The Expertise Reversal Effect:

Implications for the Use of Schematic Drawings in Sonography Instructional Design

Didi Bourbon, Kristen Lueck, and Mary Wingold

Purdue University

Abstract

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Introduction

Cognitive load theory offers a framework for research into the demand placed on working memory by performance of mental tasks. Studies show that cognitive load may be reduced by instructional design elements which provide educational interventions. (Khacharem, Zoudji, & Kalyuga, 2015; Sweller, 1994). Research into the interaction of prior knowledge and educational supports has shown that while instructional aids may be useful to students with low prior knowledge, they may increase cognitive load and create an obstacle to learning for students with high prior knowledge (Kalyuga, 2007). The research into these adverse interactions is known as expertise reversal effect.

Since the mid-90s, researchers have created experimental designs to investigate how learners' prior knowledge may affect transfer. Numerous research studies have investigated the interactions of prior knowledge levels and iconic representation in instructional design across multiple domains. To our knowledge, none have specifically considered instructional modes for ultrasound technology, which will be the basis of this experiment.

This study will evaluate the effects of prior knowledge regarding relational anatomy as it relates to the introduction of schematic drawings within the sonography curriculum. If schematic drawings improve transfer and retention regardless of levels of expertise, then the expertise reversal effect does not take place within this setting and schematics should be used in all levels of training. It is our hypothesis, however, that expertise levels will influence effectiveness of schematic usage.

Literature Review

Redundancy

There are several factors that impact cognitive transfer. Increased cognitive load, secondary to redundant material, leads to an expertise reversal effect in high prior knowledge learners (Blayney et al., 2016; Leslie et al., 2012). This concept is based on the principle that learners' working memory may be overwhelmed by duplicate information. Kalyuga, Chandler & Sweller (2004) suggested that an increased cognitive load would be generated if learners were required to coordinate redundant materials. For example, in research on the impact of complexity on the expertise reversal effect, Blayney et al. (2016) found evidence that segmentation of instruction of complex tasks into isolated elements benefitted novice accounting students but negatively impacted higher performing students through the redundancy effect. Rather than reducing cognitive load, the visuals forced higher level students to assimilate an iconic representation of already known material. Similarly, Leslie et al. (2012) found that audiovisual, as opposed to audio only, presentations had a negative impact on learners with prior knowledge, also suggesting an expertise reversal effect due to redundancy.

Visual Representations and Expertise Reversal Effect

Visual aids are often incorporated into instruction across many topics and fields of study. Although visual representation may be useful for students with lower prior knowledge, multiple studies suggest that expertise reversal effect may occur for students with higher prior knowledge (Chung, 2008; Hoffler, Prechtl, & Nerdel, 2010; C. H. Lee & Kalyuga, 2011; Spanjers, Wouters, Van Gog, & Van Merrienboer, 2011). In H. Lee, Plass, and Homer's (2006) study on optimizing cognitive load in computer-based science simulations, evidence suggested that visual intrinsic cognitive load may be manipulated both in comprehension and in transfer, but also found that expertise reversal effect may have occurred in students with a higher level of prior knowledge. Incorporating visuals into instruction may not always be beneficial to novice learners. For instance, Chung (2008) concluded that using only visuals resulted in better recall and less cognitive load for pronunciation, but not for meaning when he tested low prior knowledge students learning Chinese characters as a second language. Rather, the students benefited more from a dual-modality representation consisting of audio and visual representations.

A number of studies concluded that learners benefit from the addition of visuals despite their level of expertise. For instance, Kyun and Lee (2009) concluded that incorporating both conceptual and procedural worked samples into computer-based learning resulted in better learning for all students, regardless of their prior knowledge. However, the authors noted that on a relatively simple transfer task, learners with high prior knowledge did not perform as well as low prior knowledge learners. In a study of middle and high school students utilizing iconic and non-iconic science simulations by Homer and Plass (2009), they discovered that expertise reversal effect was minimal in the middle school students with higher levels of prior knowledge. They determined that the three-way interactions between cognitive development level, visuals and prior knowledge offset the reversal effect in the younger students. All levels benefitted from the use of icons. These studies provide conflicting evidence as to the effect that expertise reversal can produce within instruction.

