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Managing One's Own Cognitive Load when Evidence of Split Attention is Present

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Summary: There is an increasing expectation in tertiary education that students take control of their own learning, experience independence and manage their own cognition. This research sought to investigate techniques for university students to manage their own cognitive load. This paper presents two experiments conducted with postgraduate university students enrolled in an educational psychology subject in an Australian university. A total of 86 students participated in Experiment 1 and 85 in Experiment 2. The results of both experiments show that it is possible to instruct students on how to self-manage split attention. Furthermore, the findings from Experiment 2 show that students can transfer skills of split-attention management when provided with new instructional materials. The implications for this unique direction of cognitive load theory research are discussed.

Cognitive load theory (CLT; Paas, Renkl, & Sweller, 2003; Sweller, Ayres, & Kalyuga, 2011) has identified a number of design principles that inform the development of instructional materials to support the efficient use of working memory. The focus of research in CLT over the last three decades has been on how instructional designers or educators can optimally design learning materials on the basis of CLT principles (instructor-managed cognitive load). One well-known design principle is integrating spatially separated sources of information such as text and diagram to reduce the need for a learner to search and match the relevant information (split-attention effect). The study reported in this paper examined how learners can self-manage cognitive load when presented with instructional materials with evident split attention. This study represents a new area in CLT research, as this is one of the first studies that has focused on empowering learners to manage their own cognitive load by being taught CLT design principles that they can apply when studying instructional materials not designed on the basis of CLT techniques (self-managed cognitive load).

Cognitive load theory is premised on human cognitive architecture that assumes a working memory with limited capacity and an unlimited long-term memory in which information is stored in the form of schemas. From this theoretical framework, a variety of strategies have been developed to reduce the load placed on a learner's working memory to provide better learning opportunities. Principles to emerge from the research, named after the manipulations that demonstrate them, include worked example effect (e.g. Paas & Van Merriënboer, 1994; Sweller & Chandler, 1994), split-attention effect (e.g. Chandler & Sweller, 1992; Tarmizi & Sweller, 1988), redundancy effect (e.g. Bobis, Sweller, & Cooper, 1993; Chandler & Sweller, 1991), expertise reversal effect (e.g. Kalyuga, Ayres, & Sweller, 2003; Kalyuga, Chandler, & Sweller, 1998) and the imagination effect (e.g. Leahy & Sweller, 2004; Tindall-Ford & Sweller, 2006).

The split-attention effect is an attentional phenomenon that has a direct effect upon the comprehension of information. Research on the split-attention effect has demonstrated that split-attention instructions are very difficult to understand and consequently have negative outcomes for learning (Ayres & Sweller, 2005; Ginns, 2006). For example, to understand the information in Figure 1, one needs to mentally integrate the diagram and accompanying text, as neither is intelligible in isolation. To understand this material, the learner must hold small segments of text in working memory while searching for the matching diagrammatic entity, with this ongoing process continuing until all the information is rendered intelligible. Because there is less need to search and match with integrated materials, extraneous cognitive load is significantly reduced, making it easier to learn (Sweller, Van Merriënboer, & Paas, 1998).

A focus of CLT research over the last two decades has been on developing alternative instructional formats that physically locate related information and joining them together in order to avoid extensive searching and matching and thus reducing extraneous load. An example of an integrated instructional design is demonstrated in Figure 2. Fragments of text are directly embedded into the diagram in close proximity to corresponding components of the diagram. Arrows directed from the text to the corresponding elements of the diagram are used to make the search process easier for learners.

The foundation research into split attention was conducted by Tarmizi and Sweller (1988) using geometry problems and worked examples. Tarmizi and Sweller (1988) were concerned that previous attempts to use worked examples in the mathematical domain were highly effective, but for geometry, it was not the case. Further investigation led Tarmizi and Sweller (1988) to conclude that the separation of diagram and the necessary solution path was placing additional strain on working memory. This research demonstrated, by integrating the information contained in the worked examples (diagram and solution), that participants given the integrated information outperformed those who were presented with the original format (which required them to split their attention). Following the Tarmizi and Sweller (1988) work, a number of key studies explored the split-attention effect in the content domains of mathematics (Sweller, Chandler, Tierney, & Cooper, 1990), physics (Ward & Sweller, 1990), electrical engineering (Chandler & Sweller, 1991), instruction of computer software (Kalyuga, Chandler, & Sweller, 1999), instructional multimedia

