COGNITIVE LOAD ASSESSMENT IN COMPUTER BASED VIDEO TRAINING FOR THE PURPOSES OF ONE-HAND KNOT TYING

By

© Reuben Newton Addison

A thesis submitted to the

School of Graduate Studies

In partial fulfillment of the

requirements for the degree of

Master of Science

School of Human Kinetics and Recreation

Memorial University of Newfoundland

September 2016

St. John's Newfoundland and Labrador

Cognitive load assessment in computer based video training of one hand knot tying

Abstract

The purpose of practice is to enable learning and this can be indirectly observed through performance. The current study employed the dual task methodology to assess the effectiveness of computer based video training during the practice of the one-hand knot tying among novice learners. Sixteen students were randomly assigned to one of two groups: practice and non-practice groups. A pre-recorded instructional video was presented to all participants. The practice group completed 10 trials of the one-hand knot tying on a bench top simulator, while the non-practice group did not. All returned a week later for a transfer task. Subjective ratings of mental effort and reaction time were indices of cognitive load. Time on task served as an indication of task performance. Results showed the practice group had reduced cognitive load and shorter performance times compared to the no practice counterparts. These findings imply that self-directed practice alongside Computer based video training (CBVT) is an effective tool in teaching technical clinical skills.

KEYWORDS: CBVT, cognitive load and technical clinical skills

Acknowledgements

The completion of this study and my Master's degree in Kinesiology has been a journey carried out through the support of many people whose contributions I gratefully acknowledge.

To my supervisors, Linda Rohr and Adam Dubrowski. You welcomed me as I navigated my way through many questions and decisions, helping me as your student and friend to discover and learn. I am forever grateful for the wisdom you shared and the advice to settle down in the midst of it all. You have taught me about more than researching my interests. You have helped me to discover more within my own life.

Table of Contents

Contents

List of Figures

List of Appendices

Cognitive load assessment in computer based video training of one hand knot tying

Chapter 1: Introduction

1.1 Background

The purpose of practice is to enable learning and can be indirectly observed through performance. Generally, motor skill acquisition requires practice (Fitts & Posner, 1967). Central to motor learning there is a need to understand the distinction between learning and performance. Learning differs from performance in the sense that the latter can be observed and measured. When performance on tasks improves it becomes evidence that learning has occurred. Learning is the relative permanent change of an individual's ability to perform a particular skill due to experience or practice. This change is inferred from one's performance (Magill & Anderson, 2014).

Schmidt & Lee (1999) describe motor learning as a process involving practice or experiences, resulting in a relatively permanent change in one's capability for movement. These changes can be inferred from assessing one's performance on either retention or transfer tests. Magill (2001) defines retention as the movement information that can be recalled on task in the same context in which the task was practiced or learnt. Transfer refers to the effect previous learning has on performing a skill in a new context from where the task was acquired.

Practice is an attempt to perform a particular task with the aim of attaining a certain level of skill proficiency (Schmidt & Lee, 1999). Proficiency involves refining the smoothness and accuracy of the movements related to the task that is often necessary for complicated medical skills such as the one-hand knot tying (Uccelli, Kahol, Ashby, Smith, & Ferrara, 2011).

Practicing a skill within the context of its application is closely related to the test conditions and leads to better performance through retention due to the similarity of cognitive processes (Henry, 1968). One defining factor that influences skill learning is the learning environment and how the learner interacts with it. For example, Lewthwaite & Wulf (2012) theorized that practice environment characteristics can have an impact on performance and learning. Janelle, Barba, Frehlich, Tennant, & Cauraugh, (1997) further indicated that in order to enhance motor skill learning, the learner must have some control over the practice condition or be actively involved in the process. For instance, learners should be able to decide which strategies they will employ with no active input from an instructor. This is known as self-directed practice.

In self-directed practice an individual is responsible for their own learning and must identify their learning needs, the resources required, the learning goals, the most favorable learning strategies, and finally, assess the learning outcomes (Knowles, 1975). Duvivier, Van Dalen, Muijtjens, Moulaert, Van der Vleuten, & Scherpbier (2011) described self-directed practice as a form of deliberate practice since the learner has the opportunity to shape his or her own learning. Recent research suggests self-directed practice with expert instruction may be effective to acquire simple technical skills (Safir, Williams, Dubrowski, Backstein, & Carnahan, 2013). Instructors often use technology to effectively carry out a self-directed learning approach (Rogers, Regehr, Yeh, & Howdieshell, 1998).

In the field of medical education, junior and senior undergraduate medical trainees rely on both human patient simulators and bench models to practice the needed basic clinical skills (Davies & Hamdorf, 2003). Originally introduced in the medical skills laboratories, technologies address ethical, economic, and medico-legal concerns related to the traditional apprenticeship model of medical education (Kneebone & Apsimon, 2001). For example, simulation and bench-model training typically allow repeated practice in a learner-centered environment, devoid of apprehensions associated with patient care. Simulation and bench-model training mimics operating room experience and helps boost surgical confidence among users, especially junior trainees (Anastakis et al., 2003). Nonetheless, there are some concerns with the use of simulation including time commitments and scheduling conflicts. To counter these concerns, computer based video training (CBVT) has emerged as a more cost effective and efficient training alternative in medical education (Jowett, LeBlanc, Xeroulis, MacRae & Dubrowski, 2007). CBVT allows basic medical skills to be taught outside the confines of an operating room (Heppell, Beauchamp, & Chollet 1995; Ellis, 1993). The system requires novices to identify their own errors and search for solutions rather than receiving external feedback from an expert (Rogers, Regehr, Yeh, & Howdieshell, 1998).

Simulator training reduces cognitive load (CL) and helps to simplify the learning process in medical education (Young, Van Merrienboer, Durning, & Ten Cate, 2014). Here, the learner practices the critical steps on the simulator while preparing for any contingencies that may arise. According to Paas & van Merriënboer (1994a), cognitive load is a multidimensional concept that indicates the burden imposed on a learner's cognitive system during the performance of a particular task. The CL associated with learning a new procedure gradually decreases with persistent simulator practice (Bharathan, Vali, Setchell, Miskry, Darzi, & Aggarwal, 2013). Simulation gives learners the opportunity to make errors in a safe environment rather than in a real life clinical setting. Further, it allows the learner manipulate their learning environment based on the learner's expertise and knowledge. This manipulation optimizes the learning experience (Reedy, 2015). Simulator practice has shown promising results on learning outcomes in medical education across all levels of learners (i.e. students, residents, fellows, senior attending doctors) as well as across clinical specialties (McGaghie, Issenberg, Petrusa, & Scalese, 2006). For instance, Merali & Tse (2010) reported that even novices can improve and reach competency levels similar to that of experts in a technical skill such as endoscopy after trials on a computer based simulator.

The cognitive load theory (CLT) may be used to assess the effectiveness of learning with new technologies, including CBVT (Mayer, 2001). When learning novel tasks, the cognitive effort can fluctuate intensely and occasionally exceed a user's ability. CLT holds the view that in order to develop proficiency in a particular task, instructional methods should decrease demand on a learner's working memory. This can be achieved by minimizing the CL during the learning process, making it easier for schema acquisition and automation (Chandler & Sweller, 1991). Schema construction begins with knowledge acquisition through combining smaller elements into larger and more refined chunks (Taylor & Hamdy 2013). In order to conduct research involving CL for the purposes of assessing CBVT effectiveness, various available techniques, include dual task methodology, subjective rating of mental effort and heart rate variability.

1.2 Dual task methodology

In the dual task paradigm, two tasks have to be processed at the same time. Parallel to the primary task, an additional secondary task must be concurrently performed. Fisk, Derrick, & Schneider (1986) describe the dual task methodology as the secondary probe technique. According to Fisk et al., (1986) during the performance of the primary task, participants are asked to respond a secondary task otherwise known as the probe stimulus. As fewer resources are available for processing each individual task, resources for the secondary task depend heavily on the resources allocated to the primary task, leading to a reduction in the response speed to the probe. Consequently, response speed inversely represents the cognitive load imposed by the primary task (Bru¨nken et al., 2002).

In practice participants are usually instructed to sustain a given level of attention on the primary task under a dual task condition. An observed change in the performance on the secondary task, relative to the initial performance, is taken to represent the attentional demands of the primary task. When the demands of the two tasks surpass the available processing capacity, a decline in performance of one or both tasks are expected (Abernethy, 1988).

1.3 Aim

The aim of the study is to employ dual task methodology to assess the effectiveness of a CBVT based on performance and cognitive load during a self-directed practice of the one-hand knot tying between practice and no practice novice learners.

Chapter 2: Review of literature

2.1 Introduction:

Practice is one of the best ways to enhance learning and ensure relatively permanent changes in behavior. Learning is often inferred from changes in the desired behavior mostly in the form of improvement (Schmidt &, Lee 2005). When performance on tasks improves it becomes evidence that learning has occurred. The observed change is inferred from one's performance described by the three-stage model of learning by Fitts & Posner (1967).

2.2 The Three-stage model of learning

According to Fitts et al. (1967), while motor skills may differ in terms of complexity and type, the processes involved in learning motor tasks are similar across individuals. Fitts et al. (1967) proposed a three-stage model of learning: the cognitive, associative, and autonomous stages. During the cognitive stage the learner begins to experiment with different strategies in order to recognize what is required of them to reach the goal stage. This stage requires much cognitive activity; overall movements are generally slow and the learner consciously pays attention to fine details. Here, performance is largely inconsistent. As the learner gets used to the required movements, the associative phase starts. At this stage some inconsistent movement adjustments take place. The movements become more consistent as practice continues. Initial inconsistencies of movements seen in the first stage are gradually reduced, and the movement becomes more efficient. Some movement parts are now performed more automatically. After more practice, the learner reaches the third stage, the autonomous phase, where the learner's motions seem effortless. Observed movements have few or no errors and are consistently performed. The skill at this stage requires little or no attention. Overall, the three-stage model of learning suggests that as skill and experience increase, the demands on attentional or cognitive resources required are less.

One cannot discount the role of practice in improving performance. The crucial role of practice in motor performance is well studied. For instance, Derossis, Bothwell, Sigman, & Fried (1998) compared two randomized groups: one of which group had a five-week practice session and the other had no-practice group. The purpose was to examine the effect of practice on performance on a laparoscopic simulator. This was achieved by objectively measuring laparoscopic skill in a simulator for 2 groups of 6 surgery residents at the postgraduate year (PGY3) level who were randomly assigned to one of the two groups. The laparoscopic performance was measured as a factor of seven tasks scoring precision and speed during transferring, cutting, clip divide, placement of a ligating loop, mesh placement fixation, and suturing with intracorporeal and extracorporeal knots. Participants were assessed for baseline evaluation purposes and each group was then retested seven weeks later. Scores on participants' improvement, from baseline to final performance were compared for both groups. Findings showed significant improvement for participants in the practice group for each individual task and total score. However, in the no practice group, improvement was observed only in four of the seven tasks and for the total score. Overall, the practice group improved significantly more than the non-practice group, suggesting that laparoscopic skill significantly improves with practice and the repetition of procedures.

