SHORT REPORT

Incorporating cognitive load theory into curriculum design for the teaching of novel clinical skills in Australian osteopathy students

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Abstract

Introduction: Cognitive load theory provides a theoretical framework through which the teaching of skills to health students can be optimised. The aim of this study was to evaluate the intrinsic and extraneous cognitive load of first-year osteopathy students as they learn a psychomotor-based clinical skill (neurological examination of the upper limb).

Methods: First-year osteopathy students (n = 78) at an Australian university completed an 8-item cognitive load survey at the end of the session where they were taught, and conducted, their first hands-on assessment task (neurological examination of the upper limb). The task was completed in a learning environment designed with low-medium complexity, medium fidelity and high levels of instructional support for learners.

Results: Intrinsic and extraneous load data indicate varied levels of cognitive demand of the task across the cohort. On average, intrinsic load made up three quarters of the total cognitive load associated with this task.

Conclusion: Understanding and utilising cognitive load theory in the design of lesson plans may provide improved opportunity to optimise student learning of novel clinical skills. Extraneous load was much lower than intrinsic load, suggesting the learning environment was fit for purpose for these learners.

Keywords: cognition; health education; neurological examination

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Introduction

Learning hands-on clinical skills in pre-professional health professional education programs can be a challenging educational experience for both students and teachers (Yu et al., 2021). This form of experiential learning often requires the application of in-depth prior knowledge (e.g., anatomy, physiology, biomechanics) combined with psychomotor skill development (Gonzalez & Kardong-Edgren, 2017). Additionally, such learning demands physical contact between classmates in simulation-type settings (Aldridge, 2017; Yu et al., 2021), including peer physical examination (Vaughan & Grace, 2016). Physical contact is also required between teacher and student in the form of hands-on demonstrations. Irrespective of a student's level of prior study, the scenario can be considered a novel and/or unusual learning task. Of interest to educators is determining how this learning environment influences skill development.

Learning theories help to illuminate how, and why, environments and pedagogical approaches have an effect on learners (Brown et al., 2019; Laksov et al., 2017; Taylor & Hamdy, 2013). In the context of psychomotor skill development in the health professions, cognitive load theory can be used to inform the educational design for learning psychomotor skills. In cognitive load theory, working memory is utilised to manage the interplay between the complexity of the information processed as part of task performance (*intrinsic* load) and the environmental factors (*extraneous* load). With repetition and exposure, an individual begins to develop schemas when exposed to similar stimuli, which can streamline performance (*germane* load).

Fundamentally, cognitive load theory posits that the amount of information an individual can consciously maintain and manipulate is finite (Leppink & Duvivier, 2016). To maximise learning gains of new information, an environment where intrinsic load is maximised and extraneous load is minimised is ideal. For educators, controlling the extraneous load is key to manipulating cognitive load in this way. Hence, the ideal environment for the novice learner is one with clear and comprehensible information, aided support from teachers and minimal distraction from the environment. This combination will, theoretically, control the extraneous load and allow the learner to expend working memory on intrinsic load.

Leppink and Duvivier (2016) advocate the evaluation of cognitive load to inform curriculum design and changes. Lesson plan design for skill development can be aided by deliberate evaluation of task complexity, instructional supports and fidelity. Initial psychomotor skill development may begin with low task complexity, high instructional support and low fidelity supports. As the student progresses, complexity increases (combining tasks or information), support is maintained and fidelity increases. Learning informed by cognitive load theory can result in task design tailored to the level and needs of students.

Contemporary research focuses on the evaluation of total cognitive load without regard for the demarcation between *intrinsic*, *extraneous* and *germane* load. Understanding this demarcation is of value, as it showcases how a student is utilising their mental resources. As *germane* load involves the development of complex schemas and heuristics to process information, it is not appropriate to measure in novel learning.

The present study aims to evaluate the intrinsic and extraneous cognitive load of first-year osteopathy students as they learn a psychomotor-based clinical skill (neurological examination of the upper limb). This evaluation will inform the teaching approach utilised for the lessons where psychomotor skills are taught in this program, given this particular skill is the first in a series of skill development tasks and all lesson plans follow a similar pattern.

Methods

This is a questionnaire-based cross-sectional study. The study was approved by the Victoria University (Melbourne, Australia) Human Research Ethics Committee (HRE17-192).