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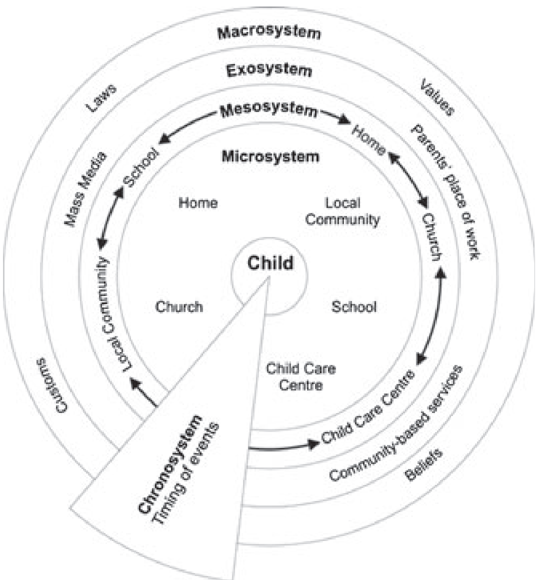
Ecological Systems Theory (by Urie Bronfenbrenner)

The child is viewed as developing within a complex system of relationships that are shaped by influences at many levels within the surrounding environment. The theory focuses on the context or the environment in which children develop, rather than on development itself. The environment is regarded as a series of structures (illustrated as layers) that are embedded in one another. From this perspective each layer in the child's environment is seen as exerting a powerful influence on development. Figure 1 below illustrates the layers of the theory;



Microsystem – Immediate context where the child develops: Home (including parents, siblings) school (including friends, peers) and the local community. This setting is where the majority of research into child development takes place.

Mesosystem – connections between the microsystem. For example, the way the family interact with the school will demonstrate the influence that both environments have on academic progress. When learning is valued in the home and effective communication with the school, opportunities for success are likely to be increased.

Exosystem – Places the child does not enter very often but has an indirect effect on their development. This includes; parents place of work, community based services, mass media and extended family. For example, children's lives can be significantly affected by what happens in their parents' places of employment, even though they may never enter them. Factors such as pay rise, loss of employment or added pressures all influence the relationships and contexts in which children operate. Another example is mass media: television, radio and other aspects of the media affect children constantly and yet they generally have no control or input into their content

Macrosystem – Values, Beliefs, customs and laws shared by the culture. These factors all contribute to the functioning of various systems such as the family, the legal system and the education system.

Chronosystem – Changes in the child's overall environment that occurs across time. These changes may produce changes that significantly impact on a child's development. Examples include birth of a sibling, moving house, parent divorce.

Bronfenbrenner's model allows one to develop a more comprehensive picture of child development by taking into account the child, the immediate setting in which interactions occur as well as the variety of other contexts that influence development. It emphasises the dynamic nature of a child's development through the integration of a complex array of factors.

Adapted from: Vialle, Lysaght & Verenikina, 2008, p.122-124.

Figure 1. Example of split-attention materials

(Mayer & Chandler, 2001; Moreno & Mayer, 1999) and, more recently, music instruction (Owens & Sweller, 2008).

Cognitive load theory research focused on split attention has consistently indicated the reduction of extraneous load that occurs when learning materials are integrated to assist more efficient processing. Currently, the most efficient method for dealing with split attention is thought to be through integrated instructions. This technique, which requires instructor-manipulated interventions, represents a form of *instructor-managed cognitive load*.

The two experiments reported in this paper represent a different direction for the use of CLT in education. Previous research has focussed on the use of CLT in designing instructional material for educators, but there is no research that has investigated student application of CLT design principles. Thus, this series of experiments examined the effects of teaching students strategies to manage their own cognitive load. The split-attention effect was chosen as it is the most common effect demonstrated in instructional materials across all educational domains (Clark, Ngyuen, & Sweller, 2006).

The overall objective of this study was to examine how learners can self-manage cognitive load when presented with instructional materials with evident split attention. The central hypothesis was that learners who are guided on how to self-manage cognitive load when presented with instructional materials with split attention will outperform learners who are presented with instructional materials with split–attention and not given guidance.

For both experiments, participants were randomly assigned to one of three conditions:

1. Conventional split attention formatted instructional materials (Group 1—split attention)
2. Integrated instructional materials (Group 2—instructor-managed cognitive load)
3. Conventional format and given guidance on how to manage split attention (Group 3—self-managed cognitive load)

The purpose of Experiment 1 was to firstly confirm the split-attention effect in the instructional materials, that is, test that condition 2 (Group 2) was superior to condition 1 (Group 1) and, secondly, test whether the guidance devised to assist learners to self-manage the split-attention effect (Group 3) led to better learning performance than the conventional split-attention condition (Group 1).