Another study conducted by Hashimoto, Sirimanna, Gomez, Beyer-Berjot, Ericsson, Williams, Darzi, & Aggarwal (2013) examined the impact of deliberate practice in medical training among 2 groups of 7 junior residents. Here, participants were randomly assigned to one of two groups; deliberate practice or standard training. Participants from each group performed 10 sessions consisting of two virtual reality and porcine laparoscopic cholecystectomies (LC) each. During the main trial, the group assigned to deliberate practice had to practice for 30 minutes between LCs whereas the standard practice group watched an unrelated educational video. Participants from both groups then performed five porcine LCs as a transfer test. Performance on the LC's was measured as a factor of speed, dexterity, and quality on the OSATS global rating scale. Data from the study indicated both groups were similar in terms of skill both at baseline and in speed/dexterity after training. Subsequently, participants in the deliberate practice group showed greater improvement in LC performance over multiple sessions besides recording significantly higher quality in performance compared to standard training. This shows the role of deliberate practice cannot be underestimated in the learning of medical skills.

The effect of practice was assessed on cognitive and motor performance among a group of younger and older adults in a dual task condition by Voelcker-Rehage & Alberts (2007). Overall 14 younger adults between the ages 19–28 years and 12 older adults between the ages 67–75 years performed a precision grip sine wave force-tracking as well as a working memory task under single- and dual task conditions. Participants performed a pretest followed by 100 motor practice trials then a post-test. As expected, young adults were superior in the force-tracking and cognitive task compared to the older adults. Motor practice improved force-tracking under single- and dual task conditions for both groups. Furthermore, older adults' cognitive performance significantly improved in the dual task conditions after practice.

2.3 Computer-based video training

In clinical practice, computer-based video training (CBVT) is a multimedia platform that seeks to provides straightforward opportunities for medical trainees to learn the most basic technical skills. This form of training is effective in self-directed practice settings (Jowett, LeBlanc, Xeroulis, MacRae, & Dubrowski, 2007). Generally, CBVT makes it easier and possible for learners to easily take initiative and responsibility for their own learning allowing learners to personalize their own learning according to their own schedules. This is one of the fundamental principles of self-directed learning (Spencer, & Jordan, 2001; Knebel 2000; Greenhalgh 2001). This form of learning is convenient, flexible, and cost effective. CBVT makes way for repeated practice in a learner-centered environment, taking out some of the apprehensions experienced by learners especially in the clinical settings (Anastakis, et al., 2003).

2.4 Simulation in medical education

In the context of medical education, simulation can be defined as an educational technique that allows interactive and immersive activity by recreating all or part of a clinical experience while minimizing the patient safety risks associated with on-the-job training (Curtis, DiazGranados, & Feldman, 2012; Lazzara, Benishek, Dietz, Salas, & Adriansen, 2014; Perkins, 2007). Simulation provides meaningful feedback, repetitive practice and the ability to vary the presentation of clinical symptomatology to meet learners' needs (Issenberg, McGaghie, Petrusa, Lee Gordon, & Scalese, 2005). Such feedback can be provided directly to the learner while they are learning or after they take time to reflect.

Based on the assumption that human working memory capacity is limited (Mayer & Moreno, 2003), Cognitive load theory (CLT) contends that simple human-technology designs affects the cognitive load less than more complex designs, especially when the user of this technology needs to multi-task and function in a complex and/or unfamiliar environment.

2.5 Cognitive Load Theory

Cognitive load involves the interaction between task, learner characteristics as well as measurable concepts such as mental effort and performance through the use of assessment procedures that reflect the concept (Paas & van Merriënboer, 1994). Cognitive load reflects the total amount of mental effort being used in working memory. The main tenets of the CLT are based on strategies that help minimize the load imposed on the working memory in order to enhance changes in schema acquisition in the long term memory. The theory identifies three components of cognitive load, namely intrinsic, extraneous, and germane. First, intrinsic load deals with the load imposed on the working memory as a result of the number of basic elements and their interactivity of the information. For example, the complexity of a video instruction for didactic purposes. Furthermore, extraneous load is the manner in which individuals are presented with the "to be learned information" as well as the working memory requirements of the learner.

The germane load involves the whole process of activities directly linked to the learner that foster the acquisition of schema. This form of load is also known as effective load. A schema represents any behavior or thought pattern that organizes groups of information and draws a link between them (DiMaggio, 1997). These three components of cognitive load augment each other and must not exceed the memory resources available if effective knowledge acquisition is to take place (Paas, Tuovinen, Tabbers, & Van Gerven, 2003).

The majority of research on CLT has primarily focused on reducing extraneous cognitive load. Some of the ways to reduce extraneous load include trying to avoid redundancy and allowing time between the presentations of materials to be learnt (Mayer & Moreno, 2003). According to Paas, Renkl & Sweller (2003), practice is one of the way to reduce cognitive load during skill acquisition and can be a productive way to improve the learning of a complex cognitive task. When working memory capacity is not exceeded, keeping a minimal CL may not necessarily be helpful. Instructional designers note that the source of the load matters more than level of load (Paas et al., 2003). For instance, if the source of the load is a result of mental activities such as redundant information that impede the construction or automation of schemas then it will impede learning. However, if the load is caused by useful mental activities (i.e. media/technology related to learning material) then it will have a constructive effect on learning (Paas, et al., 2003).

2.6 Practice effect and cognitive load

CLT largely focuses on methods that manage the load faced by the working memory in order to enhance changes in long-term memory. For meaningful learning to occur, learning conditions must be in line with human cognitive architecture. This model of the human cognitive architecture assumes the working memory has a limited capacity when faced with new information, and hence the working memory treats novel information as partially independent subcomponents (Paas et al., 2003; Sweller 1988, 1999). When practicing a motor skill it is always helpful to begin with a simple task before progressing to more complicated ones as the intrinsic load imposed on the learner by the simple task is relatively low (Gagne, 1962).

Studies have examined the role of practice on cognitive load. For example, Paas & Van Merrienboer (1994) invited 60 4th year students between the ages of 19-23 years from a secondary technical school. In this study, mental effort was measured as a factor of heart-rate variability and a subjective rating-scale. It was assumed participants were able to self-assess their own cognitive processes and report the amount of mental effort they spent on a given task. Participants were randomly assigned to one of four equal instructional (learning) conditions. They were assigned to two conditions; a low- and a high-variability conventional condition (i.e. participants had to try solve conventional practice problems before studying worked examples) and a low- and a high-variability worked example condition (i.e. all problems were presented with their solutions), where participants were to study the problems and corresponding worked out solutions. Findings demonstrated that participants who first studied worked examples expended significantly less time and mental resources in practice, and had superior transfer performance compared to students who attempted to solve conventional problems first before studying the worked examples.

Bharathan, Vali, Setchell, Miskry, Darzi & Aggarwal (2013) employed a virtual reality simulator for training and assessment of laparoscopic tubal surgery while tracking cognitive load among 25 novices and nine senior gynecologists. The study used a prospective cohort design and took place at the Imperial College Virtual Reality Surgical Skills Laboratory. In order to assess learning, nine novices performed ten sessions of salpingectomy and salpingotomy procedures on a virtual reality simulator. Learning was evaluated using the Friedman test and Wilcoxon Signed Ranks test whereas the relationship between dexterity metrics and cognitive load was assessed using Spearman's rank order correlation. Results showed the learning for salpingectomy plateaued after the eighth trial and the same was true during the fourth session for movements. Moreover, there was a significant relationship between CL and dexterity parameters alongside fidelity scores that were not significantly different between the two procedures. Overall the simulator was an effective tool for reducing cognitive load among novice learners.

Van Merriënboer, Schuurman, de Croock & Paas (2002) conducted a series of experiments to assess the effect of redirecting learners' attention from extraneous to germane processes during training on cognitive load, transfer test performance and training efficiency. In the first experiment, with 26 participants, the researchers compared completion problems, conventional problems, and a learner-controlled condition in which participants had the option of choosing between problem formats. Here, data showed that completion problems significantly decreased cognitive load during training, and had either no effect or a positive effect on transfer performance.

In the second experiment, practice schedule conditions were compared between high or low contextual interference for 69 participants. Findings showed high contextual interference increased cognitive load during training. Moreover, data indicated a trend towards higher transfer performance. The third experiment employed 87 participants; the study combined factors from both the first experiment problem format (completion vs. conventional) and second experiment contextual interference (high vs. low). Findings indicated the completion-high contextual interference group significantly recorded the highest training efficiency even though their performance on the transfer test was disappointing. This suggests that when participants have their attention redirected from extraneous to germane processes they demonstrate improvement in their training efficiency. These studies show how practice enhances learners' germane load, especially when practicing a simple task first. This supports Gagne's (1962) classical instructional design.

2.7 Cognitive Load Assessment

Various factors impact cognitive load during information processing. To evaluate CL, either objectivity measures or causal relations are compared. Objectivity measures indicate whether the technique employed to assess CL is a reflection of subjective, self-reported data or objective observations of behavior, physiological conditions or performance with corresponding changes in cognitive load. Alternatively, the causal relations indicate whether the construct observed is reflective of the attribute of interest (i.e. CL). For example, heart rate variability is related to cognitive load as heart rate variability has been shown to reflect a learner's emotional response to instructional material (Brünken, Plass, & Leutner, 2003). Heart rate variability has been associated with changes in one's level of mental workload (Henelius, Hirvonen, Holm, Korpela & Muller, 2009).

Context (i.e., health care) appropriate measures of cognitive load have been recently documented (Haji, Hoppe, Morin, Giannoulakis, Koh, Rojas & Cheung, 2014), highlighting the importance of the human-technology interface with computer based video training. Current methods of measuring cognitive load fall into three broad categories: psychophysiological measures e.g., pupillometry and heart rate variability, (Haapalainen, Kim, Forlizzi, & Dey, 2010); subjective rating techniques (Paas et al., 2003) and dual task performance e.g., memory or stimulus detection tasks (Brünken, Plass, & Leutner 2004).

Psychophysiological measures obtain a direct, objective measure of cognitive load and are most often based on visual perception and cognitive speed (Haapalainen et al., 2010). The psychophysiological approach is based on existing evidence confirming that task difficulty affects certain psychophysiological signals in the human body. These signals include pupillary responses, eye movements and blink interval, heart rate (HR) and heart rate variability (HRV), electroencephalogram (EEG), electrocardiogram (ECG), galvanic skin response (GSR), and respiration (Haapalainen et al., 2010). Responses from these sources can be viewed as objective.

On the other hand, the subjective rating of cognitive load employs post-treatment questionnaires where learners respond to statements concerning the amount of mental effort they expended in acquiring the information in the learning materials. (Paas, Tuovinen, Tabbers & Van Gerven, 2003). Alternatively, participants rate the difficulty of the materials being presented to them, supposedly representing the cognitive load imposed on them (Kalyuga, Chandler & Sweller (1999). However, these methods rely on perceptions that may be influenced by individual differences such as competency levels or different attentional processes rather than changes in cognitive load.

2.8 Dual task methodology

Dual task methodology provides an indirect, objective measure of cognitive load; however, the sensitivity of the secondary task on the primary task has been an issue of debate (Brünken, Plass, & Leutner, 2004). In the dual task methodology, two stimuli (primary and secondary tasks) are presented concurrently. Performance on one or both tasks is assessed. There is a resource trade-off as the two tasks compete for attentional resources. The negative trade-off is larger when the two stimuli share similar features (e.g., two verbal stimuli) compared to when they share few features (e.g., one verbal stimulus and one visual stimulus) (Baddeley & Hitch, 1974).

Regardless of the type of task, the secondary task can be a threat to the validity of the study. In most cases the secondary task involves basic activities that require participants to pay consistent attention to sensory signals (i.e. visual or auditory).

