manipulated trials with vs. without seductive details; LT_{int} learning times in manipulated trials with vs. without interrupting system-notifications; previous knowledge scores ranged from 0 to 10, retention performance scores ranged from 0 to 40, transfer performance scores ranged from 0 to 25

featured content, but completely irrelevant for understanding the core steps and concepts of factor analysis. For instance, one passage discussed the development of a scale to measure attitudes by Louis Guttman, whereas other passages dealt with facts related to the terms *eigenvalue* or *synthetic*, or told biographical anecdotes about Raymond Bernard Cattell, Gordon William Allport, Maurice Stevenson Bartlett or Louis Leon Thurstone.

The second attention impairing factor was implemented by distracting system-notifications, appearing routinely while working on a standard computer. In detail, a report window on results of an antivirus scan, a windows update information pop-up, a request to check and repair new hardware, and an information on the necessity to do a restart of the computer due to successfully updating the antivirus software were used. At predefined pages, one of these announcements popped up in the middle of the screen after an initial unimpaired period of 5 s, and had to be erased by mouse click. Each interruption occurred only once, resulting in a total of four interruptions during the learning task. As displayed in Fig. 1, due to enhancing external validity, real screenshots with just minimal modifications were used.

Dependent variables

Retention performance and transfer performance were measured according to Rey (2014) with a set of mainly multiple choice questions on the presented contents. Multiple choice questions on retention performance comprised three to five possible answers and were mainly directed towards the correct reproduction of the previously presented information, for instance facts on factor rotation. Participants had to rate each answer statement as true or false, while the proportion of appropriate answers per question varied from none to all options being correct. To assess transfer performance, five multiple choice questions and five questions containing graphs or tables were used. They went beyond pure reproduction and

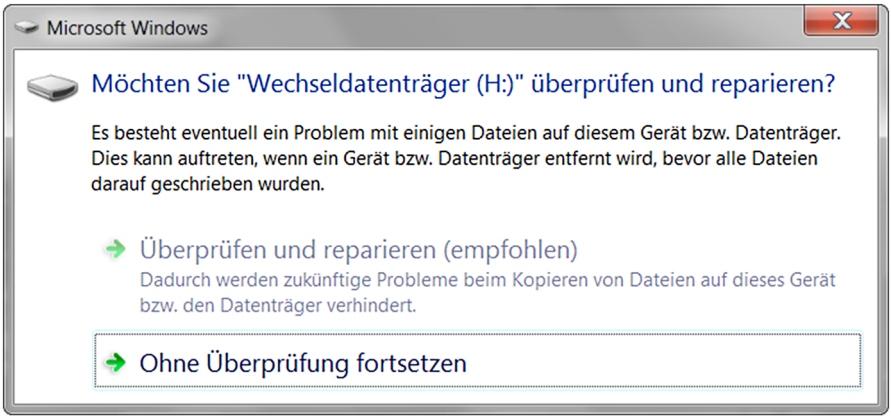

Fig. 1 Sample system-notification requesting to check and repair hardware. Alternative selections greyed out

required to apply the gained knowledge within new contexts, for instance by computing the explained variance out of a set of eigenvalues. Participants either had to rate each answer statement whether it was true or false in the case of multiple choice questions, or had to fill in the fitting number or tick off the correct box. In addition, learning time was captured from the amount of time participants spent on each page.

Control variables

Another ten multiple choice questions (Rey 2014) that had to be rated as true or false were used to query previous knowledge. By contrast, the operationalization of controlled attention abilities employed a standardized psychological attention inventory, the FAIR-2 (Moosbrugger and Oehlschlägel 2011). Such addresses the construct of controlled attention in a sophisticated manner and corresponds well to the chosen theoretical perspective.

Material

Learning task

According to Rey (2014), a written introduction text on factor analysis was used, based on recognized German statistical benchmarks (Backhaus et al. 2006; Bortz 2005). It consisted of 2013 words (M = 134.2 word per page, SD = 42.0, range: 63.0–211.0), four tables, and six graphs. Sixteen PNG files (960 × 720 px), including an instruction, with a mean size of 23.9 kb (SD = 6.3 kb, range: 13.7–36.0) were composed out of the introduction material. An example page containing a seductive text passage as well (marked in yellow) is displayed in Fig. 2.