Basis for This Study

It is essential for ultrasound students to develop a strong working knowledge of all human anatomy imaged within each specialty (e.g. vascular, echocardiography, abdominal, OB/GYN). This includes relational landmarks within each of the anatomical regions of the body. Introductory exposure to this information may be conducted through schematic presentations paired with ultrasound images. Undergraduate ultrasound students are required to balance traditional courses (physics, psychology, arts and humanities) while learning complex psychomotor and reasoning skills. This can produce cognitive overload, resulting in elevated stress and impaired performance.

Cognitive load may be managed within healthcare training (De Araujo Guerra Grangeia et al., 2016) if the curriculum is appropriately designed. According to Khacharem, Zoudji, and Kalyuga, "adapting instructional designs to learners with different amount of prior knowledge is a crucial part of effective learning" (2015, p. 756). Based on this information, the current study will address the following questions:

- Does the use of schematic drawings improve learner outcomes within ultrasound training?
- Does expertise of the learner impact effectiveness of schematics when used during training?
- Will the concept of expertise reversal impact the cognitive load within this case?

It is the desire of this study to determine the impact that levels of expertise may have on the effectiveness of visual aids through the use of schematic drawings within sonography training and education.

Methods

Participants

The participants were cardiovascular sonography students from a four-year university. Of the 60 participants, 30 were sophomores (novices) and had never received sonography instruction (11 males; 19 females). The other 30 participants were seniors (experts) who had extensive training in sonography (13 males; 17 females).

Design

Each group (novice and expert) was randomly assigned to one condition (15 to schematics and 15 to no schematics). We conducted a true experiment with randomized subjects, pretest-posttest control group (2 x 2) design. Pretest and posttest results were used to measure learning. In addition, each participant completed a computerized cognitive load subjective experience questionnaire (adapted from Kyun & Lee, 2008) after the posttest.

Materials

The study participants were provided instruction in separate classrooms (schematics vs no schematics) with both novice and expert learners present. All students received direct instruction for one hour, which consisted of ultrasound videos and lecture to emphasize coronary artery distribution and subsequent quality of cardiac wall motion. Instruction for the schematics group was enhanced using diagrams of coronary artery distributions for all parasternal and apical views (Figure 1).

The pretest was a computer-based assessment consisting of 12 video loops depicting various examples of wall motion qualities (3 normal; 5 hypokinetic; 4 akinetic). Students were given a total of 20 minutes to watch the video loops and determine whether the video shows a heart with normal, hypokinetic, or akinetic wall motion. Responses were electronically scored and reported as percentages correct. One week after instruction, participants completed a posttest. This posttest assessed the same content as the pretest, with different test items, but the number of each type of wall motion remained consistent with the pretest. In addition, students completed a cognitive load subjective experience questionnaire (adapted from Kyun & Lee, 2008). See Appendix. Participants answered each of the following 3 questions using a 5-point scale to measure cognitive load: “What effort did you make to understand the questions?” “How easy or difficult was it to understand questions?" and "How easy or difficult was it to understand the quality of wall motions?"

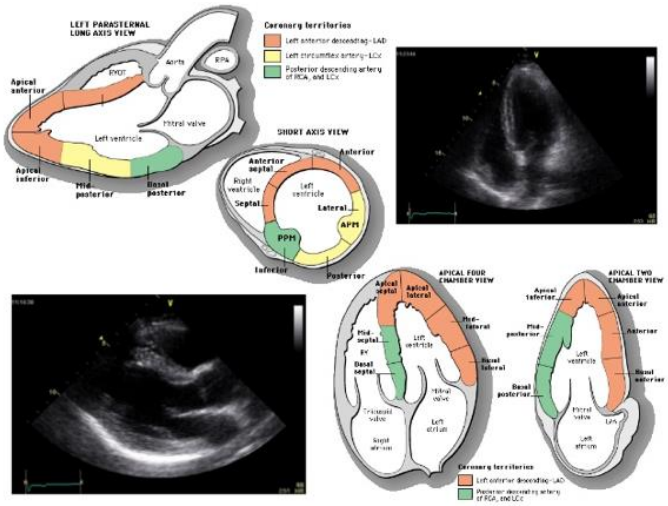

Figure 1: Schematics Example

Procedure

The procedures are summarized in Table 1.

Table 1: Procedures

Step	Schematics Group (Novice and Expert)	No Schematics Group (Novice and Expert)	Time
1	Pretest (12 questions: 3 normal, 5 hypokinetic, 4 akinetic)		20 min.
2	Direct Instruction (lecture + videos) with schematic diagrams	Direct Instruction (lecture + videos)	1 hour
1 week interval			
3	Postest (12 questions: 3 normal, 5 hypokinetic, 4 akinetic)		20 min.
4	Cognitive Load Questionnaire (3 Items)		5 min.