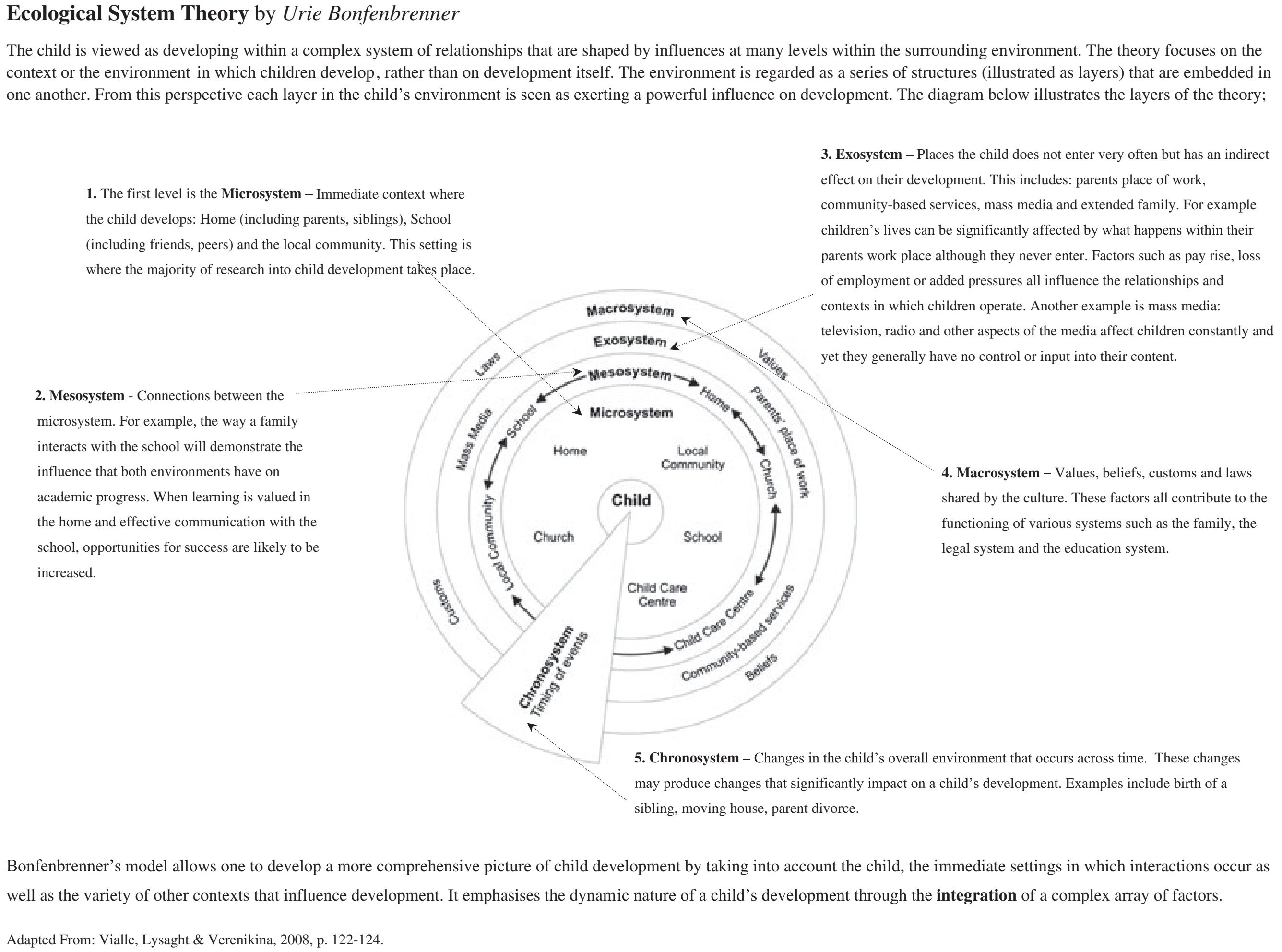


Figure 2. Example of integrated materials

Experiment 2 used the same instructional materials as Experiment 1 but was extended to include a transfer task that examined if participants (Group 3) could apply their knowledge of self-managing the split-attention effect to a new learning domain. There were two parts to the experiment. Part 1 replicated Experiment 1, and in Part 2, participants in each of the three groups were presented with a set of new instructional materials with evident split attention, and performance was measured similar to Part 1. Pilot studies were conducted prior to each experiment to refine the instructional and test materials.

EXPERIMENT 1

It was predicted that the integrated condition (Group 2) would outperform the split-attention condition (Group 1) in performance measures because of the reduction in extraneous cognitive load imposed by integrated instructional formats (Hypothesis 1). It was also expected that the conventional split attention plus guidance condition (Group 3) would outperform Group 1 (conventional split attention) in performance measures because the guidance about self-managing cognitive load would serve to reduce extraneous load (Hypothesis 2).

Method

Participants and design

A total of 86 university students (61 female, 25 male, aged 21–44 years) volunteered to participate in Experiment 1. The mean age for participants was 26.31 ($SD = 4.78$). All participants were enrolled in a graduate teaching programme (2009 cohort) at an Australian university. Three participants who indicated prior knowledge of the information being presented were excluded from the study.

Participants took part in this experiment during the final 25 minutes of tutorial time. Four separate tutorial classes were involved in the study. They had been informed of the study one week prior to it being conducted. All were informed of the general nature of the experiment and what would be required if they agreed to participate.