To enable the recording of reaction times, the learning content was embedded in the java-based experimental software PXLab (Irtel 2007). Navigation within the task occurred by pressing the space key and determined the recording of reaction times. Participants had no opportunity to repeat a page once they proceeded to the following one. Stimuli were presented on a 15” Notebook with a maximum display resolution of 1024 × 768 px. The used PXLab version 2.1.19 was able to run with a screen resolution of 96 dpi, a timer resolution of less than one ms and a video refresh rate of 51.30 Hz.

FAIR-2

The standardized psychological attention inventory FAIR-2 (Moosbrugger and Oehlschlägel 2011) forces participants to discriminate visual target patterns (circles with three dots and squares with two dots in the used form A) from similar but distinct distractor patterns within a fixed time period. Patterns are arranged on two pages with 16 lines and 20 items per line each, resulting in a total of 640 items that have to be marked within 3 min per page. The principle of entire marking is applied, implying that participants need to draw a continuous line below the items and mark

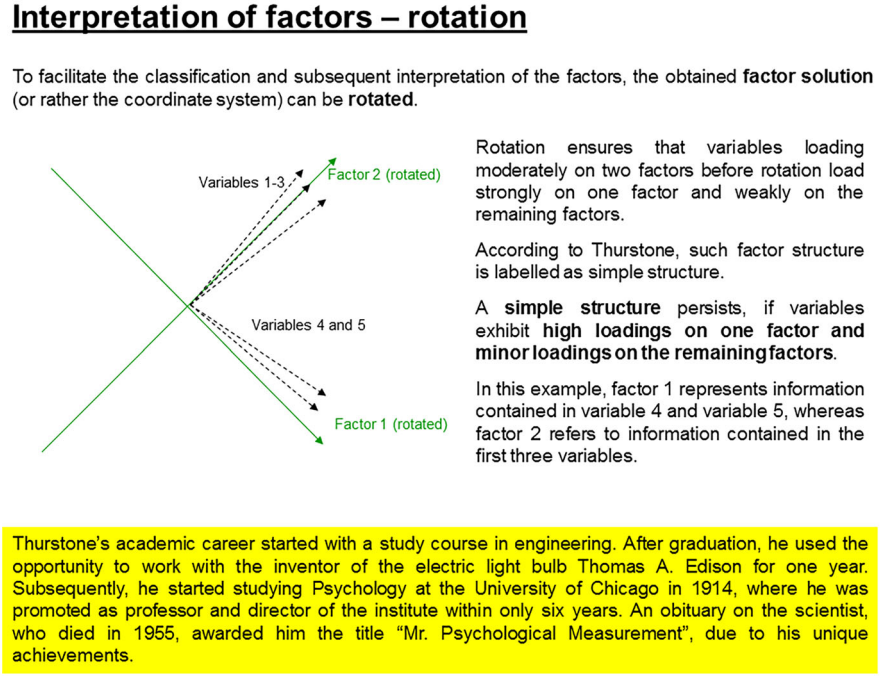

Fig. 2 Sample page from introduction text on factor analysis with seductive text passage. Seductive text passage marked in yellow for purposes of clarification. Translation from original German version

each target item by drawing a spike towards its direction. Breaking the line, missing items or correcting markings afterwards are judged as errors. To assess participants' performance, four parameters are computed: The marking score M (r_{tt} = .625) indicates comprehension of the instruction by counting the number of correctly marked items, whereas the performance score L (r_{tt} = .923) refers to the individual working speed and characterizes cognitive resources used for concentration. The quality score Q (r_{tt} = .791) describes the ratio of concentrated judgments and signifies accuracy and correctness, and the continuity score K (r_{tt} = .914) as product of performance and quality score represents cognitive resources as well as self-control.

Procedure

After being welcomed and signing the consent form, participants completed the FAIR-2. Essential instructional details were outlined orally as well, to ensure broad comprehension. Before presenting the introduction text on factor analysis, participants filled out the questionnaire on previous knowledge. They were instructed to rate all questions and guess in case of doubt. The following presentation of the introduction text was induced by some procedure-related hints regarding navigation between pages or comprehension questions. While working on the learning material, participants' goal was to learn as much as possible about the procedure of factor analysis. After spending as much time as they want on the

written introduction, participants completed another questionnaire on retention and transfer performance, questions on the employed system-induced interruptions within the respective conditions, and some questions on demographical details. Finally, they were debriefed and approved. Individual sessions lasted on average 72 min (SD = 16), but entailed a broad range from 45 min in the fastest to 112 min in the slowest case. The experimental procedure followed the principles outlined in standard 8 of the ethical principles and code of conduct for psychologists (American Psychological Association 2010).