Performance is evaluated by measuring factors like reaction time, accuracy, and error rate on the secondary task. One of the issues surrounding the dual task methodology is that the secondary task can impair performance on the primary task. This is more likely if the primary task in question is complex and cognitive resources of the learner are limited (Van Gerven, Paas, van Merriënboer & Schmidt, 2006). Hartley (2001) assessed dual task interference. Participants were presented with two simple tasks in which the onset of the second task interfered with the first task. The study had four versions of the dual task i.e., tone or color discrimination as the primary task, and manual or oral responses to the second letter-identification task. Findings showed there was statistically significant interference when both tasks were presented in the same modality; this is known as the modality effect as described by Brünken et al. (2002).

In a study conducted by Brünken, Plass & Leutner (2004), two different experiments employed the dual task approach. Using the secondary task to assess cognitive load they reported that using spoken rather than written text with pictures or diagrams increased the load imposed on the learner's auditory channel. This modality effect suggests audiovisual presentations are superior to visual-only presentations whereas the secondary task indicated an increase in auditory channel cognitive load by the use of spoken rather than written text. Brünken, Steinbacher, Plass & Leutner (2002) observed the modality effect when they employed a visually based secondary task. Here the visual channel was overwhelmed by the use of written (compared to spoken) text when simultaneously employed with visual material. However, in the quest to measure cognitive load for the assessment of instructional design principles, Rojas, Haji, Shewaga, Kapralos & Dubrowski (2014) suggested that simple reaction time measures are sensitive enough to track changes in cognitive load that novice learners experience during simulation-based medical skill training. They argued that different forms of the secondary task imposed various degrees of cognitive load on the learner.

Of the various measures of cognitive load, there is evidence supporting the sensitivity of both dual task performance and subjective ratings to changes in cognitive load for novices performing complex health care related skills in normal and hospital based environments. (Dubrowski, Brydges, Satterthwaite, Xeroulis & Classen, 2012; Kurahashi, Harvey, MacRae, Moulton & Dubrowski, 2011; Stefanidis, Scerbo, Korndorffer Jr. & Scott, 2007; Stefanidis, Acker & Heniford, 2008). In particular, subjective rating of mental effort (SRME) and dual task performance measurement using simple reaction-time (SRT) to a vibrotactile stimulus detection task show significant results in the tracking of cognitive load during medical skill performance (Rojas et al., 2014).

Dubrowski et al. (2012) examined context specific measures which sought to determine if technical medical experience enhances the learning of new information under multitasking conditions among 41 general surgery trainees with various expertise levels. Participants were sampled from five academic training hospitals from the state of Ohio with both reaction time (RT) on the secondary task and a multiple-choice questionnaire (MCQ) to assess knowledge acquisition. The findings showed the dual task methodology was sensitive in differentiating performance between senior and junior trainees. Kurahashi et al. (2011) on the other hand assessed load using a global rating scale and error scores based on task-specific checklists among 16 first-year medical residents in order to examine how laboratory-based medical training on a technical procedure affects concurrent acquisition of other nontechnical information. Results based on the Global Rating Scores (GRS) and error scores reflected practice group performance (i.e. group that underwent training) on both tests: the transfer test and dual task test were greater than the non-practice group.

2.9 Cognitive theory of multimedia learning

The Cognitive Theory of Multimedia Learning (CTML) posits that learner's process information more deeply when information is presented in words and pictures together compared to words or pictures alone (Mayer 2005). Multimedia, in general, is conceptualized as information that has elements of both text and pictures (Mayer, 2005). The CTML states that multimedia supports the way that the human brain acquires information by suggesting that learning occurs when mental representations are built from these words and pictures. CTML suggests learners to form logical connections between materials, make sense of them and eventually create new knowledge (Mayer, 2005).

CTML is a multifaceted concept consisting of three cognitive models: the dual-channel model, the limited capacity model and the active processing model. According to Baddeley's (1986) dual-channel model, the working memory has two independent channels: auditory and visual. This model postulates that information is processed separately in these two channels and this model was further augmented by the dual coding hypothesis which argues that the working memory processes visual and verbal information along independent channels based on the mode presented (Paivio, 1986; Clark & Paivio, 1991). The second proposal, the limited capacity model (Sweller, 1988, 1994) argues that each subsystem of working memory has a limited capacity. Finally, the active processing model holds the view that learners go through a series of steps in order to acquire knowledge. These steps include paying attention to the target material, organizing its components it into a coherent whole, and trying to assimilate it with prior knowledge (Mayer, 1996, 1999).

Studies that assessed the strength of the CTML include Brünken et al. (2002) who investigated the effect of mode of material presentation on phonological cognitive load during learning while using multimedia learning systems. The study also examined the influence of background music in an audiovisual information presentation that indicated some form of modality effect in the patterns of secondary task performance as well as the primary learning task. The modality effect is primarily a learning effect observed when information is made up of the same sensory mode (either visual or auditory alone) causing interference in information processing (Brünken et al. 2002). Mayer et al. (2003) suggested that features of self-explaining environments affect how well learners understand multimedia information. In their study, 223 participants were employed in four different experiments that assessed the impact of the various components of multimedia learning on performance. Findings showed that students performed significantly better on a problem-solving transfer test when explanations were presented as narration using an image rather than on-screen text. Also students given a pre-question to guide their self-explanations during learning recorded significantly higher performance. Finally deleting the image from the screen had no significant effect on problem-solving transfer performance. Results from the above studies support the CTML and offer guidelines for the design of interactive multimedia learning environments. Jowett, et al., (2007) employed the computer-based video training (CBVT), an interactive multimedia learning environment teach one-handed square knot tying among a group of novice trainees. Participants had to practice the skill while assessing their own proficiency within regular time intervals (i.e. every 3 minutes). As expected, performance improved significantly over time. The observation suggest CBVT is an effective tool for skill training in a self-directed learning environment for novice learners as well as indicating the enhancing role of multimedia learning in skill acquisition.

Another study by Mayer et al. (2005) showed that static illustrations, with printed text, reduce extraneous processing and promote germane processing compared to narrated animations. The observation posits that presenting learners with multimedia information in isolated, interactive forms is one way of reducing the load (Pollock, Chandler, & Sweller 2002)

Multimedia messages may have facilitating, enabling or inhibiting effects on a learner's ability to learn. Schnotz & Rasch (2005) observed that manipulation pictures had an enabling function for individuals with high learning prerequisites (i.e. high cognitive ability and high prior knowledge), whereas simulation pictures had a facilitating function for individuals with low learning prerequisites. However, they indicated that the facilitating effect was not beneficial for learning as the novice were prevented from performing relevant cognitive processes on their own. Overall, the study failed to explore the various components of cognitive load.

According to Wouters, Paas, & Van Merriënboer, (2009) modality effects observed during multimedia learning can be minimized when learners consciously attend to and process the given information. Wouters, et al., (2009) examined modality effects during observational learning from animated models in a factorial experiment with modality (written, spoken) and reflection (reflection prompts, i.e. participants consciously attended to the presented information and effortfully processed it, no reflection prompts) conditions as factors. Findings indicated written explanations produced superior performance during transfer when reflection prompts were used compared to a condition without reflection prompts. Moreno (2007) further showed that segmenting multimedia information (i.e. animations or video instructions) improved learning outcomes and reduced levels of cognitive load for novice learners. In his study, pre-service teachers had to learn teaching skills with or without classroom video/animation showing how an expert teacher applied such teaching skills. Results indicated how segmenting multimedia information had a positive impact on learning outcomes and for novice learners.

Learning instructions also influence the novice (Kalyuga, Chandler & Sweller, (2004). Participants were randomly assigned to either a concurrent text group or a non-concurrent text group. Concurrent refers to simultaneous presentation of an auditory-based text alongside its corresponding visual text information. Non-concurrent refers to information presented sequentially. Results indicated simultaneous rather than sequential presentations of learning instructions overloaded working memory, and inhibited learning.

Wulf, Shea, & Lewthwaite, (2010) posit that the observation alongside physical practice proves to be an effective way of learning motor skills. This makes CBVT one of the most efficient procedures in medical skill learning. CBVT reflects observational learning by employing technology anchored with instructions to provide realistic scenarios in which the target knowledge or skills are needed (CTGV, 1993). Motor skills are an integral aspect of medical skill acquisition and are required of health professionals working in the area medical education. Over the past years, the teaching and practice of medical skills changed significantly. Especially, with technological advancement, medical skill training now resorts to virtual-reality simulation (Seymour, 2008; Xeroulis, Park, Moulton, Reznick, LeBlanc, & Dubrowski, 2007).

Medical education and training is expensive (Wulf, Shea, & Lewthwaite, 2010), so it is critical to explore instructional procedures that may be effective and efficient and can target cost savings goals. An intuitive method may be to examine how effective self-directed practice with the use of CBVT will be to the reduction of cognitive load imposed on a novice learner's cognitive systems in order to enhance optimal performance. Practice may offset the distracting effect of a secondary task on performance of a technical skill since practice allows for skills to become automated (Schneider, & Shriffrin 1977). To date, very few studies have examined the effect of self-directed practice alongside CBVT on the load imposed on a novice's ability to perform a basic medical skill such as the one-hand knot tying.

2.10 Purpose

The purpose of the study is to assess the effectiveness of CBVT on performance and cognitive load during a self-directed practice of the one-hand knot tying between practice and no practice novice learners.

2.11 Statement of Hypotheses

1. Performance will be better for the practice group compared to the no-practice group on the transfer test.
2. SRT will be lower for the practice group compared to the no practice group on the transfer test.
3. SRME will be lower for the practice group compared to the no practice group on the transfer test

Chapter 3: Methodology

3.1 Participants

Informed consent was obtained from 16 students (11 males and five females) with a mean age of 22.38 years (sd=3.83), none of whom had no previous experience with the one-handed square knot tying. There was no compensation for participation in the study. Ethics was approved by ICEHR at Memorial University, number 20152065-HK. Participants were randomly assigned into two groups of eight (i.e. practice and no-practice group).

Based on G- power analysis version 3.1.9.2 (Faul, Erdfelder, Lang, & Buchner, 2007), with an expected sample variance of 1.40 SD, α value of .05, and a ***B*** value of .20, at least eight participants per group were required to achieve a minimum power of .80.

3.2 Materials

A pre-recorded instructional video provided real-time and slow motion demonstrations of an expert tying a one-handed surgical knot with voiceover instructions describing the technique. Slow-motion and real-time demonstrations with verbal instruction, using a 2-color shoelace and silk suture tie (SofSilk; Tyco, Princeton, NJ) were included. The one-handed knot-tying tasks were developed using a bench top simulator, similar to the apparatus described by Brydges, Classen, Larmer, Xeroulis, & Dubrowski (2006). The training video was run on an iPad permitting easy interaction with the video material.

Simple reaction time (SRT) was measured by an apparatus developed by the Memorial University of Newfoundland Technical Services (Electronics, Newfoundland, Canada). The testing apparatus consisted of a stop clock (58007, Lafayette Instrument Company, Lafayette, IN), an analog timer (L15–365/ 099, Triton Electronics, UK), a stop clock latch (58027, Lafayette Instrument Company) that connected the stop clock and the analog timer, a custom-designed box (62 cm x 15.5 cm x 9 cm) with 50 cm from the center of the start button to the center of the stop button. With the device situated on the floor, the ball of the foot was placed on the start button. Upon a single illumination of the light signal, the participant would release the start button in response to the illumination of an incandescent light bulb. SRT was measured as the time between the illumination of light stimulus and release of the start button by the foot.

