Reducing Cognitive Load While Teaching Complex Instruction to Occupational Therapy Students

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Cognitive load theory is a field of research used to improve the learning of complex cognitive tasks by matching instruction to the learner’s cognitive architecture. We used an experimental posttest control-group design to test the effectiveness of instruction designed to reduce cognitive load (CL) and improve instructional effectiveness in teaching complex instruction to 24 first-year master’s students under authentic classroom conditions. We modified historically taught instruction using an isolated-to-interacting-elements sequencing approach intended to reduce high CL levels. We compared control and modified instructional formats using written assessment scores, subjective ratings of CL, and task completion times. Analysis of variance revealed significant differences for postinstruction, posttest CL ratings, and delayed written posttest scores (p < .05). No significant differences were identified for posttest completion times. Findings suggest that this approach can be used to improve instructional efficiency in teaching human locomotion to occupational therapy students.


The cognitive task of learning entails a relatively permanent change in a person’s knowledge or behavior based on experience (Mayer, 1982). Cognitive load theory (CLT) is an instructional design theory and field of research used to construct and teach complex instruction (Sweller, 1988). The central focus of CLT is to improve learning by optimally matching instruction and instructional processes with strengths and limitations of working and long-term memory (Kirschner, 2002).

Working and Long-Term Memory

Working memory (WM) is responsible for the temporary storage and manipulation of information (Baddeley, 1992a). Although able to attend to an impressive range of cognitive tasks such as understanding and reasoning, WM presents with a commonly unrecognized information-processing bottleneck. That is, WM can only process about seven items of information at any one time, can only hold information active for a few seconds without rehearsal, and becomes increasingly prone to errors as learning tasks become more complex (Baddeley, 1992b; Cowan, 2001; Miller, 1956). If instruction exceeds the capabilities of WM, some or all information will be lost, and learning will be hampered or ineffective (Sweller & Chandler, 1994). In contrast, long-term memory (LTM) effectively stores information on a permanent basis, with the ability to recall infrequently retrieved information being somewhat variable (Baddeley, 1992a; Ericsson & Kintsch, 1995). Accordingly, human intellect and behaviors (e.g., occupational therapy problem-solving skills) are principally directed by large stores of previously acquired information (Sweller, Ayres, & Kalyuga, 2011). The capabilities of LTM are credited to the formation of well-organized collections of information called schemata (Shiffrin & Schneider, 1977).
Cognitive Load

Cognitive load (CL) is the total amount of mental effort imposed on WM resources at a point in time (Sweller, van Merriënboer, & Paas, 1998). CL is broken into extraneous cognitive load (ECL) and intrinsic cognitive load (ICL); ECL plus ICL equals total CL (Kirschner, 2002; Sweller, 1994). ECL represents cognitive resources devoted to mentally processing how instruction is structured and presented and is unrelated to learning and schema construction (Sweller et al., 2011). For example, unnecessary demands are placed on limited cognitive resources if a learner must restructure poorly designed instruction in order to make it suitable for learning. In practical terms, high ECL equates to reduced WM resources available for learning. In contrast, ICL represents cognitive resources devoted to the nature of instruction explicitly dedicated to learning and schema construction (Sweller, 1988). ICL is principally determined or generated by the complexity of relationships or sources of variation that the learner must concurrently maintain and process in WM for learning to occur (Baddeley, 1992b; Halford, Wilson, & Phillips, 1998).

Implications for Teaching Complex Instructional Materials

Acknowledging people’s undeniable strengths and limitations in cognitive capabilities, some instruction is difficult to learn simply because it requires the learner to concurrently maintain and process a high number of information elements and sources of variation in WM for learning with understanding to occur. For example, to examine human gait, a novice occupational therapy student must maintain knowledge of the eight phases of human gait in WM, each phase of which consists of roughly 10 highly interactive elements, while maintaining cognitive resources in reserve for problem solving. Accordingly, such instruction should be expected to impose high levels of CL whether the instruction is effective or not (Sweller & Chandler, 1994). Under such conditions, CL instructional design principles can be used to improve instructional effectiveness.