Scoring

According to Rey (2014), scores for retention and transfer performance were computed by rewarding each correctly filled answer option with one point, resulting in a maximum of 40 points for retention and 25 points for transfer performance. Regarding previous knowledge, participants had to mark *all* answer options per item correctly to achieve one point, and thus could achieve a maximum of 10 points within this questionnaire. The recorded reaction times enabled the computation of specific learning times by calculating average mean reaction times out of the relevant experimentally manipulated trials, resulting in one learning time measure LT_{sed} for the seductive detail manipulation based on $n = 9$ trials, and a second learning time measure LT_{int} for the manipulated interrupting system-notifications based on $n = 4$ trials. To assess learners' abilities for controlled attention, the z-standardized, adjusted K score of the FAIR-2 was used. It was computed as product of performance and quality score and provided adjusted test scores for participants with additional errors. Raw scores were transformed into z-scores for reasons of comparability with other norm scales.

Results

As displayed in Table 1, participants in all conditions held little or no previous knowledge about factor analysis, already indicated by the low mean overall previous knowledge score ($M = 0.98$, SD = 1.58 points). Nevertheless, participants' previous knowledge score significantly influenced retention performance, $F(1, 48) = 5.73$, $p = .02$, $\eta_p^2 = .11$, and transfer performance, $F(1, 48) = 10.53$, $p < .01$, $\eta_p^2 = .18$, thus, it was used as a covariate during the subsequent analyses. Hypotheses on the postulated main and interaction effects were tested by analyses of covariance (ANCOVAs). To obtain additional support for the obtained effects, Bayes factors were computed by contrasting a reduced model without the respective effect, representing the null hypothesis, with a full model including all tested effects, representing the alternative hypothesis. The resulting values specify how much more times likely one hypothesis is compared to the other (Dienes 2014). By convention, a Bayes factor[1] above the value of 3 can be taken as substantial

[1] By convention, Bayes factor values between 1 and 3 (and likewise 1/3 and 1 for the contrasting hypothesis) are regarded as anectodal support, values between 3 and 10 as moderate support, 10 to 30 as

evidence for the tested hypothesis, whereas values of less than 1/3 should be considered as substantial evidence for the contrasting hypothesis (Jeffreys 1961; Lee and Wagenmakers 2014).

Effects of seductive details

The first hypothesis postulated that learners exposed to seductive details score lower in retention and transfer performance and display extended learning times. Descriptive analyses suggest an opposite trend due to a mean retention performance of 24.22 points (SD = 4.10) in conditions without seductive details, and 26.42 points (SD = 5.29) in conditions with seductive details. However, the ANCOVA did not reveal significant differences between both conditions, $F(1, 48) = 1.41$, $p = .24$, $\eta_p^2 = .03$. Bayes factor analyses were conducted in favor of the alternative hypothesis and revealed $BF_{10} = 0.53$ (error ± 1.70%), which indicates at least anectodal support for the null hypothesis. The mean transfer performance reached nearly equal levels with 13.63 points (SD = 2.86) in conditions without, and 13.58 points (SD = 3.57) in conditions with seductive details. Again, the ANCOVA did not display significant differences between both conditions, $F(1, 48) = 0.59$, $p = .45$, $\eta_p^2 = .01$. The Bayes factor of $BF_{10} = 0.35$ (error ± 1.72%) almost moderately supports the acceptance of the null hypothesis. Taken together, the postulated negative influence of seductive details on retention and transfer performance was not confirmed. In terms of LT_{sed}, a significant difference between conditions without ($M = 1.54$, SD = 0.62 min) and with seductive details ($M = 1.85$, SD = 0.50 min) in the assumed direction showed up, according to conventions on effect sizes stated by Cohen (1988) amounting to a medium effect size, $F(1, 48) = 4.65$, $p = .04$, $\eta_p^2 = .09$. The obtained Bayes factor provided anecdotal support for the alternative hypothesis $BF_{10} = 1.79$ (error ± 2.90%).

To shed light on influences of learners' attention control, moderation analyses with the seductive detail manipulation as independent variable and the z-standardized FAIR-2 K score as moderator variable were conducted for all dependent variables. Neither analysis showed a significant moderator effect.