3.3 Procedures

After providing informed consent and demographic data, all participants began with 15 minutes of computer-based video instruction (CBVI) on clinical knot tying. Following CBVI, the non-practice group had to leave while the practice group completed a 1- minute trial on the secondary task to establish their baseline on simple reaction time (SRT).

3.3.1 Practice test

The practice group completed 10 knot-tying trials (2 minutes each) where they attempted to tie as many single square knots as possible. During each trial the practice group was given 5 minutes to review the instructional video. The total practice time (approximately 70 minutes) for the practice group was selected based on literature demonstrating that most novices achieve a plateau in knot-tying performance within this training period (Jowett, et al., 2007). Practice trials 1, 3, 7 and 10 were conducted under dual task conditions and treated as ‘test’ trials in the subsequent analysis.

During these ‘test’ trials, participants were instructed to focus on the knot-tying task, but also attend to the illumination of an incandescent light bulb. SRT was measured as the time between the illumination of light stimulus and release of the start button. Following each of these trials, the participant’s subjective rating of mental effort (SRME) was recorded using the single-item measure described by Paas, et al. (2003). Specifically, each participant was asked ‘Please rate the level of mental effort you invested towards the knot-tying task by indicating the appropriate response’ on a Likert scale ranging from 1 (very, very low mental effort) to 9 (very, very high mental effort). To anchor participant’s responses, a rating of 1 was considered to represent the effort that required little thinking of an automatic task and a rating of 9 was indicative of the effort required to write an examination.

3.3.2 Transfer test

Participants for both the practice and no practice group returned a week later for the transfer test which was carried out on a different apparatus from both the one shown in the video as well as the one used in the practice trial by the practice group. This was termed transfer test since performance focuses on the ability of participants to apply the skill in a context somewhat different from that of the initial training (Magill, 2001). Prior to the transfer test, participants in the non-practice group completed a 1- minute trial on the secondary task to establish their baseline simple reaction time (SRT) similar to the practice group. The transfer test involved five knot-tying trials (2 minutes each) where participants attempted to tie as many single square knots as possible on the simulation task. All participants had 5 minutes to review the instructional video. Practice trials 1, 3, and 5 were also conducted under dual task conditions and treated as 'test' trials for subsequent analysis. During the transfer trials, the content and presentation of instructional information were standardized in both groups to ensure equality between groups.

3.4 Dependent measures

3.4.1 Knot-tying performance

Both practice and transfer test performances were video-recorded; time taken to complete each trial indicated performance. Time on task was measured in seconds as the duration to complete a single knot during each test trial. Previous literature has shown that time on task is a good predictor of performance (Goldhammer, Naumann, Stelter, Tóth, Rölke, & Klieme, 2014: Martin, Belmont, Schoenfeld, Todd, Cameron, & Owens, 2011).

3.4.2 Cognitive Load

Cognitive load was assessed objectively using participant's SRT on the secondary task. This was achieved by averaging the SRTs for all stimuli presented in a given trial. SRT was measured in seconds as time it takes for participants to respond to the illumination of an incandescent light bulb during each test trial. SRME was another measure of CL which was a self-reported measure given to participants after each test trial. In accordance with the original conceptualization of these measures, (Paas, et al., 2003; Brünken, et al., 2002) both SRT and SRME were treated as estimates of total CL.

3.5 Analysis

Statistical analysis was performed using SPSS 15.0 software (SPSS, Chicago, IL). All data were tested for normality using the Kolmogorov Smirnov test. The effect of practice on performance, SRT and SRME across practice trials among the practice group was assessed using the repeated measures analysis of variance (ANOVA). Differences in performance between the groups were analyzed using a mixed analysis of variance (ANOVA), with practice condition (practice group, no practice group) as the between-subject measure and test trials as the within-subject repeated measure. The same was done for cognitive load performances (SRT and SRME). Alpha was set at .05 for the null hypothesis to be rejected.

Chapter 4: Results

4.1 Introduction

The following chapter discusses the results of the study with a summary of the results for all variables of interest. Normality tests were performed for time on task, simple reaction time and subjective rating of mental effort. Some showed a normal distribution whereas others did not. Some simulation studies have shown an ANOVA test is not very sensitive to moderate deviations from normality. Most of the observations using a number of non-normal distributions indicated the rate of false positives was not affected very much by this violation of the assumption since the current data were not significantly skewed (Glass, Peckham, & Sanders, 1972; Harwell, Rubinstein, Hayes, & Olds. 1992; Lix, Keselman, & Keselman, 1996). Due to the robustness of the F-test to non-normality the mixed ANOVA was used to explore both the first (i.e. performance will be better for the practice group compared to the no-practice group on the transfer test) and second hypothesis (cognitive load will be lower for the practiced group compared to the no practice group on the transfer test).

4.3. Practice test

The practice test was the initial introduction of the task to be learnt (i.e. one-hand knot tying) and was intended to prepare participants for replication through retention or transfer test. In this current study it was a single session of 10 trials of the one-hand knot tying.

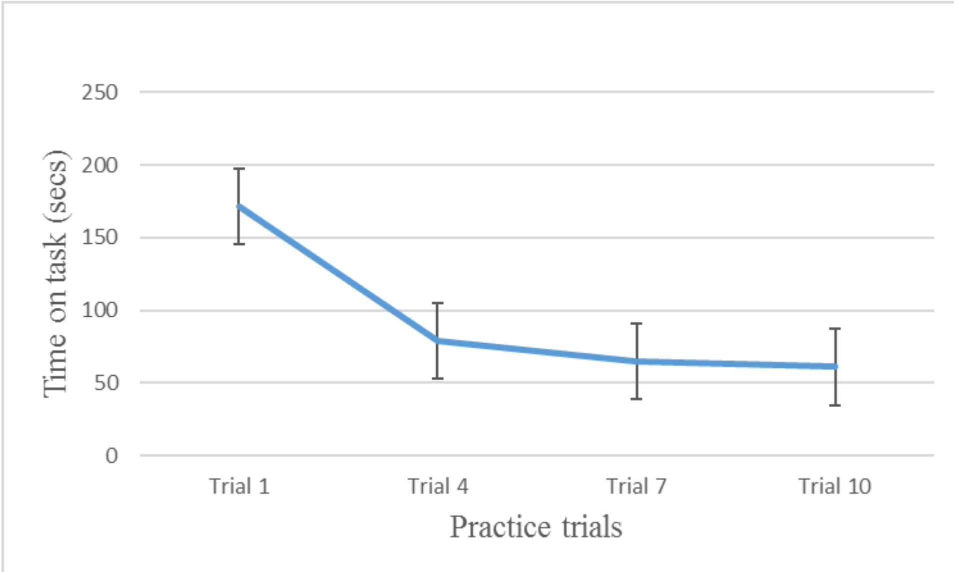

Figure 1. Learning curve indicating time taken to complete practice test trials

Fig. 1 illustrates the learning curve. The slope of the ascent shows the rate at which individuals improve. A significant main effect for time on task was found, with performance improving as practice increased, ($F_{(1.12, 7.84)} = 34.21$, $p < .05$). Post hoc tests using the Least significant difference (LSD) revealed a significant difference in time taken to complete a single knot between trial 1 and trial 4 ($p = 0.001$), trial 4 and trial 7 ($p = 0.005$) but no significant difference between trial 7 and trial 10 ($p = 0.005$).

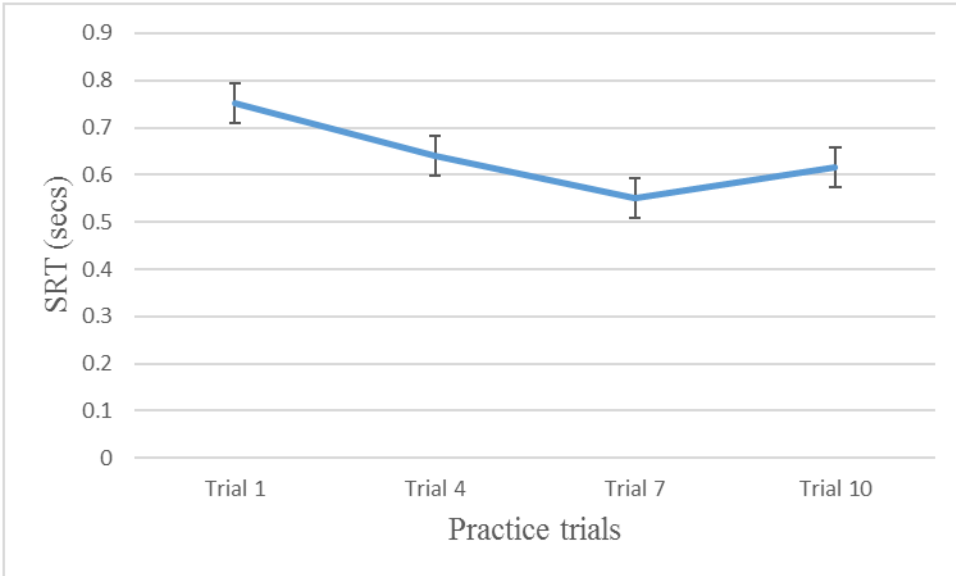

Figure 2. Learning curve indicating simple reaction time during practice trials

Fig. 2 illustrates the learning curve based on the simple reaction time among the practice group during the practice test trials. The starting point indicates time at which practice began. The slope of the decent shows rate at which individuals' cognitive load reduces with increasing number of practice. A significant main effect for SRT was found, with SRT improving as practice increased, ($F_{(3, 21)} = 11.75$, $p < .05$). Post hoc tests with the LSD revealed a significant difference in SRT between trial 1 and trial 4 ($p = 0.007$), trial 1 and trial 7 ($p = 0.034$) and trial 1 and trial 10 ($p = 0.028$). However, there was no significant difference between trial 4 and trial 7 ($p = 0.082$) as well as between trial 7 and trial 10 ($p = 0.098$).

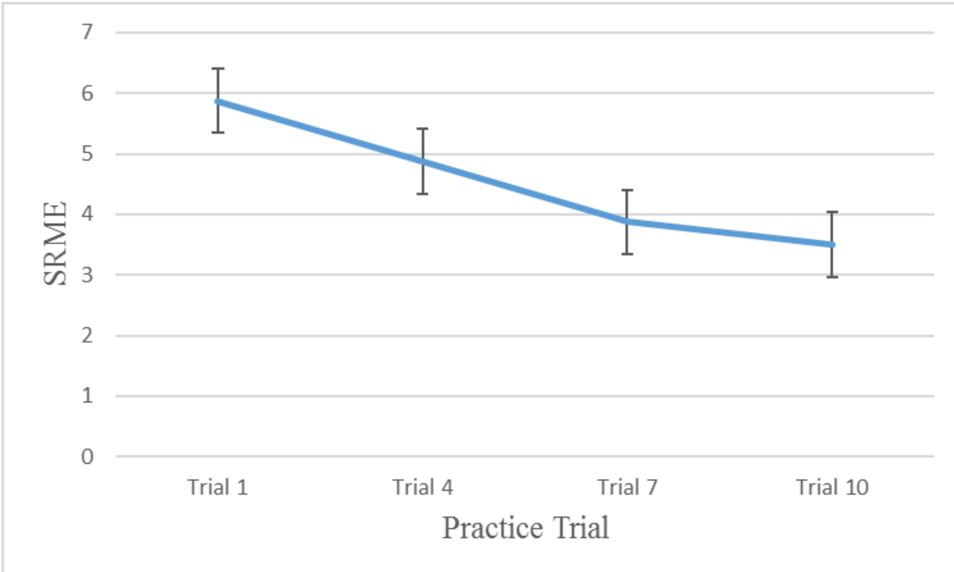

Figure 3. Learning curve showing subjecting rating of mental rating during the practice test trials

Fig. 3 illustrates the learning curve based on subjective rating of mental effort among practice group during the practice test trials. The starting point indicates time at which practice began. This is followed by when the curve further descends. The slope of the decent shows rate at which individuals' cognitive load reduces with increasing number of practice. Results indicates a significant main effect for SRME, with SRME improving as practice increased, ($F_{(3, 21)} = 12.42$, $p < .05$). Post hoc tests using the LSD revealed a significant difference in SRME between trial 1 and trial 4 ($p = 0.033$), trial 4 and trial 7 ($p = 0.018$) but no significant difference between trial 7 and trial 10 ($p = 0.080$).