Materials and procedure

The instructional material explaining Urie Bronfenbrenner's 'Ecological systems theory' was presented in an educational psychology textbook (Vialle, Lysaght, & Verenikina, 2008, pp.172–174) in the form of split attention. Thus, for purposes of this research, the same content about the 'Ecological systems theory', which comprised two pages in the textbook, was presented to each group but formatted as follows for each of the three conditions:

Group 1—conventional split attention: The content was formatted in a similar way as in the textbook but presented on an A3 sheet of paper so that participants could view all the content from one sheet of paper (Figure 1).

Group 2—instructor-managed cognitive load: The content was reformatted to reduce split attention by integrating the text with the diagram. Developing the integrated material involved, firstly, reviewing the research concerning split attention (e.g. Ayres & Sweller, 2005; Chandler & Sweller, 1991; Tarmizi & Sweller, 1988) and reformatting the content presentation appropriately (Figure 2).

Group 3—self-managed cognitive load: Group 3 instructional materials were developed to assist participants to integrate the text with the diagram in a similar fashion to the integrated format. The explicit guidance was presented on a separate A4 piece of paper attached/stapled to the front of the learning materials that were presented on an A3 sheet of paper. Participants were explicitly asked to implement the guidance (Figure 3) before attempting to learn the materials.

All participants were asked to review their materials for 10 minutes (learning phase). Following the learning phase, the researcher handed out to all participants a post-test that was formatted as single sided stapled A4 booklet. The test consisted of recall, near transfer and far transfer items. Participants were given 15 minutes to complete the post-test.

The recall item required participants to record all relevant aspects of the diagram (each component of ecological systems theory—see Figure 1) and had a maximum score of 15. Example of near transfer was 'What system impacts on the child due to changes in their environment over time?' and participants could achieve a maximum score of 3. Far transfer items included 'A homework centre in the local community has closed down due to lack of funding. What system does this correspond to?' and participants could achieve a maximum score of 4. All post-test measures were considered dependant variables (recall, near transfer, far transfer).

Compliance was an additional measure included for analysis. 'Compliance' was measured for participants allocated to Group 3 of the experiment and referred to participant use of the guidance attached to the instructional materials. Participants in Group 3 were considered 'compliant' if they utilised at least one of the three strategies provided in the guidance. Evidence of compliance required examination of the instructional materials (A3 sheet of paper) to determine if participants had implemented the guidance.

Mental effort ratings were asked from participants at the completion of the learning phase, for example, 'How much mental effort did you invest to learn this material?' and after each question in the post-test, for example, 'How much mental effort did you invest to answer this question?' Mental effort ratings are considered a subjective measure of cognitive load that have been developed and tested during the past 20 years of CLT research (for an overview, see Paas, Tuovinen, Tabbers, & Van Gerven, 2003). The rating provides an indication of the mental effort involved in a task. Subjective measures have been demonstrated to be as effective in assessing mental load as physiological measures such as pupil dilation and heart beat patterns (Paas et al., 2003; van Gog & Paas, 2008). The mental effort rating scale as developed by Paas (1992) was used, except that because of text formatting constraints, only 1, 3, 5, 7 and 9 were labelled. Rating 1 indicated 'very, very low mental effort', 3 'low mental effort', 5 'moderate mental effort', 7 'high mental effort' and 9 'very, very high mental effort'.

At the completion of the testing session, participants were given the opportunity to describe the techniques they used in conducting the learning task. Although qualitative analysis of these responses has been conducted, these data have not been extensively reported here because of length restrictions.

Results and discussion

One-way analysis of variance (ANOVA) was conducted on test performance scores to explore any difference between the three groups involved in Experiment 1. Means and standard deviations are included in Table 1. An alpha level of 0.05 was used as the criterion for determining statistical significance.

Performance measures

A one-way ANOVA indicated a significant main effect of group for the recall test items, $F(2, 83) = 4.91$, $MSe = 9.266$,

The 3 tasks below will help you to learn the material more effectively by making efficient use of your working memory.

Please complete the tasks <u>before</u> you start reading the material presented on the A3 page:

1. Draw a circle around the information for each system on the right hand of your page (microsystem, mesosystem, exosystem, macrosystem, chronosystem). NOW draw an arrow to link it to it's corresponding place in the diagram. The first one has been done for you.
2. NUMBER each system in sequence (eg., 1. Microsystem, 2. Exosystem, 3. Mesosystem etc) on the diagram and the text. The first one has been done for you.
3. Now read through the material. Whilst learning the material, emphasise (circle, underline, highlight) key words on your paper (with a pen/ highlighter).