Effects of interrupting system-notifications

The second hypothesis stated that learners confronted with interrupting system-notifications score lower in retention and transfer performance and display extended learning times. Descriptive analyses revealed a mean retention performance of 25.50 points (SD = 4.57) in conditions without system-induced interruptions, and 25.11 points (SD = 5.11) in conditions with system-induced interruptions, revealing a slight tendency towards the assumed direction. However, the ANCOVA did not show significant differences between both conditions, $F(1, 48) = 0.59$, $p = .45$, $\eta_p^2 = .01$. Again, Bayes factor analyses in favor of the alternative hypothesis

Footnote 1 continued
strong support, 30 to 100 as very strong support, and values above 100 as extreme support for the tested hypothesis.

revealed $BF_{10} = 0.35$ (error ± 3.05%), which almost moderately supports the null hypothesis. Similar results were found for transfer performance with $M = 13.19$ points (SD = 2.77) in conditions without, and $M = 14.00$ points (SD = 3.56) in conditions with system-induced interruptions, slightly aligned to the opposite direction. Likewise, the difference between both conditions did not reach significance, $F(1, 48) = 0.09$, $p = .76$, $\eta_p^2 < .01$, which received moderate support by the obtained Bayes factor of $BF_{10} = 0.30$ (error ± 1.71%). Regarding average learning times in trials with system-induced interruptions, participants needed $M = 1.93$ min (SD = 0.87) in conditions without interrupting system-notifications, and $M = 2.04$ min (SD = 0.63) in conditions with interrupting system-notifications, which aligns to the expected direction at least by trend. Nevertheless, the ANCOVA for LT_{int} did not indicate a significant difference between both conditions, $F(1, 48) = 0.40$, $p = .53$, $\eta_p^2 = .01$. The Bayes factor analysis provided moderate evidence for the acceptance of the null hypothesis with $BF_{10} = 0.33$ (error ± 3.04%).

In addition, a significant moderation effect of learners' attention control abilities on the relationship between system-induced interruptions and retention performance resulted, $\beta = .28$, $t(49) = 2.09$, $p = .04$. As displayed in Fig. 3, under conditions with interrupting system-notifications, learners with decreased attention control abilities achieved significantly lower retention scores, compared to learners with increased attention control abilities, $R^2 = .28$, $p < .01$. Under conditions without interrupting system-notifications, no such effect was found, $R^2 = .01$, $p = .73$. For

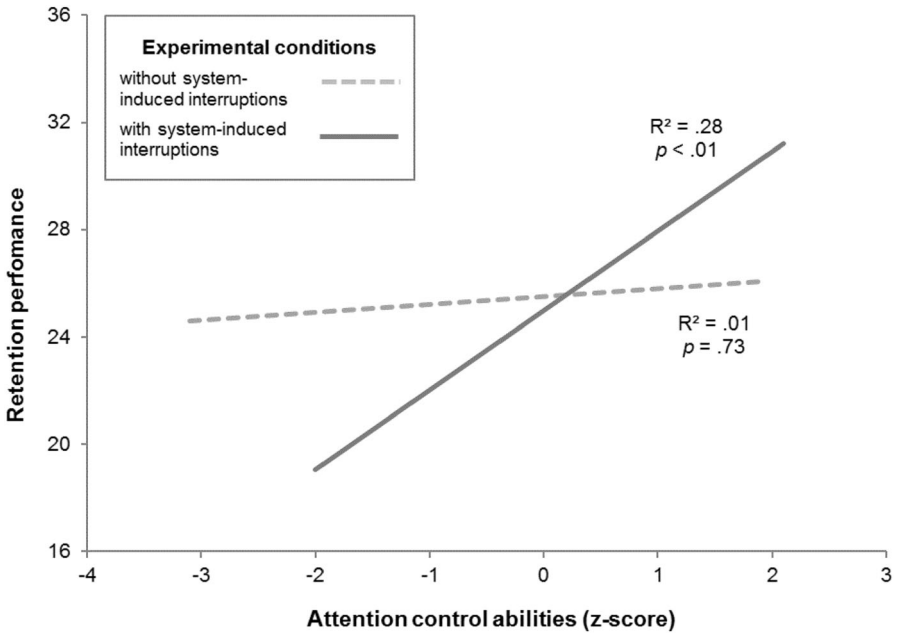

Fig. 3 Influence of attention control abilities on retention performance in conditions with and without interrupting system-notifications. The figure shows regression lines, not observed data points

neither transfer performance nor learning times a significant moderation effect could be observed.