4.4 Transfer test

The transfer test refers to the performance of the one-hand knot tying in a new context from the initially context where the skill was practiced. In this current study it was a single session of 5 trials of the one-hand knot tying.

4.4.1 Time on task

A mixed-design ANOVA with scores on time taken to complete transfer test trials (trial 1, trial 3 and trial 5) as a within-subjects factor and practice condition (practice group, no practice group) as between-subjects' factors revealed a main effect of trial for the time taken to complete the task, $F_{(1.20,\ 16.79)} = 11.33$, $p <. 05$. Mean scores for time on task reduced with increasing trials as shown in appendix 4. A main effect of practice condition on time taken to complete transfer test trials, $F_{(1,\ 14)} = 241.29$, $p <.05$ was evident. Data indicates the mean scores for time to complete trials was higher for the no practice group 111.80s (42.70s) compared to the practice group 54.70s (16.40s). However, there was no interaction between time taken to complete transfer test trials and practice conditions, ($F_{(1.20,\ 16.79)} = 1.91$, $p > .05$).

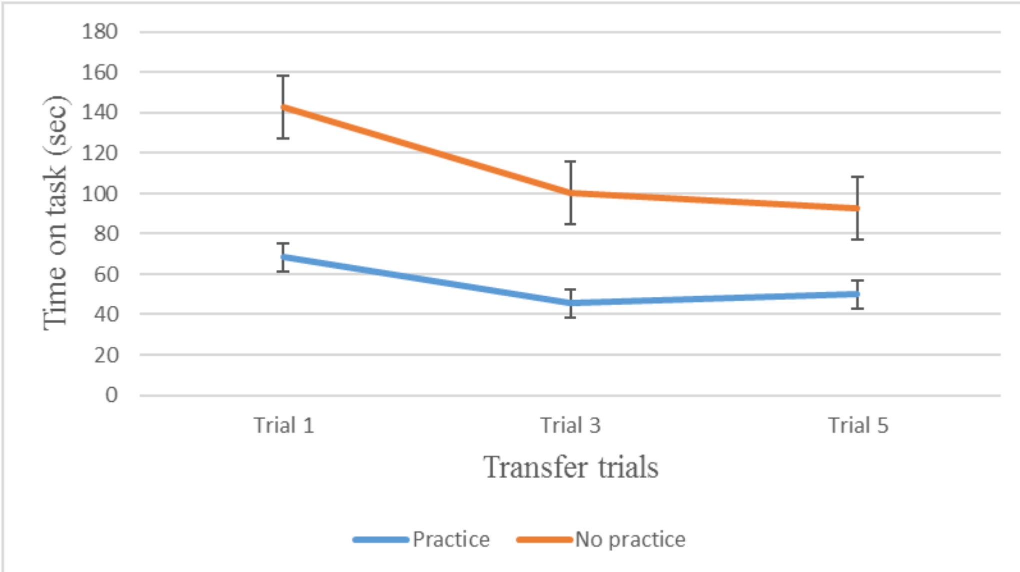

Figure 4. Mean plots for practice condition and time on task during transfer trials

4.4.2 Simple reaction time

Results revealed main effect of transfer trials on simple reaction time, $F_{(2, 28)} = 4.00$, $p < .05$, Mean SRT reduced with increasing trials as presented in appendix 4. This was followed by main effect of practice condition on simple reaction time during transfer test trials, $F_{(1, 14)} = 328.84$, $p < .05$. Mean scores for SRT was higher for the no practice group 0.70s (0.22s) compared to the practice group 0.50s (0.12s).

Nonetheless, there was no interaction effect between simple reaction time during transfer test trials and practice conditions, ($F_{(2, 28)} = 2.01$, $p > .05$).

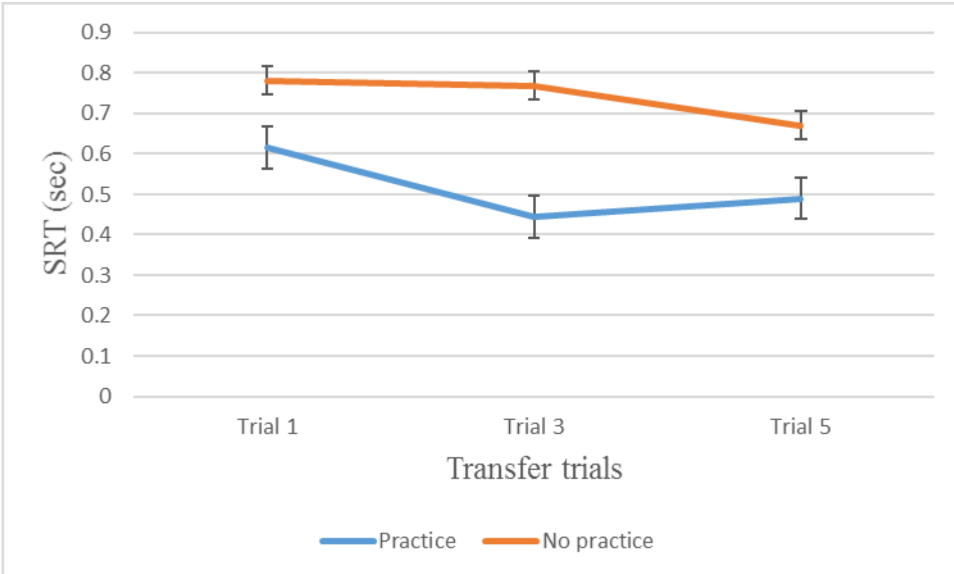

Figure 5. Mean plots for practice condition and SRT during transfer trials

4.4.3 Subjective rating of mental effort

Results from the mixed-design ANOVA indicates main effect of transfer test trials on subjective rating of mental effort, $F_{(2, 28)} = 3.41$, $p < .05$, Mean SRME reduced with increasing trials as shown in appendix 4. There was also a main effect of practice condition on subjective rating of mental effort during transfer test trials, $F_{(1, 14)} = 184.87$, $p < .05$. Mean SRME scores for the no practice group 5.30 (1.52) was higher compared to the practice group 3.70 (1.70). Finally, there was no interaction between subjective rating of mental effort during transfer test trials and practice conditions, ($F_{(2, 28)} = 0.44$, $p >$ .05).

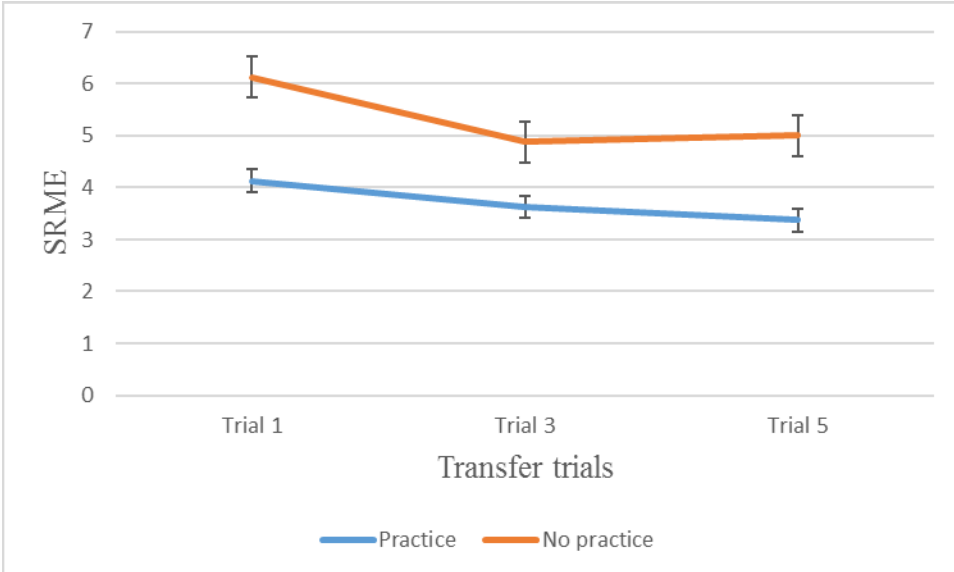

Figure 6. Mean plots for practice condition and SRME during transfer trials

Chapter 5: Discussion and conclusions

5.1 Discussion

Many clinical technical skills are complex motor skills (Dubrowski, & Backstein, 2004). This is a result of the intense involvement of cognitive resources compared to other motor tasks. The reason for assessing cognitive load assumptions with regards to how well learning principles apply to medical education cannot be underestimated. This study centers on cognitive load and skill performance assessment during the practice of the one-hand knot tying using computer based video instruction. The focus was on changes in intrinsic load used to represent cognitive load, which deals with the load imposed on the working memory as a result of the number of separate elements and their interactivity of the given information (i.e. one-hand knot tying).

5.2 Practice and skill performance

The study emphasizes the importance of practice, as data during the practice trials indicates a consistent trend in practice's main effect on all dependent variables (i.e time on task, SRT and SRME among the practice group). Similar to observations in the literature, participants were at the first stage (cognitive) of the proposed three-stage model of learning (Fitts et al. 1967). Here the learner experiments with different strategies to identify what is required to complete a one-handed knot-tying. Initial overall movements were slow and began to improve with practice as the learner consciously payed attention to the fine details during the trials. Post hoc tests revealed practice elicited a significant reduction in SRT from trial to trial.

A transfer phase assessed whether learning was retained in the study. That is, the learner was assessed to observe if the movement information during the practice trial was retained in a different context (Magill, 2001). Performances of the practice group was compared to a control that had no practice to ensure changes in the dependent variables (time on task, SRT and SRME) was as a result of practice. The first hypothesis predicted performance will be better for practice group compared to non-practice group on the transfer test based on the fact that literature has shown that practice plays a significant role in reducing intrinsic load while improving performance in the one-hand knot-tying among novice learners (Kurahashi, et al. 2011). Results in the current study revealed the predicted patterns (i.e. improvement from trial 1 to trial 4 ($p = 0.001$), trial 4 to trial 7 ($p = 0.005$)) similar to the findings of Derossis et al., (1998), where laparoscopic skill improved with increased practice and the repetition of certain procedures. The same observation was true for the second hypothesis; cognitive load was lower for the practiced group compared to the no practice group on the transfer test. Hashimoto, et al., (2013) provided evidence to support how practice for a group of participants brings about improvement in a given task. Paas, and Van Merrienboer (1994) demonstrated a similar trend. Participants in their study who first had the opportunity to practice with worked examples spent less time and mental resources in their task, and had superior transfer performance compared to students who had not practiced.