The 4.5 year osteopathy course at Victoria University (Melbourne, Australia) is one of three accredited osteopathy courses in Australia and the only one of the three delivered in a "block" design (Tripodi et al., 2020). All first-year students complete two 4-week clinical skills units in the academic year, each of these being offered in the last block of the two 16-week semesters (i.e., Weeks 13–16 of the semester). Each clinical skills unit is undertaken after the students have successfully completed two prerequisite units (Weeks 5–12). Prerequisite units include content related to anatomy, physiology and biomechanics. The first of the two clinical skills units focuses on the upper limb, and all theoretical prerequisite classes are aimed at preparing students for this region focused clinical unit.

The current research focuses on a neurological examination of the upper limb. Osteopaths learn and utilise the neurological examination of the upper limb within the context of musculoskeletal care (Adams et al., 2018). This is a novel task taught to first-year students in the first 6 months of their program, and most (if not all) students have no exposure to this task in their previous studies.

Before each class, students are able to access video resources via the online learning management system. These video resources demonstrate each examination and/or technique. These resources are constantly available to students, and they are encouraged to access and revise as often as possible. This approach leverages the benefits of the flipped-classroom model (Hew & Lo, 2018). In class, students are instructed in techniques through the use of video to ensure consistency within and across classes (Tripodi, 2018). This is followed by a generous amount of peer-practice time observed and assisted by both academic staff and near-peer educators (fourth- and fifth-year osteopathic students) to ensure adequate skill development and feedback time before moving on to the next sections/areas. All classes follow a lesson plan to ensure students are taught using the same methods.

Potential participants were all first-year Bachelor of Science (Osteopathy) students at Victoria University in June 2021. One hundered and thirty-four students were enrolled in the unit of study where neurological examination of the upper limb was taught. All students were free to decide whether to participate.

Three independent variables were evaluated: *intrinsic* cognitive load, *extraneous* cognitive load and *total* cognitive load. Data on the *intrinsic* and *extraneous* cognitive load were collected using a paper-based 8-item questionnaire (Leppink & van den Heuvel, 2015). This questionnaire was chosen for its brevity, enabling measurement at multiple time points and minimal interruption to the class. The questionnaire contains eight questions that each require a rating from 0–10 (0 being *"not at all the case"* and 10 being *"completely the case"*). The first four items relate to intrinsic load, and the remaining four items relate to extraneous load. The individual questions are detailed in Table 1.

The questionnaires were distributed to students immediately after the completion of the upper limb neurological examination during class time. Students were made aware of the study prior to the class via the online learning management system and in the classroom. Participation in the study was voluntary, and participation (and completion of the questionnaire) was not required as part of any assessment for the unit or task.

Data were entered into JASP 0.15.0 for analysis and cleaned—missing data were not imputed. Descriptive statistics were generated for the demographic variables and each of the eight cognitive load items. A paired sample *t*-test was calculated to determine whether there was a significant difference between intrinsic and extraneous load. Cohen's *d* is also reported. Cronbach's alpha (α) was calculated for all eight items in addition to the *intrinsic* and *extraneous* load subscales with values over 0.80 considered acceptable.

Results

Of the 134 students, 78 (37 females, 41 males) provided responses (58.2% response rate). Mean student age was 21.5±3.8 years. The respondents comprised 37 (47.4%) students who commenced this degree after completing high school (or equivalent) in the previous year, and 41 (52.6%) students who had previously completed a higher education degree before entering the course.

Descriptive data indicate *intrinsic* load scores are higher than *extraneous* load scores and make up a greater proportion of total cognitive load (on average around 75%) (Table 1). The spread of scores indicates that for some students, the upper limb neurological examination task required minimal *intrinsic* load (0/40), whilst for others it required near maximum load (37/40). *Extraneous* load scores were broadly lower than *intrinsic* load scores. Several students did report scores of 23/40 on this aspect, even though the most common score was 0.