Interaction effects

The third hypothesis dealt with the interaction between both experimental factors and assumed that learners with already impaired attention due to interrupting system-notifications display a further decrease in retention and transfer performance, as well as an additional extension in learning times when inserting seductive details. Analyses indicated neither a significant interaction of seductive details and system-induced interruptions on retention, $F(1, 48) = 0.93$, $p = .34$, $\eta_p^2 = .02$, $BF_{10} = 0.49$ (error $\pm$ 7.17%), nor transfer performance $F(1, 48) = 1.58$, $p = .22$, $\eta_p^2 = .03$, $BF_{10} = 0.70$ (error $\pm$ 2.51%). In both cases, Bayes factor analyses provided anecdotal support for the null hypothesis. Likewise, corresponding effects on learning times LT_{sed}, $F(1, 48) < 0.01$, $p = .90$, $\eta_p^2 < .01$, $BF_{10} = 0.35$ (error $\pm$ 4.86%), and LT_{int}, $F(1, 48) = 0.01$, $p = .98$, $\eta_p^2 < .01$, $BF_{10} = 0.36$ (error $\pm$ 3.05%), did not show up. Considering the obtained Bayes factors, the acceptance of the null hypothesis received nearly moderate support for both variables.

Discussion

This research systematically induced impaired attention via distracting system-notifications and seductive details, and additionally assessed learners' ability for controlled attention with a standardized psychological attention inventory. When inspecting the results, a significant increase in learning times under the presence of seductive details occurred, but no significant differences in terms of retention or transfer performance could be observed. The presence of system-induced interruptions did not significantly affect retention or transfer performance nor learning times, but learners' ability for controlled attention significantly moderated the influence of system-induced interruptions on retention performance. Neither for retention and transfer performance nor learning times the interaction between seductive details and interruptions achieved significance.

A potential explanation for the lack of influence of seductive details on learners' performance might be the use of free instead of fixed learning times. Although previous research on this design issue had shown much stronger effects with fixed learning times (Rey 2012), the decision for using unlimited learning times was made to enhance external validity by achieving a situation closer to natural learning contexts. However, the significant increase in learning times in this case could be a hint on potential significant effects when using fixed learning times. Regarding the lack of effects of the induced interrupting system-notifications, participants could already have been familiar with the used screenshots, obvious by means of the high percentage of Windows and Avira users in the tested sample. Therefore, the influence of these distractors might lacked strength to evoke significant effects. Using different means of system-induced interruptions, like social media

notifications, might be able to alter that pattern. Moreover, the sample consisted mainly of distant students, being more involved in multimedia learning contexts due to their study arrangements. Familiarity could have been an influencing factor in this regard as well. Additionally, compared to traditional student samples, such sample usually holds higher between-subject variance due to the broader range of age and learning experience, compared to student samples commonly used in psychological research. Finally, impacts of impaired attention on learning performance might be more complex than just consisting of seductive details and interrupting system-notifications. By contrast, individual differences like age, learning history, or contextual variables like time of day could serve as additional moderators, as already indicated by marginal influences in post hoc analyses. On this account, a promising approach would be the use of more complex statistical models to lighten the connections within this network. Another core problem of the conducted study had been the small sample size, resulting in a lack of power for the conducted statistical analyses. For a really valid conclusion on the postulated hypotheses, additional testing with bigger samples needs to be conducted.

Implications

Inspecting the observed moderation effect between attention control abilities and the induced interrupting system-notifications in more detail, learners with enhanced ability to maintain their attentional focus might possess additional resources that could be allocated in different ways, related to mechanisms of compensation, load and activation.

Compensation hypothesis

Within the compensation hypothesis, it is assumed that enhanced abilities to preserve the attentional focus can compensate for system-induced interruptions by providing additional cognitive resources to cope with the impairment. Such resources should be used to maintain distracting stimuli, corresponding to the previously stated perspective of controlled attention in terms of working memory resources (Kane et al. 2001). A potential experimental induction might be inspired by a principle known from the embodiment literature, postulating that people can compensate for cognitive limitations via off-loading cognitive work onto the environment (Wilson 2002), for example by taking notes (Mueller and Oppenheimer 2014). Compared to participants without compensation, especially people with lower abilities in attention control should suffer less from attentional impairments, due to the enhanced capacity to deal with distractions. By contrast, no additional benefit is expected for people with higher abilities in attention control.