Results

Pretest

Posttest

Cognitive Load Questionnaire

Discussion

Appendix

Cognitive load subjective experience questionnaire (adapted from Kyun & Lee, 2008)

1. What effort did you make to understand the questions?
    1 I just skipped the questions.
    2 I roughly read the questions.
    3 I earnestly read the questions.
    4 I read the questions trying to understand well.
    5 I completely concentrated on reading the questions.
2. How easy or difficult was it to understand the questions?
    1 The questions were easy to understand.
    2 The questions were a little bit easy to understand.
    3 The questions were neither easy nor difficult to understand.
    4 The questions were a little bit difficult to understand.
    5 The questions were extremely difficult to understand.
3. How easy or difficult was it to understand the quality of wall motions?
    1 The quality of wall motions was very easy to understand
    2 The quality of wall motions was a little bit easy to understand.
    3 The quality of wall motions was neither easy nor difficult to understand.
    4 The quality of wall motions was a little bit difficult to understand.

5 The quality of wall motions was extremely difficult to understand.

References

Blayney, P., Kalyuga, S., & Sweller, J. (2016). The impact of complexity on the expertise reversal effect: experimental evidence from testing accounting students. *Educational Psychology*, *36*(10), 1868-1885. doi:10.1080/01443410.2015.1051949 (DB)

Chung, K. H. (2008). What effect do mixed sensory mode instructional formats have on both novice and experienced learners of Chinese characters?. *Learning and Instruction*, *18*(1), 96-108. (KL)

de Araujo Guerra Grangeia, T., de Jorge, B., Franci, D., Martins Santos, T., Vellutini Setubal, M. S., Schweller, M., & de Carvalho-Filho, M. A. (2016). Cognitive load and self-determination theories applied to E-learning: Impact on students' participation and academic performance. *Plos One, 11*(3), e0152462. doi:10.1371/journal.pone.0152462 (MW)

Hoffler, T. N., Prechtl, H., & Nerdel, C. (2010). The influence of visual cognitive style when learning from instructional animations and static pictures. *Learning and Individual Differences, 20*(5), 479-483. (MW)

Homer, B. D., & Plass, J. L. (2010). Expertise reversal for iconic representations in science visualizations. *Instructional Science*, *38*(3), 259-276. (DB)

Kalyuga, S. (2007). Expertise reversal effect and its implications for learner-tailored instruction. *Educational Psychology Review*, *19*(4), 509-539. (DB)

Kalyuga, S., Chandler, P., & Sweller, J. (2004). When redundant on-screen text in multimedia technical instruction can interfere with learning. *Human Factors*, *46*(3), 567-581. (MW)

Khacharem, A., Zoudji, B., & Kalyuga, S. (2015). Expertise reversal for different forms of instructional designs in dynamic visual representations. *British Journal of Educational Technology*, *46*(4), 756-767. (KL, MW)

Kyun, S. A., & Lee, H. (2009). The effects of worked examples in computer-based instruction: Focus on the presentation format of worked examples and prior knowledge of learners. *Asia Pacific Education Review*, *10*(4), 495-503. (KL)

Lee, C. H., & Kalyuga, S. (2011). Effectiveness of on-screen pinyin in learning Chinese: An expertise reversal for multimedia redundancy effect. *Computers in Human Behavior*, *27*(1), 11-15. doi:10.1016/j.chb.2010.05.005 (KL)

Lee, H., Plass, J. L., & Homer, B. D. (2006). Optimizing cognitive load for learning from computer-based science simulations. *Journal of Educational Psychology*, *98*(4), 902-913. (DB)

Leslie, K. C., Low, R., Jin, P., & Sweller, J. (2012). Redundancy and expertise reversal effects when using educational technology to learn primary school science. *Educational Technology Research and Development*, *60*(1), 1-13. (KL)

Spanjers, I.A.E., Wouters, P., Van Gog, T., & Van Merriënboer, J.J.G. (2011). An expertise reversal effect of segmentation in learning from animated worked-out examples. *Computers in Human Behavior*, *27*(1), 46-52. (MW)

Sweller, J. J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning & Instruction*, *4*(4), 295-312. (DB)

Van Gog, T., & Kester, L. (2012). A test of the testing effect: acquiring problem-solving skills from worked examples. *Cognitive Science, 36*(8), 1532-1541. (MW)