Table 1

Cognitive Load Questionnaire Items and Summarised Scores

Questionnaire item	M±SD	Range	Mode	IQR
Intrinsic load				
The content of this activity was very complex.	4.3±2.4	0–9	3	2.25–6
The problem/s covered in this activity was/were very complex.	4.2±2.3	0–10	3	3–6
In this activity, very complex terms were mentioned.	4.7±2.5	0–10	2	3–7
I invested a very high mental effort in the complexity of this activity.	4.9±2.3	0–10	5	3–7
Extraneous load				
The explanations and instructions in this activity were very unclear.	1.3±1.4	0–8	0	0–2
The explanations and instructions in this activity were full of unclear language.	1.5±1.8	0–6	0	0–2
The explanations and instructions in this activity were, in terms of learning, very ineffective.	1.6±2.0	0–8	0	0–2
I invested a very high mental effort in unclear and ineffective explanations and instructions in this activity.	2.0±2.3	0–8	0	0–3
Total intrinsic load/40	18.2±8.5	0–37	23, 28	12–25
Total extraneous load/40	6.4±6.3*	0–23	0	1–11
Total cognitive load/80	24.7±12.6	0–53	15	14–33

* significant difference between intrinsic and extraneous load ($p < 0.001$, $d = 1.45$)

The data highlights that students were utilising intrinsic load significantly ($p < 0.001$) more than they were utilising extraneous load. This showcases that most of the students' cognitive capacity was dedicated to completing the task at hand, and there were minimal environmental factors influencing task completion. Reliability estimations for the total score (0.88), intrinsic load score (0.92) and extraneous load score (0.84) were all above acceptable levels.

Discussion

This study evaluated the self-reported cognitive load associated with osteopathy students learning to perform an upper limb neurological examination. The task is one that osteopaths use in clinical practice (Adams et al., 2018) and is necessary for safe patient care and referral to other health professionals.

We proffer that the structure of the learning associated with the task represents high instructional support, low-medium complexity and medium fidelity (Leppink & Duvivier, 2016). The instructional supports were varied and informed by flipped classroom principles (Hew & Lo, 2018; Youhasan et al., 2021). Splitting the whole task into smaller tasks was a deliberate instructional support choice (Brich & Rijntjes, 2016). Allowing students to view these tasks prior to the class may allow students to transition from a low-fidelity (observation) to a medium-fidelity task (performance on a peer), reducing the extraneous load. A facilitator-to-student ratio of 1:16 was another instructional support. This ratio afforded the opportunity for learners to be observed and provided with feedback.

Task complexity was considered to be low to medium. The upper limb neurological examination was a new task for these students. However, the psychomotor skills required to perform the neurological examination were considered to be low complexity, except for the elicitation of tendon reflexes, which could be considered medium complexity. The mid-range intrinsic load subscale scores may be a reflection that some aspects of the neurological examination are easier/harder to perform than others (Leppink & Duvivier, 2016).

The task was considered medium fidelity owing to the use of peer physical examination. Peer physical examination is a fundamental component of osteopathy courses (Vaughan & Grace, 2016). Working with a peer with whom they have a substantial degree of social and cognitive congruence (Lockspeiser et al., 2008) may have the effect of reducing the extraneous load for learners. The use of peer physical examination could be considered an instructional support—an opportunity to receive/provide peer feedback and co-construct learning.

The low values for extraneous load suggest that the learning environment was suitable for the learning of this task. It is possible that the flipped learning classroom, coupled with the instructional support, reduced the incidence of environmental distractions during the practical tasks. As a result of these findings, no changes are intended for the teaching of this skill for the subsequent academic year. The intention is to repeat cognitive load data collection after implementing the same teaching plan with a new cohort of first-year students to determine whether the lesson plan is transferrable across cohorts.

The limitations of the study were the single time point, use of self-report data and no evaluation of cognitive load associated with performance in an assessment. That said, the data suggest the learning design was consistent with a cognitive load suited to the task and learner stage. Furthermore, the cognitive load theory questionnaire items are similar to that which are incorporated into evaluations of units that students complete routinely. The cognitive load component of this involved the demarcation of items into intrinsic and extraneous load sections. While the items in general may be similar, the categorisation and the analyses of these items adds a novel component to the study.

Conclusions

The nature of the practice of osteopathy as a predominantly “hands-on” health profession affords a unique opportunity to explore the utility of cognitive load theory in task, unit (subject) and course (program) design. By using cognitive load as one of the key theories underpinning osteopathy course design, learners are afforded the opportunity to learn psychomotor clinical examination, manual therapy and exercise prescription skills in a manner that maximises intrinsic cognitive load whilst reducing the influence of extraneous variables.