Even though both groups demonstrated a reduction in performance and cognitive load from trial to trial, the practice group recorded lower time on task, SRT and SRME on all transfer trials compared to the no practice group, suggesting the effectiveness of practice intervention. The results are in line with CLT's theory that posits the observed intrinsic load imposed by the primary task (i.e. one-hand knot-tying) reduces with practice as novice learners develop schemas for the skill through practice using simulation-based practice (Bharathan, et al, 2013). Clinical technical skills develop with time due to consistent practice (Young et al, 2014) and simulation training creates the environment for repeated practice in a learner-centered environment and helps enhance clinical confidence among novice trainees (Anastakis, et al., 2003). Bharathan and colleagues (2013) in validating a virtual reality simulator for the training and assessment of laparoscopic tubal surgery, tracked cognitive load among participants and showed practice reduce cognitive load.

The effectiveness of computer based video training also played a role in skill acquisition. Jowett et al., (2007) had participants practice the one-handed square knot tying task using CBVT which followed significant improvement in performance of trainees supporting the idea of CBVT being an effective tool that creates a multimedia environment to enhance learning among novice learners.

5.3 Learning curve

The learning curve for the practice group showed that the practice on simulators led to higher levels of proficiency and decreased cognitive loads. From a motor learning standpoint, the plateau in knot-tying performance is expected to be observed between trials 5 and 9 (Haji, et al. 2015), typically the plateau reflects learners' shift from the one phase of motor skill acquisition (in which the necessary stages required to tie surgical knots are stored as schema) to the another phase of skill learning (in which this schema is elaborated as a result of practice to make task performance more efficient) (Fitts et al., 1967).

5.4 Limitations

The current study had some methodological considerations. First, the measures for cognitive load i.e. SRME and SRT, although both useful for tracking changes in CL during multiple learning trials, they provided only estimates of average CL within a specific period of time. These measures failed to provide further details on instantaneous changes in CL during learning trials unlike the physiological measures such as the cognitive pupillary response measure (Paas, et al., 2003). Future research should explore physiological measures of CL such as the cognitive pupillary response measure in order to track instantaneous changes in CL. This would provide information on the specific aspects of the knot tying procedure that caused cognitive processing difficulties and would in turn require higher mental effort from learners (Zheng, 2009).

Secondly, sample size was limited. This limitation placed some constraints on some of the analyses, such as correlations, that could offer insight into the relationship between changes in CL and performance. Furthermore, increasing sample size as well as increasing the number of transfer trials would make it easier to trace the various phases of Fitts & Posner's (1967) three-stage model of learning.

5.5 Conclusions

Findings from this study have both theoretical and practical implications. In theory, the results support the three-stage model of learning showing a progressive improvement of performance with increasing practice. The measures of cognitive load were sensitive to changes in performance with reduction in cognitive load followed by a corresponding improvement in performance resulting from practice on a simulator using computer based video instructions among a group of novices. In tandem with existing literature, findings also show the importance of matching primary and secondary tasks during the use of dual task methodology in measuring CL.

From a practical perspective, the study provides directions for assessing the learning needs as well as help curriculum development in medical education. First of all, educators need to recognize the learning needs for novice learners when using the CBVT in order to enhance skill proficiency. Educators can create a learning environment that supports the novice learning by providing enough information to the learner. Secondly, educators should focus on factors that hinder learning and highlight factors that facilitate learning during CBVT and simulation training.

References

Abernethy, B. (1988). Dual-task methodology and motor skills research: some applications and methodological constraints. *Journal of Human Movement Studies*, 14, 101–132.

Anastakis, D. J., Wanzel, K. R., Brown, M. H., McIlroy, J. H., Hamstra, S. J., Ali, J., Hutchison, C. R., Murnaghan, J., Reznick, R. K., & Regehr, G. (2003). Evaluating the effectiveness of a 2-year curriculum in a surgical skills center. *The American Journal of Surgery*, 185, 378–85.

Baddeley, A. D. (1986). *Working memory*. Oxford, England: Oxford University Press.

Baddeley, A., & Hitch, G. J. (1974). Working memory. In G. A. Bower (Ed.), *Recent Advances in Learning and Motivation*. (Vol. 8, pp. 47-90). New York: Academic Press.

Bernstein, N. (1967). *The Coordination and Regulation of Movements*. Oxford, UK: Pergamon Press.

Bharathan, R., Vali, S., Setchell, T., Miskry, T., Darzi, A., & Aggarwal, R. (2013). Psychomotor skills and cognitive load training on a virtual reality laparoscopic simulator for tubal surgery is effective. *European Journal of Obstetrics and Gynecology*, 169(2), 347-352.

Brown, L. A., McKenzie, N. C., & Doan, J. B. (2005). Age-dependent differences in the attentional demands of obstacle negotiation. *The Journals of Gerontology Series A: Biological Sciences and Medical Science*, 60(7), 924–927.

Brünken, R., Plass, J. L., & Leutner, D. (2004). Assessment of Cognitive Load in Multimedia Learning with Dual-Task Methodology: Auditory Load and Modality Effects. *Instructional Science*, 32(18), 115-132.

Brünken, R., Plass, J., & Leutner, D. (2003). Direct measurement of cognitive load in multimedia learning. *Educational Psychologist*, 38(1), 53–61.

Brydges, R., Classen, R., Larmer, J., Xeroulis, G., & Dubrowski, A. (2006). Computer-assisted assessment of one-handed knot tying skills performed within various contexts: a construct validity study. *The American Journal of Surgery*, 192, 109 – 13.

Cao, C., G., Taylor, H. (2004). Work with Computing Systems. In: H. M. Khalid, M. G Helander, & A.W. Yeo (Eds.), *Effects of New Technology on the Operating Room Team*. Kuala Lumpur: Damai Sciences.

Chi, M., Glaser, R., & Rees, E. (1982). Expertise in problem solving. In: R. Sternberg (Ed.), *Advances in the Psychology of Human Intelligence*, (pp. 7–75). Hillsdale, NJ: Erlbaum.

Clark, J. M., & Paivio, A. (1991). *Dual coding theory and education.* Educational Psychology Review, 3, 149-210.

Chandler, P. & Sweller, J. (1991). Cognitive load theory and the format of instruction. *Cognition and Instruction*, 8, 293-332.

Cognition and Technology Group at Vanderbilt. (1993). Anchored instruction and situated cognition revisited. *Educational Technology*, 40, 52–67.

Curtis, M. T., DiazGranados, D. & Feldman, M. (2012). Judicious use of simulation technology in continuing medical education. *Journal of Continuing Education in the Health Professions*, 32, 255–260.

Davies, R. J., & Hamdorf, J. M. (2003). Surgical skills training and the role of skills centres. *British Journal of Urology*, 91, 3– 4.

Derossis, A. M., Bothwell, J., Sigman, H. H., & Fried, G. M. (1998). The effect of practice on performance in a laparoscopic simulator. *Surgical Endoscopy*, 12, 1117-1120.

DiMaggio, P. (1997). Culture and cognition. *Annual Review of Sociology*, 23, 263-287.

Dubrowski, A., Brydges, R., Satterthwaite, L., Xeroulis, G., & Classen, R. (2012). Do not teach me while I am working! *The American Journal of Surgery*, 203(1), 253-257.

Dubrowski, A., & Backstein, D. (2004). The contributions of kinesiology to surgical education. *Journal of Bone and Joint Surgery*, 86(12), 2778.

Duvivier, R., Van Dalen, J., Muijtjens, A., Moulaert, V., Van der Vleuten, C., & Scherpbier, A. (2011). The role of deliberate practice in the acquisition of clinical skills. *BMC Medical Education*, 11, 101.

Ellis, H. (1993). Teaching surgeons to stitch. *Australian and New Zealand Journal of Surgery*, 63(12), 919–920.

Faul, F., Erdfelder, E., Lang, A., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175-191.

Fisk, A. D., Derrick, W. L., & Schneider, W. (1986). A methodological assessment and evaluation of dual task paradigms. *Current Psychological Research and Reviews*, 5(4), 315–327.

Fitts, P. M., & Posner, M. I. (1967). *Human Performance*. Belmont, CA: Brooks/Cole.

Gagne, R. M. (1962). Military training and principles of learning. *American Psychologist*, 17(2), 83-91.

Glass, G., Peckham, P., & Sanders, J. (1972). Consequences of failure to meet assumptions underlying fixed effects analyses of variance and covariance. *Review of Educational Research*, 42, 237-288.

Greenhalgh, T. (2001). Computer assisted learning in undergraduate medical education. *British Medical Journal*, 322(7277), 40-44.

Goldhammer, F., Naumann, J., Stelter, A., Tóth, K., Rölke, H., & Klieme, E. (2014). The Time on Task Effect in Reading and Problem Solving Is Moderated by Task Difficulty and Skill: Insights from a Computer-Based Large-Scale Assessment. *Journal of Educational Psychology*, 106(3), 608-626.

Haapalainen, E., Kim, S., Forlizzi, J. F., & Dey, A. K. (2010). Psycho-Physiological Measures for Assessing Cognitive Load. *Ubiquitous Computing Proceedings of the 12th ACM International Conference, 301-310.*

Haji, F. A., Hoppe, D. J., Morin, M., Giannoulakis, K., Koh, J., Rojas, D., & Cheung, J. J. H. (2014). What we call what we do affects how we do it: a new nomenclature for simulation research in medical education. *Advances in Health Sciences Education*. 19(2), 273-280.

Haji, F., Rojas, D., Childs, R., Ribaupierre, S., & Dubrowski, A. (2015). Measuring cognitive load: Performance, mental effort and simulation task complexity. *Medical Education*, *49*(8), 815-827.

Hartley, A. A. (2001). Age differences in dual-task interference are localized to response-generation processes. *Psychology and Aging*, 16(1), 47-54.

Harwell, M. R., Rubinstein, E. N., Hayes, W. S. & Olds. C. C. (1992). Summarizing Monte Carlo results in methodological research: the one- and two-factor fixed effects ANOVA cases. *Journal of Educational Statistics*, 17, 315-339.

Hashimoto, D. A., Sirimanna, P., Gomez, E. D., Beyer-Berjot, L., Ericsson, K. A., Williams, N. N., Darzi, A. W., & Aggarwal, R. (2013). Effect of deliberate practice on learning and surgical performance: a randomized control trial. *Journal of the American College of Surgeons*, 217(3), S118.

Hemond, C., Brown, R. M., & Robertson, E. M. (2010). A distraction can impair or enhance motor performance. *Journal of Neuroscience*, 30(2), 650–654.

Henelius, A., Hirvonen, K., Holm, A., Korpela, J. & Muller, K. (2009). Mental workload classification using heart rate metrics. *Conference proceedings: Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, 1, 1836–1839.

Henry, F. M. (1968). *Specificity vs. generality in learning motor skill*. In R.C. Brown & G.S. Kenyon, Classical Studies on Physical Activity (pp. 328-331). Englewood Cliffs, NJ: Prentice Hall.

Heppell, J., Beauchamp, F. & Chollet, A. ((1995). Ten-year experience with a basic technical skills and perioperative management workshop for first-year residents. *Canadian Journal of Surgery*, 38, 27–32.

Issenberg, S. B., McGaghie, W. C, Petrusa, E. R, Lee Gordon, D., & Scalese, R. J. (2005). Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. *Medical Teacher*, 27, 10–28.