Managing Intrinsic Cognitive Load

Research into the management of ICL is in part based on the observation that instruction typically incorporates all information that is necessary for learning and understanding to occur (van Merriënboer, Kirschner, & Kester, 2003). Although doing otherwise may seem counterintuitive, CLT recognizes that such approaches to instruction can paradoxically overwhelm a learner’s available cognitive resources and impede learning under conditions such as teaching complex and new information to novice learners (Pollock, Chandler, & Sweller, 2002). At present, several studies have shown that ICL can be reduced by means of an isolated-to-interacting-elements approach in technical knowledge domains such as electrical engineering, mathematics, and accounting (Ayres, 2006a, 2006b; Blayney, Kalyuga, & Sweller, 2010; Pollock et al., 2002).

Previous studies have used a two-stage approach for teaching complex instruction in which the first stage of instruction presented isolated but meaningful subdivisions of information that could be processed by the learner without overwhelming WM. The second stage of instruction taught knowledge of relationships necessary for understanding. Benefits of the isolated-to-interacting-elements approach were attributed to the reduction of WM load and development of rudimentary schemata awarded by the first or isolated stage of instruction (Pollock et al., 2002). As expected, significantly improved test performance and significantly reduced CL were found only with high-element-interactivity test problems because low-element-interactivity content did not overburden WM resources. Additionally, no significant findings were identified between instructional formats for experienced apprentices because existing schemata allowed experienced students to learn from either format without overburdening WM resources. Acknowledging the potential benefits of an isolated-to-interacting-elements approach, the level at which interacting elements should be broken into isolated elements and guidelines describing when whole tasks should be broken down for different content areas, and knowledge domains are not known (Sweller et al., 2011; van Merriënboer & Sweller, 2005).

The purpose of this study was to test the effectiveness of instruction designed to improve attainment of learning objectives and reduce ICL in teaching introductory human locomotion to novice occupational therapy students under authentic classroom conditions. We tested the following hypotheses: Participants who receive the modified instructional formats will, compared with control group participants, (1) report lower subjective ratings of CL after instruction and a delayed written posttest, (2) have higher delayed written posttest scores, and (3) have lower assessment completion times.

Method

Research Design

We used an experimental posttest-only, randomized controlled group design. We selected the posttest-only design to support the classroom nature of this study (i.e., a pretest would be artificial and obtrusive) and to reduce
procedural threats to external validity. That is, conducting this study under authentic classroom conditions and constraints allowed for improved ecological and population validity, or generalization of study findings (e.g., settings and condition), to classroom teaching. To the contrary, contrived approaches to educational research, although they appear factually sound, are artificial; they are typically nonsense materials that could not be used for actual classroom or instructional purposes. A high potential for pretest sensitization (i.e., learners using the pretest as preinstructional strategy) was a chief concern given the short time between a pretest and a posttest. Additionally, the inability to construct a pretest that was sufficiently different than the instructor's examination questions posed clear testing threats (Trochim & Donnelly, 2006). In contrast, randomization to treatment group, homogeneity of the high-ability and known learning group, and nominal concern with participant dropout and maturation effects minimized concerns regarding internal validity.

The independent variable was instructional format, and dependent variables were postinstruction and posttest subjective ratings of CL, delayed written posttest scores, and posttest completion times. In this article, we refer to the group receiving the traditional or unmodified instruction as the control group. This study was approved by the institutional review board of Wayne State University after expedited behavioral review; recruitment entailed an information meeting and written consent.

**Participants**

Twenty-four 1st-yr master of occupational therapy (MOT) students were recruited on a voluntary basis from a total of 24 possible participants and randomly assigned to modified (n = 12) or control group (n = 12) instruction using Research Randomizer (Urbaniak & Plous, 2008). All participants were 1st-yr, third-semester MOT students enrolled in the course responsible for the introductory gait analysis curriculum; descriptive statistics are provided in Table 1. Graduate research assistants recruited potential participants by asking them to volunteer for “a study that will test the effectiveness of two instructional formats designed to teach human locomotion.” On study enrollment, participants agreed to keep details of the instruction private until study completion.