Conflicts of interest and funding

The authors report no potential conflicts of interest or funding relevant to this article.

References

Adams, J., Sibbritt, D., Steel, A., & Peng, W. (2018). A workforce survey of Australian osteopathy: Analysis of a nationally-representative sample of osteopaths from the Osteopathy Research and Innovation Network (ORION) project. *BMC Health Services Research*, *18*, Article 352. https://doi.org/10.1186/s12913-018-3158-y

Aldridge, M. D. (2017). Nursing students’ perceptions of learning psychomotor skills: A literature review. *Teaching and Learning in Nursing*, *12*(1), 21–27. https://doi.org/10.1016/j.teln.2016.09.002

Brich, J., & Rijntjes, M. (2016). A station-based concept for teaching the neurological examination: A prospective quasi-experimental study. *GMS Journal for Medical Education*, *33*(5), Article 77. https://doi.org/10.3205/zma001076

Brown, J., Bearman, M., Kirby, C., Molloy, E., Colville, D., & Nestel, D. (2019). Theory, a lost character? As presented in general practice education research papers. *Medical Education*, *53*(5), 443–457. https://doi.org/10.1111/medu.13793

Gonzalez, L., & Kardong-Edgren, S. (2017). Deliberate practice for mastery learning in nursing. *Clinical Simulation in Nursing*, *13*(1), 10–14. https://doi.org/10.1016/j.ecns.2016.10.005

Hew, K. F., & Lo, C. K. (2018). Flipped classroom improves student learning in health professions education: A meta-analysis. *BMC Medical Education*, *18*, Article 38. https://doi.org/10.1186/s12909-018-1144-z

Laksov, B. K., Dornan, T., & Teunissen, P. W. (2017). Making theory explicit: An analysis of how medical education research(ers) describe how they connect to theory. *BMC Medical Education*, *17*, Article 18. https://doi.org/10.1186/s12909-016-0848-1

Leppink, J., & Duvivier, R. (2016). Twelve tips for medical curriculum design from a cognitive load theory perspective. *Medical Teacher, 38*(7), 669–674. https://doi.org/10.3109/0142159X.2015.1132829

Leppink, J., & van den Heuvel, A. (2015). The evolution of cognitive load theory and its application to medical education. *Perspectives on Medical Education*, *4*(3), 119. https://doi.org/10.1007/s40037-015-0192-x

Lockspeiser, T. M., O'Sullivan, P., Teherani, A., & Muller, J. (2008). Understanding the experience of being taught by peers: The value of social and cognitive congruence. *Advances in Health Sciences Education*, *13*(3), 361–372. https://doi.org/10.1007/s10459-006-9049-8

Taylor, D. C. M., & Hamdy, H. (2013). Adult learning theories: Implications for learning and teaching in medical education: AMEE Guide No. 83. *Medical Teacher*, *35*(11), e1561–e1572. https://doi.org/10.3109/0142159X.2013.828153

Tripodi, N. (2018). First-year osteopathic students' use and perceptions of complementary video-based learning. *International Journal of Osteopathic Medicine*, *30*, 35–43. https://doi.org/10.1016/j.ijosm.2018.09.004

Tripodi, N., Kelly, K., Husaric, M., Wospil, R., Fleischmann, M., Johnston, S., & Harkin, K. (2020). The impact of three-dimensional printed anatomical models on first-year student engagement in a block mode delivery. *Anatomical Sciences Education*, *13*(6), 769–777. https://doi.org/10.1002/ase.1958

Vaughan, B., & Grace, S. (2016). Perception of peer physical examination in two Australian osteopathy programs. *Chiropractic & Manual Therapies*, *24*, Article 21. https://doi.org/10.1186/s12998-016-0102-2

Youhasan, P., Chen, Y., Lyndon, M., & Henning, M. A. (2021). Exploring the pedagogical design features of the flipped classroom in undergraduate nursing education: A systematic review. *BMC Nursing*, *20*, Article 50. https://doi.org/10.1186/s12912-021-00555-w

Yu, J. C., Rashid, M., Davila-Cervantes, A., & Hodgson, C. S. (2021). Difficulties with learning musculoskeletal physical examination skills: Student perspectives and general lessons learned for curricular design. *Teaching and Learning in Medicine*, *34*(2), 123–134. https://doi.org/10.1080/10401334.2021.1954930