Figure 3. Guidance provided on a separate A4 sheet of paper

Table 1. Experiment 1—means and standard deviations (in parentheses) for test scores

Group	Performance measures		
	Recall	Near transfer	Far transfer
1—Conventional ($n=27$)	9.34 (3.67)	2.00 (0.961)	1.78 (1.37)
2—Instructor-managed cognitive load ($n=29$)	11.81 (2.11)	2.38 (0.73)	3.34 (0.90)
3—Self-managed cognitive load ($n=27$)	10.11 (3.17)	2.54 (0.64)	2.64 (1.34)
Total score	/15	/3	/4

$p<.05$, partial $\eta^2=0.33$. Post-hoc comparisons using Bonferroni contrasts (used throughout) showed that Group 2 performed significantly better on recall than Groups 1 and 3. There was no significant difference between Group 1 and Group 3, despite a slightly higher mean for the group with guidance (Group 3).

The one-way ANOVA for near transfer questions also demonstrated a significant main effect of group, $F(2,\ 83)=3.384$, $MSe=0.615$, $p<.05$, partial $\eta^2=0.28$. Post-hoc comparisons indicated Group 3 performed significantly better than Group 1, and Group 3 performed slightly, but not significantly, better than Group 2.

One-way ANOVA for the far transfer test items also revealed a significant main effect of group, $F(2,\ 84)=11.640$, $MSe=1.477$, $p<.05$, partial $\eta^2=0.47$. Post-hoc results indicated Group 2 outperformed Groups 1 and 3, and again Group 3 outperformed Group 1.

Mental effort rating on instruction

A one-way ANOVA was conducted on the ratings of mental effort that participants were asked to provide directly after the learning phase. Results indicated no significant effect between groups ($F<1$). Thus, there was no significant difference between groups for mental load ratings.

Guidance compliance

For measures of compliance within Group 3, 89% of participants (24/27) utilised the split-attention guidance. Compliance ratings were recorded if participants utilised at least one of the three split-attention management tasks (Figure 3). The majority of compliant participants performed all three suggested tasks (number, link and highlight keywords).

The results from Experiment 1 confirmed both hypotheses in relation to split attention. The split-attention effect was replicated with Group 2 outperforming group 1. The second hypothesis was also confirmed, which indicated that the provision of guidance (Group 3) in managing split attention can allow participants to learn the material more efficiently. The additional guidance offered to the conventional instructions appears to have improved learning efforts for participants allocated to Group 3.

EXPERIMENT 2

Experiment 2 sought to measure the transferability of the split-attention management skills. The results from Experiment 1 showed that providing guidance on how to self-manage split-attention instructional materials was beneficial as the conventional split attention plus guidance (self-managed cognitive load) condition outperformed the conventional split-attention condition on transfer items. Experiment 2 sought to explore whether this skill might be transferred to a new learning domain. Providing participants with a new set of materials with evident split attention would test whether they would be able to transfer the skill to a new learning domain, thus providing evidence for the self-managed cognitive load effect.

Experiment 2 was structured into two parts. The aim of Part 1 was to replicate the split-attention effect (as evident in Experiment 1), and the aim of Part 2 was to test whether the self-management skills acquired by Group 3 would be transferable to a new learning domain.

Part 1 of Experiment 2 had similar hypotheses as Experiment 1; that is, it was predicted that the integrated condition (instructor-managed cognitive load, Group 2) would outperform split-attention condition (Group 1) in performance measures because of the reduction in extraneous cognitive load imposed by integrated instructional formats (Hypothesis 1). It was also expected that the conventional split attention plus guidance condition (self-managed cognitive load, Group 3) would outperform Group 1 (conventional split attention) in performance measures because the guidance about self-managing cognitive load would serve to reduce extraneous load (Hypothesis 2).

For Part 2 of Experiment 2, it was hypothesised that participants allocated to Group 3 in Part 1 of Experiment 2 would transfer self-management skills to the new split-attention instructional materials, leading to a reduction in extraneous load and thus outperform Group 1 (hypothesis 2). If the skills would be transferred, it was hypothesised that they would enhance learners' performance on post-test measures.

Method

Participants and design

In total, 85 university students (61 female, 24 male, aged 20–56 years) volunteered to participate in Experiment 2. The mean age for participants was 26.64 ($SD=7.33$). All participants were enrolled in graduate teaching programme (2010 cohort) at the same Australian university as in Experiment 1. Four participants were excluded from the study, because they indicated prior knowledge of the information being presented.

Materials and procedure

Participants who volunteered for the study were exposed to the experiment at the commencement of the four tutorial classes. They had been informed of the study one week prior to it being conducted. All were informed of the general nature of the experiment and what would be required if they agreed to participate. Participants were randomly assigned to one of the three experimental groups.

For Experiment 2, Part 1, the instructional materials were identical to Experiment 1. All participants were given the learning materials on an A3 sheet of paper and asked to study the information for 10 minutes. Participants were informed that they would be examined on the content of the document directly after the 10-minute learning phase.