**Instruments**

**Cognitive Load Rating Instrument.** The subjective CL rating instrument used a 7-point scale directly adopted from previous research (Kalyuga, Chandler, & Sweller, 1998, 2000; Pociask & Morrison, 2008). Subjective measures of mental workload are valid and reliable and correlate highly with objective measures; reported correlations range from .8 to .99 (Moray, 1982; O’Donnell & Eggemeir, 1986). The questions were, “How easy or difficult was the instruction to understand?” and “How easy or difficult was the written assessment that you just completed?” and response options ranged from extremely easy to extremely difficult with an option of neither. This measure is conducive to classroom-based research because it is easy to administer and does not interfere with the main instructional task (Mayer & Chandler, 2001; Paas, Van Merrienboer, & Adam, 1994).

**Delayed Written Posttest.** The delayed written posttest consisted of 30 similarly structured multiple-choice questions; all questions contained one correct answer and three plausible distractors. Multiple-choice questions fully matched lecture and handout content and were directly adopted from the gait instructor’s classroom examination. Internal consistency of the written posttest was acceptable (Cronbach’s α = .80). Posttest sample questions are provided in Figure 1.

**Instruction**

Lesson content was introductory gait analysis, which included gait cycles and phases, functional requirements, identification of event markers, normative range of motion values, and normal muscle activity. Understanding basic gait, such as functional objectives and foot clearance during swing, is an essential component of what occupational therapists need to consider when working toward independence throughout all activities of daily living (ADLs). Accordingly, the *Occupational Therapy Practice Framework: Table 1. Descriptive Statistics for Participants by Instructional Format*

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Instructional Format</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control, n = 12</td>
</tr>
<tr>
<td>Age, yr M (SD)</td>
<td>23.31 (2.32)</td>
</tr>
<tr>
<td>Range</td>
<td>21–28</td>
</tr>
<tr>
<td>Gender, n (%)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1 (8.33)</td>
</tr>
<tr>
<td>Female</td>
<td>11 (91.67)</td>
</tr>
<tr>
<td>Highest earned degree, n (%)</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>4 (33.33)</td>
</tr>
<tr>
<td>Associate’s</td>
<td>1 (8.33)</td>
</tr>
<tr>
<td>Bachelor’s</td>
<td>7 (58.33)</td>
</tr>
<tr>
<td>OT program cumulative GPA M (SD)</td>
<td>3.65 (0.22)</td>
</tr>
<tr>
<td>Range</td>
<td>3.20–4.00</td>
</tr>
<tr>
<td>Prior exposure to gait content, n (%)</td>
<td>2 (16.67)</td>
</tr>
<tr>
<td>Yes</td>
<td>10 (83.33)</td>
</tr>
</tbody>
</table>

*Note. GPA = grade point average; M = mean; OT = occupational therapy; SD = standard deviation.*
Domain and Process (2nd ed.; American Occupational Therapy Association, 2008) identified the need for occupational therapy practitioners to recognize walking patterns and impairments (e.g., asymmetrical gait) and stated, “Gait patterns are considered in relation to how they affect engagement in occupations of daily life activities” (p. 636). All terms, principles, and concepts used in the instruction are commonly used in gait texts (Cameron & Monroe, 2007; Lusardi & Nielsen, 2007; Neumann, 2010; O’Sullivan & Schmitz, 2007; Perry, 1992). Both formats of instruction were reviewed for accuracy by two gait subject-matter experts, as well as the classroom instructor, and judged as fully equivalent in terms of content. The same instructor—a subject-matter expert with 15 yr of experience in this topic—taught both groups.

Control Group Instruction. Control group instruction was based on work completed by Perry (2007) and directly adopted by the aforementioned classroom instructor. Control group instruction was provided during a single 80-min face-to-face classroom lecture, excluding a scheduled 10-min break midway. The introductory gait instruction included a 25-slide printout of a PowerPoint presentation and 16 pages from a commercially available gait textbook.

Modified Instruction. The control group instruction was examined, and the content was divided across three lectures using an isolated-to-interacting-elements approach to reduce the likelihood of exceeding WM processing capabilities without altering content or total lecture time. The initial two lectures and materials included serial processing tasks and rudimentary relationships for logically subdivided content and overtly withheld relationships among gait phases, event markers, and incorporation of gait phases, which were introduced in the final integrative lecture. The three lectures were 15, 25, and 40 min in length, respectively. A detailed breakdown of content for both formats is provided in Figure 2. Operationally, the modified lectures and materials did not differ from control instruction, so no special training was needed to teach the materials. However, the instructor was trained not to include content or discuss relationships in the first two lectures unless it was overtly included in the prepared content.