Load hypothesis

The load hypothesis focuses on the difference between perceptual load, for learners highly skilled in controlling their attentional focus, and load related to cognitive control, in case of learners poorly skilled in controlling their attentional focus (Lavie

et al. 2004; Lavie 2010; Konstantinou et al. 2014). Following this framework, resources are used to differ between both types of load. A reliable experimental design should address both types of load individually to avoid confounding effects. Perceptual load might then be induced by increasing the number of relevant facts offered within the learning material, whereas load related to cognitive control could be approached with a working-memory task. Compared to control-conditions without additional load, participants exposed to perceptual load are expected to display declined retention performance only in the case of low controlled attention abilities. Otherwise people should be able to cope with the situation. On the other hand, if additional load was put on working memory, all participants are expected to suffer in retention performance, independent of their abilities for controlled attention.

Activation hypothesis

Approaching the activation hypothesis, the focus persists on the concept of mental alertness (Posner and Boies 1971), being able to enhance retention performance. In this case, resources are supposed to be allocated to increase the learning outcome. A potential experimental induction is directly inspired by neurobiological research, related to stimulants like caffeine on the one hand, commonly known to foster alertness and by this means affecting learning performance (Einöther and Giesbrecht 2013). On the other hand, the reverse usually applies for strain factors like sleep deprivation, at which alertness as well as learning performance decrease straightly (Drummond et al. 2000; Killgore 2010). Based on this findings, participants are expected to increase retention performance under induction of caffeine, particularly obvious for participants with low abilities for controlled attention, compared to control conditions. In case of sleep deprivation, a reverse pattern should be observed, with participants lacking sleep showing a decline in retention performance, even when they are highly skilled in preserving their attentional focus, compared to control conditions.

Prospect and conclusion

Future research could address the compensation, load, and activation hypotheses described above by using the already outlined experimental inductions, resulting in a potential design with one factor varied for compensation, two factors varied for load, and one factor varied for activation. Above that, psychophysiological measures like gaze movements, pupillary responses, or EEG may offer further valuable insights into the cognitive processes going on during the tasks.

In summary, a strong attentional focus constitutes an important but fragile resource in multimedia each learning. Keeping that in mind when preparing beneficial instructional scenarios should therefore be an essential prerequisite for everyone concerned with this issue. However, the current study uncovered various persisting demands and open questions, which clearly need to be addressed within future research.

References

American Psychological Association. (2010). *Ethical principles and code of conduct for psychologists*. Washington: American Psychological Association.

Backhaus, K., Erichson, B., Plinke, W., & Weiber, R. (2006). *Multivariate Analysemethoden. Eine anwendungsorientierte Einführung [Multivariate methods of analysis. An application-oriented introduction]* (11th ed.). Berlin: Springer.

Bortz, J. (2005). *Statistik für Human- und Sozialwissenschaftler [Statistics for behavioral and social scientists]* (6th ed.). Berlin: Springer.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Conway, A. R. A., & Kane, M. J. (2001). Capacity, control and conflict: An individual differences perspective on attentional capture. In C. L. Folk & B. S. Gibson (Eds.), *Attraction, distraction and action. Multiple perspectives on attentional capture*. Amsterdam: Elsevier Science.

Dienes, Z. (2014). Using Bayes to get the most out of non-significant results. *Frontiers in Psychology, 5,* 781. https://doi.org/10.3389/fpsyg.2014.00781.

Drummond, S. P., Brown, G. G., Gillin, J. C., Stricker, J. L., Wong, E. C., & Buxton, R. B. (2000). Altered brain response to verbal learning following sleep deprivation. *Nature, 403,* 655–657. https://doi.org/10.1038/35001068.

Einöther, S. J. L., & Giesbrecht, T. (2013). Caffeine as an attention enhancer: reviewing existing assumptions. *Psychopharmacology (Berl), 225,* 251–274. https://doi.org/10.1007/s00213-012-2917-4.

Gerě, I., & Jaušovec, N. (1999). Multimedia: Differences in cognitive processes observed with EEG. *Educational Technology Research and Development, 47,* 5–14. https://doi.org/10.1007/BF02299630.

Harp, S. F., & Mayer, R. E. (1998). How seductive details do their damage: A theory of cognitive interest in science learning. *Journal of Educational Psychology, 90,* 414–434. https://doi.org/10.1037/0022-0663.90.3.414.