Participants answered the same items used in the testing phase of Experiment 1—a series of questions measuring recall, near transfer and far transfer. This occurred directly after the learning phase. All performance-based questions were identical to the items used in Experiment 1, including the measure of compliance. The same mental effort rating scale as in Experiment 1 was used.

Part 2 of Experiment 2 proceeded directly after Part 1. All participants in each of the three conditions were presented with a completely new set of instructional materials that demonstrated evidence of split attention (Figure 4). Again, participants were asked to study the material for 10 minutes and then to answer questions that related to the content. Similar to Experiment 1, when students had completed all items, they folded their answer booklet inside the test materials and waited for all to complete.

Results and discussion: Experiment 2, Part 1

One-way ANOVA was conducted on test performance scores to explore any difference between the three groups involved in Experiment 2, Part 1. Means and standard deviations are presented in Table 2.

Performance measures, Part 1

One-way ANOVA indicated a significant main effect of group for recall test items, $F(2, 81) = 6.37$, $MSe = 13.10$, $p < 0.05$, partial $\eta^2 = 0.37$. Post-hoc comparisons indicated that Group 2 recalled significantly more items than Groups 1 and 3, which did not differ from each other.

The one-way ANOVA for near transfer questions also demonstrated a significant main effect, $F(2, 81) = 3.38$, $MSe = 0.62$, $p < .05$, partial $\eta^2 = 0.386$. Post-hoc comparisons indicated that Group 2 and Group 3 performed significantly better than Group 1 but did not differ from each other.

The one-way ANOVA for the far transfer test items also revealed a significant main effect, $F(2, 81) = 11.64$, $MSe = 1.48$, $p < .05$, partial $\eta^2 = 0.68$. Post-hoc results indicated that Group 2 outperformed Groups 1 and 3, and again Group 3 outperformed Group 1.

The results for recall, near transfer and far transfer for Part 1 of Experiment 2 were almost identical to the results of Experiment 1. This was expected, as it was a repeat of

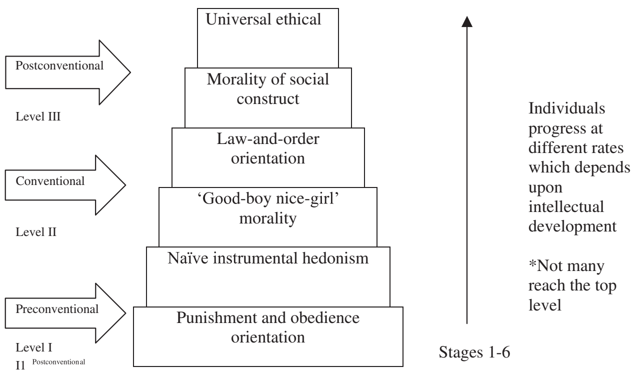
Kohlberg's Stages of Morality

Kohlberg (1969, 1980), whose research closely follows Piaget's pioneering investigations, studied moral development by posing moral dilemmas to groups of children, adolescents and adults. These dilemmas took the form of stories, among the best known of which is the story of Heinz (Kohlberg, 1969). Paraphrased here:

Heinz's wife was dying of cancer. One special drug recently discovered by a local pharmacist might save her. The pharmacist could make the drug for $200 but was selling it for 10 times that amount. So Heinz went to everyone he knew for the money but could only scrape together $1000. He asked if he could pay the rest later but the pharmacist refused. Desperate, Heinz broke into the pharmacy and stole the drug for his wife? Should he have done that? Why?

Children's responses suggest three levels in the development of moral judgements, each consisting of two stages of moral orientation (shown in Figure 1). Three levels are sequential, although succeeding levels never entirely replace preceeding ones, making it almost impossible to assign ages to them.

Figure 1. Kohlberg's levels of Morality



(Adapted from: LeFrancois, 1995)

Preconventional Level

At the preconventional level, children's judgement of right and wrong takes one of two orientations. In the first (stage 1), children believe that evil behaviour is that likely to be punished and good behaviour is based on obedience. Thus children do not evaluate right or wrong; judgement is based solely on consequences to the child.

The second preconventional moral orientation (stage 2) is a hedonistic one in which children interpret good as that which is pleasant and evil as undesirable consequences. Children will go out of their way to do something good for someone if they themselves will benefit from the deed.

Conventional Level

The second level of morality is conventional role conformity, which reflects the increasing importance of peer and social relations. Stage 3 is defined as morality designed to maintain good relations. Hence moral behaviour receives wide approval from significant people; parents, teachers, peers and society at large.

Stage 4, conformity to rules and laws, is also related to children's desire to maintain a friendly status quo. Thus conformity to law becomes important for maintaining adults' approval.

Postconventional Level

At the highest level, the postconventional level, individuals begin to view morality in terms of individual rights and as ideals and principles that have value as rules or laws apart from their influence on approval (stage 5). As noted, stage 5 moral judgements are rare, even for adults.