Data Collection

The introductory human locomotion lectures, assessments, and data collection instruments were administered...
during the course responsible for teaching this curriculum during normal course hours. The delayed posttest was administered 1 wk after the final lecture. Procedural protocols and time-tracking logs were used to ensure adherence to the prerehearsed study processes. Three graduate students and coinvestigators, excluding the principal investigator and classroom instructor, were trained to efficiently distribute and collect all materials (e.g., recording start and stop times and confirming that all materials were properly completed).

Data Analysis

We used univariate analysis of variance (ANOVA) to assess between-group differences, and the significance level was set at $\alpha = .05$; no consequential violations of normality or homogeneity of variance were detected.

Results

ANOVA revealed a significant main effect for subjective ratings of CL measured after the completion of the instruction, $F(1, 22) = 7.592, p = .012, \eta^2 = .26$; a significant main effect for subjective ratings of CL measured after the completion of assessment questions, $F(1, 22) = 8.587, p = .008, \eta^2 = .28$; and a significant main effect for delayed written posttest scores, $F(1, 22) = 28.116, p < .001, \eta^2 = .56$. No significant difference between the two groups on assessment completion times was identified. No data were missing in this experiment, and all data analysis was completed using IBM SPSS Statistics for Windows, Version 20 (IBM, Armonk, NY). Descriptive statistics are presented in Table 2.

Discussion

Significant differences between the control and modified instruction groups were identified in the expected directions for subjective measures of CL and delayed posttest scores. As such, it is apparent that the nature and structure of instruction was capable of placing considerable load on the learner’s available cognitive resources. The complexity, interactivity, and novelty of information had an equally appreciable impact on performance that was to the greater detriment of control group participants. In accordance with CLT, a reduction in CL experienced by modified instructional group participants in the early stages of instruction offers an explanation for these findings. Specifically, the first two stages of the isolated-to-interacting-elements approach introduced individual
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Less consequential, no significant differences were identified for posttest completion times. We suspect study participants had no motivation or incentive to change time management tactics with examination time that was more than adequate for the task at hand. Future studies should question participants to better understand utilization of examination time.

Limitations and Future Research

The limited number of participants enrolled in this study and narrow content area does not allow for generalization of the isolated-to-interacting-elements approach. Many studies need to be conducted to develop instructional methods that can be more readily applied to the design of gait and similarly complex instruction. Correspondingly, teaching complex curricula is a lengthy process, and a single topic in one class does not adequately reflect the complexity of real-life learning that occurs over longer periods of time.

Relative to methodology, we used a three-stage approach to prevent overwhelming WM capacity. Although the three-stage approach was based on careful analysis of the instructional materials, future studies will need to examine different permutations of content grouping and sequencing to better understand relationships among CL, content structure, and performance. Additionally, although the authentic nature of this study allows for improved generalization to classroom teaching, such an approach poses equal barriers that are typically not experienced in simulated instructional research. That is, the degree of invasiveness, number of permutations in the experimental condition, available time, and faculty availability and willingness to put forth their instructional materials are understandably constrained.

Future research should enlist a greater number of participants and incorporate more robust statistical procedures (e.g., multivariate analysis of variance) to better understand relationships among dependent variables. Many studies will be needed to better quantify and qualify relationships among CL, content structure, and performance; this research may be best accomplished using concept-based and student-paced instruction over longer periods of time. The implications of motivational factors and delivery methods, and how such instructional strategies must be modified to account for increasing learner expertise within a knowledge domain, will also require investigation. Although it was not possible in this study, the simultaneous management of ECL and ICL would be expected to further enhance performance (Sweller et al., 2011). Last, the applicability of CLT instructional principles to the transfer of declarative knowledge to psychomotor performance should prove valuable (Pociask & Morrison, 2008).