Janelle, C. M., Barba, D. A., Frehlich, S. G., Tennant, L. K., & Cauraugh, J. H. (1997) Maximizing performance effectiveness through videotape replay and a self-controlled learning environment. *Research Quarterly for Exercise and Sport*, 68, 269–79.

Jowett, N., LeBlanc, V., Xeroulis, G., MacRae, H., & Dubrowski, A. (2007). Surgical skill acquisition with self-directed practice using computer-based video training. *The American Journal of Surgery*, 193(1), 237-242.

Kahol, K., Vankipuram, M., & Smith, M. L. (2009). Cognitive simulators for medical education and training. *Journal of Biomedical Informatics*, 42(4), 593-604.

Kalyuga, S., Chandler, P., & Sweller, J. (1999). Managing split-attention and redundancy in multimedia instruction. *Applied Cognitive Psychology*, 13, 351–371.

Kalyuga, S., Chandler, P., & Sweller, J. (2004). When redundant on-screen text in multimedia technical instruction can interfere with learning. *Human factors*, 46(3), 567-81.

Knebel, E., (2000). *The use and effect of computer based training: what do we know?* Bethesda, MD: Published for the U.S. Agency for International Development (USAID) by the Quality Assurance Project (QAP), Center for Human Services, University Research Co., LLC.

Kneebone, R., & Apsimon, D. (2001). Surgical skills training: simulation and multimedia combined. *Medical Education*, 35, 909 –15.

Knowles, M. S. (1975). *Self-directed Learning: A Guide for Learners and Teachers*. Cambridge Book Co.: New York.

Kurahashi, A. M., Harvey, A., MacRae, H., Moulton, C., & Dubrowski, A. (2011). Technical skill training improves the ability to learn. *Journal of Surgery*. 149(1), 1-6.

Lazzara, E.H., Benishek, L.E., Dietz, A. S., Salas, E., & Adriansen, D. J. (2014). Eight Critical Factors in Creating and Implementing a Successful Simulation Program. *Joint Commission Journal on Quality and Patient Safety*, 40(1), 21-29.

Lee, T. D., Swinnen, S. P., & Serrien, D. J. (1994). Cognitive effort and motor learning. *Quest*, 46, 328–344.

Lewthwaite, R., & Wulf, G. (2012). "*Motor learning through a motivational lens,"* in Skill Acquisition in Sport: Research, Theory and Practice, 2nd Edition, eds Hodges N. J., Williams A. M., editors. (London: Routlegde), 173–191.

Lix, L. M., Keselman, J. C. & Keselman H. J. (1996). Consequences of Assumption Violations Revisited: A Quantitative Review of Alternatives to the One-Way Analysis of Variance "F" Test. *Review of Educational Research*, 66(4), 579-619.

Magill, R. & Anderson, D. (2014). *Motor Learning and Control: Concepts and applications.* 10th Edition. New York, NY: McGraw Hill.

Martin, K. D., Belmont, P. J., Schoenfeld, A.J., Todd, M., Cameron, K. L., & Owens, B. D., (2011). Arthroscopic basic task performance in shoulder simulator model correlates with similar task performance in cadavers. *The Journal of bone and joint surgery. American volume,* 2, 93(21), e1271-e1275.

Mayer, R. E. (2001). *Multimedia learning*. New York: Cambridge University Press.

Mayer, R. E. (2005a). Cognitive theory of multimedia learning. In R.E. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning*. New York: Cambridge University Press.

Mayer, R. E. (1996). Learning strategies for making sense out of expository text: The SOI model for guiding three cognitive processes in knowledge construction. *Educational Psychology* Review, 8, 357-71.

Mayer, R. E. (1999). Research-based principles for the design of instructional messages: The case of multimedia explanations. *Document Design*, 1, 7-20.

Mayer, R. E., Dow, G. T., & Mayer, S. (2003). Multimedia Learning in an Interactive Self-Explaining Environment: What Works in the Design of Agent-Based Microworlds? *Journal of Educational Psychology,* 95(4)*,* 806-812.

Mayer, R. E. & Moreno, R. (2003). "Nine Ways to Reduce Cognitive Load in Multimedia Learning." *Educational Psychologist*, 38(1), 43-52.

Mayer, R. E., Hegarty, M., Mayer, S., & Campbell, J. (2005). When Static Media Promote Active Learning: Annotated Illustrations Versus Narrated Animations in Multimedia Instruction. *Journal of Experimental Psychology*, 11(4), 256-265.

Mayer, R. E., & Moreno, R. (1998). A split-attention effect in multimedia learning: Evidence for dual processing systems in working memory. *Journal of Educational Psychology*, 90, 312-320.

McGaghie, W., Issenberg, S., Petrusa, E., & Scalese, R. (2006). Effect of practice on standardized learning outcomes in simulation-based medical education. *Medical Education*, 40(8), 792-797.

Merali, P & Tse. F (2010). T1033 Assessing the Learning Curve for the Acquisition of Endoscopy Skills on a Computer-Based Endoscopy Simulator. *Gastroenterology*, 138(5), S-473.

Moreno, R. (2007). Optimizing learning from animations by minimizing cognitive load: Cognitive and affective consequences of signaling and segmentation methods. *Applied Cognitive Psychology*, 21, 765–781.

Paas, F., Tuovinen, J.E., Tabbers, H. & Van Gerven, P.W.M. (2003). Cognitive load measurement as a means to advance cognitive load theory, *Educational Psychologist*, 38, 63–71.

Paas, F., & van Merriënboer, J. J. G. (1994a). Instructional control of cognitive load in the training of complex cognitive tasks. *Educational Psychology Review*, 6, 51–71.

Paas, F. G. W. C., & Van Merrienboer, J. J. G., (1994). Variability of Worked Examples and Transfer of Geometrical Problem-Solving Skills: A Cognitive-Load Approach. *Journal of Educational Psychology*, 86, (1), 122-133.

Paivio, A. (1986). *Mental representations: A dual coding approach*. Oxford, England: Oxford University Press.

Patla, A. E. (1998). How is human gait controlled by vision? *Ecological Psychology*, 10(3-4), 287–302.

Perkins, G. D. (2007). Simulation in resuscitation training. *Resuscitation*, 73(2), 202-11.

Pollock, E., Chandler, P., & Sweller, J. (2002). Assimilating complex information. *Learning and Instruction*, 12(1), 61-86.

Reedy, G. B. (2015). Using Cognitive Load Theory to Inform Simulation Design and Practice. *Clinical Simulation in Nursing*, 11, 355-360.

Roche, R. A, Commins, S, Agnew, F., Cassidy, S., Corapi, K., Leibbrand, S., Lipson, Z., Rickard, J., Sorohan, J., Wynne, C., & O'Mara, S. M. (2007). Concurrent task performance enhances low-level visuomotor learning. *Perception & psychophysics*, 69(4), 513–522.

Rogers, D. A., Regehr, G., Yeh, K. A., & Howdieshell, T. R., (1998). Computer-assisted learning versus a lecture and feedback seminar for teaching a basic surgical technical skill. *The American Journal of* Surgery, 175, 508 –10.

Rojas, D., Haji, F., Shewaga, R., Kapralos, B., & Dubrowski, A. (2014). The impact of secondary-task type on the sensitivity of reaction-time based measurement of cognitive load for novices learning surgical skills using simulation. *Studies in health technology and informatics*, 196, 353–35.

Safir, O., Williams, C. K., Dubrowski, A., Backstein, D., & Carnahan, H. (2013). Self-directed practice schedule enhances learning of suturing skills *Canadian journal of surgery*. 56(6), 142-7.

Schmidt, R. A., & Lee, T. D. (2005). *Motor Control and Learning: A Behavioral Emphasis*. 3rd ed. Champaign, IL: Human Kinetics.

Schmidt, R. A., & Lee, T. D. (1999). *Motor control and learning*: A behavioral emphasis (3rd ed.). Champaign, IL: Human Kinetics.

Schmidt, R. A., & Lee, T. D. (2005). *Motor control and learning. A behavioral emphasis*. 4th ed. Champaign (IL): Human Kinetics.

Schneider, W. & Shriffrin, R. M. (1977). Controlled and automatic human information processing: I. Detection, search, and attention. *Psychological Review*, 84, 1–66

Schnotz, W., & Rasch, T. (2005). Enabling, Facilitating, and Inhibiting Effects of Animations in Multimedia Learning: Why Reduction of Cognitive Load Can Have Negative Results on Learning. *Educational Technology Research and Development*, 53(3), 1042-1629.

Seymour, N. (2008). VR to OR: A Review of the Evidence that Virtual Reality Simulation Improves Operating Room Performance. *World Journal of Surgery*, 32(2), 182-188.

Spencer, J. A., Jordan, R. K. (1999). Learner centered approaches in medical education. *British Medical Journal*, 318(7193), 1280-1283.

Stefanidis, D., Acker, C., & Heniford, B. T. (2008). Proficiency-Based Laparoscopic Simulator Training Leads to Improved Operating Room Skill That Is Resistant to Decay. *Surgical Innovation*, 15, 69-73.

Stefanidis, D., Scerbo, M. W., Korndorffer Jr J. R., & Scott, D. J. (2007). Redefining simulator proficiency using automaticity theory. *The American Journal of Surgery*, 193(1), 502-506.

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

Sweller, J. (1999). *Instructional Design in Technical Areas*. Melbourne, Australia: ACER Press.

Taylor, D. C., & Hamdy, H. (2013). Adult learning theories: implications for learning and teaching in medical education: *AMEE Guide* No. 83. *Medical Teacher*, 35(11), e1561- e1572.

Uccelli, J., Kahol, K., Ashby, A., Smith, M., & Ferrara, J. (2011). The validity of take-home surgical simulators to enhance resident technical skill proficiency. *The American Journal of Surgery*, 201(3), 315-319.

Van Merriënboer, J. J. G., Schuurman, J. G., de Croock, M. B. M., & Paas F. G. W. C. (2002). Redirecting learners' attention during training: effects on cognitive load, transfer test performance and training efficiency. *Learning and Instruction*, 12, 11–37.

Van Merriënboer, J. J. G., & Sweller, J. (2010). Cognitive load theory in health professional education: Design principles and strategies. *Medical Education*, 44, 85-93.

Van Gerven, P. W. M., Paas, F., van Merriënboer, J. J. G., & Schmidt, H. G. (2006). Modality and variability as factors in training the elderly. *Applied Cognitive Psychology,* 20, 311-320.

Voelcker-Rehage, C., & Alberts, J. L. (2007). Effect of motor practice on dual-task performance in older adults. The journals of gerontology. Series B, *Psychological sciences and social sciences,* 62b(3), P141-P148.

Wouters, P., Paas, F., & Van Merriënboer, J. J. G. (2009). Observational learning from animated models: Effects of modality and reflection on transfer. *Contemporary Educational Psychology,* 34, 1-8.

Wulf, G., Shea, C., & Lewthwaite, R. (2010). Motor skill learning and performance: A review of influential factors. *Medical Education,* 44(1), 75-84.

Xeroulis, G. J., Park, J., Moulton, C-A., Reznick, R. K., LeBlanc, V., & Dubrowski, A. (2007). Teaching suturing and knot-tying skills to medical students: A randomized controlled study comparing computer-based video instruction and (concurrent and summary) expert feedback. *Surgery*, 141(4), 442-449.

Young J. Q., Van Merrienboer, J., Durning, S., & Ten Cate, O. (2014). Cognitive Load Theory: Implications for medical education. *AMEE Guide No. 86. Medical Teacher*, 36, 371–384.