Stage 6 judgments are based on fundamental ethical principles, are even rarer. Colby and Kohlberg (1984) suggest that there is some doubt as to whether or not stage 6 should even be included as a stage in moral development.

Kohlberg's early research suggests that children progress through the stages of moral development in predictable sequence and at roughly the same ages. Theoretically this makes sense because moral judgments are essentially cognitive and would therefore be expected to reflect the level of cognitive development.

(Source: Lefrancois, 1995)

Figure 4. Part 2, Experiment 2 learning material

Table 2. Experiment 2, Part 1—means and standard deviations (in parentheses) for test scores

Group	Performance measures		
	Recall	Near transfer	Far transfer
1. Conventional ($n = 29$)	9.052 (4.09)	1.90 (1.05)	1.38 (.86)
2. Instructor-managed cognitive load ($n = 24$)	12.58 (2.87)	2.58 (0.72)	3.42 (0.72)
3. Self-managed cognitive load ($n = 28$)	10.23 (3.67)	2.57 (0.50)	2.64 (1.10)
Total score	/15	/3	/4

Experiment 1, with a similar number of participants used for the study. Again, compliance measures were recorded to ensure participants implemented the guidance provided.

Mental effort rating on instruction, Part 1

A one-way ANOVA was conducted on the ratings of mental effort that participants were asked to provide directly after the learning phase. Results indicated no significant effect between groups, $F(2, 81) = 1.23$. Thus, like Experiment 1, there was no significant difference between groups for mental load ratings, $p = .298$.

Guidance compliance, Part 1

For measures of compliance within Group 3, 89% of participants (25/28) utilised the split-attention management guidance. As with Experiment 1, compliance was measured by evidence of using the suggested guidance regarding management of split attention. Compliant ratings were recorded if participants utilised at least one of the three split-attention management tasks. The majority of compliant participants (18/25) performed all three suggested tasks (number, link and highlight keywords).

The results from Experiment 2, Part 1, confirmed both hypotheses in relation to split attention. The split-attention effect was again replicated with Group 2 outperforming conventional groups in performance-based tasks. The second hypothesis was confirmed, which indicated that the provision of guidance in managing split attention can help participants to learn instructional material more efficiently.

The additional guidance offered to the conventional instructions improved performance across all three measures. For recall, the difference was not statistically significant, but for both near and far transfer items, Group 3 outperformed Group 1. This leads to the conclusion that the additional instructions provided to Group 3 in the form of guidance allowed learners to actively self-manage extraneous load by conducting the three tasks considered ‘preliminaries to learning’ before attempting to study the experimental materials.

Results and discussion: Experiment 2, Part 2

One-way ANOVA was conducted on test performance scores to explore any difference between the three groups involved in Experiment 2, Part 2. Means and standard deviations are included in Table 3.

Performance measures, Part 2

The one-way ANOVA indicated a significant main effect for recall test items, $F(2, 81) = 4.29$, $MSe = 3.510$, $p < .05$, partial $\eta^2 = 0.32$. Post-hoc tests indicated that Group 3 recalled more items than Groups 1 and 2.

The one-way ANOVA for near transfer questions also demonstrated a significant main effect, $F(2, 81) = 7.76$, $MSe = 1.901$, $p < .05$, partial $\eta^2 = 0.41$. Post-hoc tests indicated that Group 3 outperformed both Group 1 and Group 2.

The one-way ANOVA for the far transfer test items again revealed a significant main effect, $F(2, 81) = 13.04$, $MSe = 1.54$, $p < .05$, partial $\eta^2 = 0.50$. Post-hoc tests indicated that Group 2 and Group 3 outperformed Group 1.

Mental effort rating on instruction, Part 2

A one-way ANOVA was conducted on the instructional rating (of mental effort) that participants were asked to provide directly after the learning phase. Results indicated no significant effect between groups, $F(2, 81) = 1.23$. Thus, like in Experiment 1, there were no significant differences between groups for mental effort ratings.

Guidance compliance, Part 2

An examination of the experimental materials for those allocated to Group 3 occurred. The results indicated that a number of participants repeated the instructions given ($n = 13$) in Part 1 of the experiment. The most common response was underlining key words ($n = 10$), with only a few numbering ($n = 5$), and two linked the text with diagram (drew lines connecting information in the diagram with its corresponding place in text).

The results for Part 2 of Experiment 2 did demonstrate that those allocated to Group 3 were at an advantage to Groups 1

Table 3. Experiment 2, Part 2—means and standard deviations (in parentheses) for test scores

Group	Performance measures		
	Recall	Near transfer	Far transfer
1—Conventional ($n = 29$)	7.21 (2.26)	2.34 (1.59)	1.86 (1.46)
2—Instructor-managed cognitive load ($n = 24$)	8.12 (1.78)	2.75 (1.26)	3.42 (0.78)
3—Self-managed cognitive load ($n = 28$)	8.64 (1.52)	3.75 (1.24)	3.25 (1.32)
Total score	/10	/4	/4

and 2 because they were exposed to self-management of split-attention techniques. This in turn provided an ability to reduce extraneous load imposed by the need to search and match between text and diagram to make sense of the materials.