Table 2. Descriptive Statistics for the Control (n = 12) and Modified Instruction (n = 12) Groups

<table>
<thead>
<tr>
<th>Dependent Variables and Instructional Format</th>
<th>M</th>
<th>SD</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total instructional cognitive load&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>3.83</td>
<td>0.58</td>
<td>[3.52, 4.14]</td>
</tr>
<tr>
<td>Modified</td>
<td>3.25*</td>
<td>0.45</td>
<td>[2.94, 3.56]</td>
</tr>
<tr>
<td>Total examination cognitive load&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>5.00</td>
<td>0.95</td>
<td>[4.54, 5.46]</td>
</tr>
<tr>
<td>Modified</td>
<td>4.08*</td>
<td>0.51</td>
<td>[3.63, 4.54]</td>
</tr>
<tr>
<td>Total time to complete assessment questions&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>38.83</td>
<td>9.21</td>
<td>[19.70, 22.14]</td>
</tr>
<tr>
<td>Modified</td>
<td>37.25</td>
<td>5.23</td>
<td>[24.11, 26.56]</td>
</tr>
<tr>
<td>Total examination scores&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>20.92</td>
<td>2.23</td>
<td>[19.35, 23.23]</td>
</tr>
<tr>
<td>Modified</td>
<td>25.33**</td>
<td>1.83</td>
<td>[23.77, 27.03]</td>
</tr>
</tbody>
</table>

Note. CI = confidence interval; M = mean; SD = standard deviation.

<sup>a</sup>Possible range for cognitive load measurement 1 and 2 (1 = lower to 7 = higher); the average of three measures is reported for the modified instruction format.

<sup>b</sup>The possible range of time to complete written assessment was 0–50 min.

<sup>c</sup>The possible range for written assessment scores was 0–30.

<sup>d</sup>CIs for the difference between the means.

<sup>*</sup><i>p</i> < .05.  <sup>**</sup><i>p</i> < .001.

Acknowledging the rationale for withholding information necessary for full understanding in the initial two stages of instruction under the experimental condition, we found that the isolated-to-interacting-elements approach resulted in superior, as opposed to deleterious, effects. As such, the common practice of presenting novice learners with all information necessary for understanding in a single lecture may, in fact, impede learning when teaching certain complex information. To the contrary, matching instruction and instructional processes with the learner’s cognitive capabilities may foster learning and attainment of learning objectives.

Concepts and rudimentary relationships that could be understood in isolation, without overwhelming WM resources. In simple terms, this approach reduced CL by limiting interactions between elements of information at the short-term expense of fully understanding lesson content in early stages of instruction. Most important, the learner’s ability to process rudimentary schema formed during the isolated stages of instruction allowed for an increase in cognitive resources available for learning during the final integrative lecture. The latter is suspected as the principal explanation for the superior performance demonstrated by the modified instruction group. In terms of practical significance, the difference in posttest scores between the modified instruction group (84% or B), in combination with decreased instructional difficulty, and the control group (70% or C–), are important findings of this study.

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The implications of motivational factors and delivery methods, and how such instructional strategies must be modified to account for increasing learner expertise within a knowledge domain, will also require investigation. Although it was not possible in this study, the simultaneous management of ECL and ICL would be expected to further enhance performance (Sweller et al., 2011). Last, the applicability of CLT instructional principles to the transfer of declarative knowledge to psychomotor performance should prove valuable (Pociask & Morrison, 2008).
Finally, implications of trends in occupational therapy and higher education, such as the growth and expansion of the profession, growing political and economic pressures on higher education to control costs and improve efficiency, and new forms of mass media and communication are unclear. The need for increased teaching and learning scholarship in this area of study is apparent.

Implications for Occupational Therapy Practice

The results of this study have the following implications for occupational therapy practice:

- The degree to which learning of complex instruction is effective will, in part, be dependent on the extent to which instruction and instructional processes take into consideration the unwavering characteristics of human cognition and will be particularly true in the context of teaching new information to novice learners in academic or clinical environments.
- This study emphasized the importance of bringing a concentrated effort to the instructional design and teaching of complex knowledge in the occupational therapy curriculum to improve instructional effectiveness while recognizing the importance of including gait analysis in the occupational therapy curriculum.
- This study helps extend CLT and instructional design practices to occupational therapy pedagogy.
- Finally, findings from this study may assist occupational therapy and clinical educators with alternative instructional methods for teaching human locomotion and provide insight for teaching complex knowledge and processes in other areas of academic and clinical practice.

Acknowledgments

This study was approved by the Human Investigation Committee of Wayne State University and underwent expedited Behavioral Institutional Review Board review. We thank all Wayne State University master of occupational therapy students who participated in this study and the course instructor for her willingness to support scholarship of teaching and learning research.

References