Irtel, H. (2007). *PXLab: The Psychological Experiments Laboratory* (Version 2.1.19) [Computer software]. Mannheim, Germany: University of Mannheim, Retrieved February 10th, 2016 from http://www.pxlab.de.

Jeffreys, H. (1961). *Theory of probability* (3rd ed.). New York: Oxford University Press.

Kane, M. J., Bleckeley, M. K., Conway, A. R. A., & Engle, R. W. (2001). A controlled-attention view of working-memory capacity. *Journal of Experimental Psychology: General, 130,* 169–183. https://doi.org/10.1037/0096-3445.130.2.169.

Killgore, W. D. S. (2010). Effects of sleep deprivation on cognition. In G. A. Kerkhof & H. P. A. Van Dongen (Eds.), *Progress in brain research* (Vol. 185). Amsterdam: Elsevier Science.

Konstantinou, N., Beal, E., King, J.-R., & Lavie, N. (2014). Working memory load and distraction: dissociable effects of visual maintenance and cognitive control. *Attention, Perception, & Psychophysics, 76,* 1985–1997. https://doi.org/10.3758/s13414-014-0742-z.

Lavie, N. (2010). Attention, distraction, and cognitive control under load. *Current Directions in Psychological Science, 19,* 143–148. https://doi.org/10.1177/0963721410370295.

Lavie, N., Hirst, A., de Fockert, J. W., & Viding, E. (2004). Load theory of selective attention and cognitive control. *Journal of Experimental Psychology: General, 133,* 339–354. https://doi.org/10.1037/0096-3445.133.3.339.

Lee, M. D., & Wagenmakers, E. J. (2014). *Bayesian cognitive modeling: A practical course*. Cambridge, MA: Cambridge University Press.

Mayer, R. E. (Ed.). (2014). *The Cambridge handbook of multimedia learning* (2nd ed.). Cambridge, MA: Cambridge University Press.

Moosbrugger, H., & Oehlschlägel, J. (2011). *Frankfurter Aufmerksamkeits-Inventar 2 (FAIR-2) [Frankfurt Attention Inventory* (2nd ed.). Bern: Huber.

Mueller, P. A., & Oppenheimer, D. M. (2014). The pen is mightier than the keyboard advantages of longhand over laptop note taking. *Psychological Science, 25,* 1159–1168. https://doi.org/10.1177/0956797614524581.

Posner, M. I., & Boies, S. J. (1971). Components of attention. *Psychological Review, 78,* 391–408. https://doi.org/10.1037/h0031333.

Rey, G. D. (2011). Seductive details in multimedia messages. *Journal of Educational Multimedia and Hypermedia, 20,* 283–314.

Rey, G. D. (2012). A review of research and a meta-analysis of the seductive detail effect. *Educational Research Review, 7,* 216–237. https://doi.org/10.1016/j.edurev.2012.05.003.

Rey, G. D. (2014). Seductive details and attention distraction—An eye tracker experiment. *Computers in Human Behavior, 32,* 133–144. https://doi.org/10.1016/j.chb.2013.11.017.

Sanchez, C. A., & Wiley, J. (2006). An examination of the seductive detail effect in terms of working memory capacity. *Memory & Cognition, 34,* 344–355. https://doi.org/10.3758/BF03193412.

Styles, E. A. (1997). *The psychology of attention*. Hove, East Sussex: Psychology Press.

Wickens, C. D., Hollands, J. G., Banbury, S., & Parasuraman, R. (2013). *Engineering psychology and human performance* (4th ed.). Upper Saddle River, NJ: Pearson Education.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review, 9,* 625–636. https://doi.org/10.3758/BF0319632.

Maria Wirzberger works as researcher at the chair of Psychology of Learning with Digital Media at the TU Chemnitz. In 2012, she received a B.Sc. in Psychology from the University of Hagen, and completed the master's program Human Factors at the TU Berlin in 2014. Her Ph.D. project is affiliated with the interdisciplinary Research Training Group *CrossWorlds* and sheds light on cognitive processes and mechanism related to cognitive load in instructional scenarios.

Günter Daniel Rey holds the chair of Psychology of Learning with Digital Media at the TU Chemnitz as a full professor since 2013. He received a Ph.D. in Psychology from the University of Trier in 2007 and gained further research experience at the University of Würzburg and the University of Hagen. His research expertise focusses on cognitive, motivational, and social aspects of conducive design principles in the field of learning with multimedia.