DISCUSSION

The major finding from this study relates to the ability of students to learn to manage the cognitive load created by instructional materials that require them to split their attention between text and diagrams. As a precursor to this, it was essential to demonstrate that the materials do indeed create such a burden and that it impacts on learning. Both experiments showed that when split attention was managed for participants by presenting the text and diagram in an integrated format (cf. Chandler & Sweller, 1991), they consistently outperformed those allocated to non-integrated materials, thus replicating the split-attention effect with these materials. It is important to note that the benefit of providing integrated material was apparent even if the other participants were instructed to integrate the materials for themselves.

For Experiment 1, participants in the integrated condition performed significantly better than the self-management group across recall and far transfer performance items. For near transfer items, it was found that the self-management group slightly outperformed the integrated group but not at a statistically significant level. For Experiment 2, the integrated condition outperformed the self-management group for recall and far transfer. There were no significant differences between the self-management and integrated groups for near transfer items. Given the additional load on the self-managing group, because of the requirement to perform the integration of material, the lack of improved performance in this group is perhaps not surprising. In effect, the instructions to this group require them to split their efforts between learning the material and changing the format.

The most interesting outcome from this study is the evidence supporting the suggestion that teaching participants how to self-manage the split-attention effect will benefit learning. The aim of the study was to investigate if such instruction could provide participants with a new strategy to manage split attention and aid in their learning of novel material. When faced with the task of learning a new set of materials, the self-management group outperformed the convention split-attention format and the integrated format groups for recall and near transfer items, suggesting that they have learned a new strategy that effectively improves learning. For far transfer items, there were no differences between the self-management group and the integrated format group; however, both groups performed better than the traditional format group, but performance was quite high on this task, raising the concern of ceiling effects obscuring the pattern of results, and it may be that the test questions were not entirely appropriate.

The results from the research show promise and potential for future CLT studies to investigate how students can self-manage cognitive load when exposed to inefficiently designed learning materials. The results from Experiment 2, Part 2, are particularly promising as it shows that generic skills can be transferred to new contexts.

The main limitation of the research was the measurement of cognitive load. This study failed to produce any useful mental effort ratings that would serve to compliment performance measures to calculate efficiency measures (Paas & Van Merriënboer, 1993). This issue needs to be more closely investigated, and careful use of the original scale developed by Paas (1992) may have provided more useful data.

Another limitation of the study was an additional difference between the group taught to self-manage split attention and the other groups, which is that the instructions to the split-attention group asked them to emphasise keywords in their approach to the material. On the face of it, it is possible that this difference in instruction contributed to the difference in performance between the groups. However, in the response to the qualitative question asked at the end of each experiment, where participants were invited to comment on the methods they used, it was clear that equivalent numbers of participants in all three groups used a strategy of highlighting keywords. In Experiment 1, 44% of participants in Groups 1 and 3 and 34% of Group 2 reported highlighting keywords. For Experiment 2, 21% of participants in Group 1 indicated they highlighted keywords, Group 2 included 34% and 29% for those allocated to Group 3. This suggests that although the groups were instructed differently in this regard, it did not result in a genuine difference in behaviour that might have contributed to differences in performance. However, future research should explore the impact of using keywords with split-attention materials in more detail.

The findings of this research have a number of implications for the instructional design of learning materials. There are implications for general study skills courses provided to university students. Worked examples of split attention and basic tips on how to best manage split attention might be useful within a section at the beginning or end of a textbook. Other cognitive load effects have developed advice for instructional designers that could be relayed to students. Further research into other effects could emphasise study tips for all instances of cognitive overload.

Future research into the area of self-directed learning and cognitive load management needs to look at the other instructional effects within CLT. Experimental studies investigating efficient methods of guiding students to manage their cognitive load will further improve the tools provided to students during their studies. Replication of studies investigating a potential 'self-management effect' that focus on both paper-based and online learning materials (eg., Agostinho, Tindall-Ford, & Roodenrys, 2010) is also a future direction.

In summary, the results of the two experiments reported in this paper have demonstrated that it is possible to instruct students on how to self-manage cognitive load to benefit their learning. The procedure followed suggests that efforts to manage split attention by restructuring the material, using highlighting, arrows and placing material in proximity with diagrams, applied prior to learning the material, results in as effective learning as if the work of integration had been done for the student. Further research is required to specify the key factors involved in self-management of cognitive load and to develop efficient ways of teaching students how to self-manage cognitive load.

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