Zheng, R. Z. (2009). *Cognitive Effects of Multimedia Learning*. New York: Information Science Reference.

Appendices

Appendix 1. Recruitment email

Dear [Sir/Madam],

I am writing to tell you about my study 'Cognitive load assessment in telemedicine delivery' being conducted through the School of Human Kinetics and recreation as my Master's thesis.

The purpose of this research study is to assess cognitive load in Telemedicine delivery under specific conditions i.e. environment complexity and nature of telemedical devices. The study has two phases: the initial learning phase and the transfer phase. Participants would perform two tasks concurrently; a primary and a secondary task. For the primary task participants will be performing a simulated intubation procedure on an unstable simulated patient (mannequin) whiles being telementored. The secondary task will be a vibrotactile stimulus-monitoring task which requires participant monitor a small unit attached to their leg, which will vibrate four times per minute at random time-intervals. Participants will then be instructed to press a foot-pedal as quickly as possible each time they feel a vibration; a custom software will record each pedal-press and your reaction time (RT). The learning phase consists of four trials approximately 15 minutes per trial whereas the transfer phase which takes place a week later consists of two trials approximately 15 minutes each, making a total of approximately 1 hour 30 minutes.

You may be eligible for this study if you are a first or second year medical student in Memorial University, Faculty of medicine with no prior experience in the intubation protocol.

If you are interested in learning more about this study, please review the attachments for information and respond to this email. This includes a copy of an opt-in form (which is to be filled and returned if you are interested in learning more). You can also call us on [7097715000].

It is important to know that this mail is not to tell you to join this study. It is solely your decision. Your participation is voluntary. Whether or not you participate in this study will have no effect on your relationship with the School of Human Kinetics or Memorial University Faculty of medicine. It will also have no impact on your medical school evaluation/performance either now or in the future.

You do not have to respond if you are not interested in this study. If you do not respond, no one will contact you.

Thank you for your time and consideration. I look forward to hearing from you.

Sincerely,

Cognitive load assessment in computer based video training of one hand knot tying

REUBEN NEWTON ADDISON

ICEHR Approval statement

The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research and found to be in compliance with Memorial University's ethics policy. If you have ethical concerns about the research, such as the way you have been treated or your rights as a participant, you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at 709-864-2861.

Please find attached enclosure(s) as applicable:

Recruitment materials, e.g. consent form, etc.

OPT-IN FORM

Cognitive load assessment in Telemedicine delivery

Please complete this form scanned and returned to the email address below

 I am interested in learning more about this study. Please contact me using the following information:

Name: ____

Telephone(s): ____

Best time and day to call: ____

Email: ____@_____________________

Email: Rna820@mun.ca

Appendix 2. Recruitment poster

COGNITIVE LOAD ASSESSMENT IN TELEMEDICINE DELIVERY

MEMORIAL UNIVERSITY

You are invited to take part in a research project entitled "Cognitive load assessment in telemedicine delivery". You would have the opportunity to get an on-site experience with the intubation protocol

We will be comparing 2 different human-technology interface designs in the marine environment."

Telemedicine refers to the use of telecommunication and information technologies in order to provide clinical health care at a distance. It helps eliminate distance barriers and can improve access to medical services that would often not be consistently available in remote settings. It is also used to save lives in critical health care and emergency situations.

You may be eligible for this study if you are:

1. a first or second year medical student at Memorial University Faculty of medicine

2. without prior experience in the intubation protocol.

The first phase of the study consists of four trials approximately 15 minutes per trial whereas the transfer phase (second phase) which takes place a week later consists of two trials approximately 30 minutes, making a total of approximately 3 hours.

Cognitive Load: This indicates the perceived load or tension imposed on a learner's cognitive system (mind) during the performance of a particular task.

For more information or if interested please contact the researcher:

Reuben Addison rma820@ mun.ca
Phone: 709-771-5000

Reuben Addison rma820@ mun.ca
Phone: 709-771-5000

Reuben Addison rma820@ mun.ca
Phone: 709-771-500@ mun.ca
Phone: 709-743-8774

Reuben Addison rma820@ mun.ca
Phone: 709-771-5000

Reuben Addison rma820@ mun.ca
Phone: 709-771-5000

Reuben Addison rma820@ mun.ca
Phone: 709-771-5000

Reuben Addison rma820@ mun.ca
Phone: 709-771-5000

Reuben Addison rma820@ mun.ca

Appendix 3. Consent Form

Informed Consent Form

Title: Cognitive load assessment in telemedicine delivery: A comparison of 2 different human-technology interface design in the marine environment

Researcher: Reuben Newton Addison, School of Human Kinetics and Recreation, email: rna820@mun.ca

Supervisor: Dr. Adam Dubrowski, Emergency Medicine and Pediatrics and the Marine Institute, email: adam.dubrowski@med.mun.ca

Co Supervisor Dr. Linda Rohr, School of Human Kinetics and Recreation email: lerohr@mun.ca

You are invited to take part in a research project entitled "Cognitive load assessment in telemedicine delivery: A comparison of 2 different human-technology interface designs in the marine environment."

This form is part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. It also describes your right to withdraw from the study. In order to decide whether you wish to participate in this research study, you should understand enough about its risks and benefits to be able to make an informed decision. This is the informed consent process. Take time to read this carefully and to understand the information given to you. Please contact the researcher, Reuben Newton Addison, if you have any questions about the study or would like more information before you consent.

It is entirely up to you to decide whether to take part in this research. If you choose not to take part in this research or if you decide to withdraw from the research once it has started, there will be no negative consequences for you, now or in the future.

Introduction:
I am a Masters student at the school of human kinetics and recreation. As part of my Master's thesis, I am conducting research focused on cognitive load under the supervision of Dr. Adam Dubrowski, a content expert in medical education using

simulation, specialized in the assessment of complex clinical skills, behaviors and attitude acquisition.

Purpose of study:
Telemedicine refers to the use of telecommunication and information technologies in order to provide clinical health care at a distance. It helps eliminate distance barriers and can improve access to medical services that would often not be consistently available in remote settings. It is also used to save lives in critical health care and emergency situations. The purpose of this project is to assess the effect of a) environment complexity and b) design of telemedical devices on cognitive load and skills performance of health care professionals performing a complex skill of intubation of an unstable patient

Simulation: This refers to the replication of an event or a task for the purpose of training and/or assessment
Cognitive Load: This indicates the perceived load or tension imposed on a learner's cognitive system (mind) during the performance of a particular task

What you will do in this study:
The study has two phases: the initial learning phase and the transfer phase. You will be performing two tasks concurrently; a primary and a secondary task. For the primary task you will be performing a simulated intubation procedure on an unstable simulated patient (mannequin) while being telementored. The secondary task will be a vibrotactile stimulus-monitoring task which requires you to monitor a small unit attached to their leg, which will vibrate four times per minute at random time-intervals. You will then be instructed to press a foot-pedal as quickly as possible each time you feel a vibration; custom software will record each pedal-press and your reaction time (RT). The learning phase will take place in Memorial's Faculty of medicine state of the art simulation laboratory at the Clinical Learning and Simulation Centre (CLSC) whereas the transfer phase would be in a stationary ambulance on the parking lot of the Faculty of medicine. All simulation performances will be videotaped. Recordings will be destroyed after completion of the study and after Memorial University's mandatory 5-year holding period. You will be allowed to view your recorded performance, if desired, after completion of the study. The Global rating scale would be used by two experts to rate performances on intubation alongside an intubation checklist solely for the purpose of the study. Testing will be done individually.

Length of time:

The learning phase consists of four trials approximately 15 minutes per trial whereas the transfer phase which takes place a week later consists of two trials approximately 15 minutes each making a total of approximately 1 hour 30 minutes.

.

Withdrawal from the study:

You have a right to end participation in the course of the study at any time without any consequences hence if you decide to withdraw from the study, the information collected up to that time will continue to be used by the research team unless otherwise requested by participants then the information will be destroyed or permanently deleted. On the other hand once data from participants is aggregated, analyzed and prepared for publication (end of September 2015), your data will no longer be removed.

.

Possible benefits:

You will have an added on-site experience with the intubation protocol as well as increase your knowledge of both the content of medical education investigations and the methodologies used by researchers.

Possible risks:

There is no risk of physical harm in this study. Many learners find medical simulation to be emotionally stressful and anxiety provoking. This may be considered a potential risk of the study. In the event that you experience any form of social risk such as anxiety the session would be ended and you can be escorted to the University Counseling Centre. However, your performance or competence will not be reviewed but used solely for the purpose of the study. Furthermore, your performance will not be shared with the Residency Program Director and will have no effect on your academic standing within your training program.

Confidentiality:

The ethical duty of confidentiality includes safeguarding participants' identities, personal information, and data from unauthorized access, use, or disclosure.

Although the data from this research project will be published and presented at conferences, the data will be reported in aggregate form, so that it will not be possible to identify individuals. Moreover, the consent forms will be stored separately from the review by the Global rating scale as well as video recording of each participant, so that it will not be possible to associate a name with any given set of responses.

Anonymity:

You will be given a code number that will be assigned to all of your data so they can be kept together, you will never be identified by name and data will be presented in aggregate form so that individuals will maintain anonymity.

Recording of Data:
All videos will be destroyed after Memorial University's mandatory 5-year holding requirement. All information about your performance will be coded with and stored with no identifying information.

Storage of Data:

The data once collected in electronic form, will be stored on a password protected computer within Memorial University's School of Human Kinetics and Recreation and kept for a minimum of five years, as required by Memorial University's policy on Integrity in Scholarly Research and discarded or deleted from the memory of the host computer. My supervisor and I will have access to the data during that period. Data-sharing agreements between the researcher and other institutions (possibly RDC) will be signed prior to providing or obtaining access to data. Ownership agreement will include password protection and final data devoid of traceable personal identification. Data would be used solely for the purpose of advancing policy hence in aggregated form by institution (RDC).

Reporting of Results:
Summary information will be submitted to MUN's School of HKR upon study completion. Data is intended to be reported in peer-reviewed scientific journal and/or presented at relevant scientific research meetings in future. Results will be reported in an aggregated or summarized form. It will also be shared locally with the Faculty of medicine and available to all participants. Finally results will be published in my thesis, which will be publicly available at the QEII library.

Sharing of Results with Participants:
When the study is completed, a summary of the results will be available on the lab's website http://www.med.mun.ca/TSRC/Home.aspx or blog http://tuckamoreamonth.blogspot.ca.

Questions:
You are welcome to ask questions at any time before, during, or after your participation in this research. If you would like more information about this study, please contact: Reuben Addison (709) 771-5000, rna820@mun.ca; Dr. Adam Dubrowski, adam.dubrowski@med.mun.ca; Dr. Linda Rohr, lerohr@mun.ca.

ICEHR Approval statement
The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research and found to be in compliance with Memorial University's ethics policy. If you have ethical concerns about the research, such as the way you have been treated or your rights as a participant, you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at 709-864-2861.

Consent:
Your signature on this form means that:

- You have read the information about the research.
- You have been able to ask questions about this study.
- You are satisfied with the answers to all your questions.
- You understand what the study is about and what you will be doing.
- You understand that you are free to withdraw participation in the study without having to give a reason, and that doing so will not affect you now or in the future.
- You understand that if you choose to end participation **during** data collection, any data collected from you up to that point will be retained by the researcher, unless you indicate otherwise.
- You understand that if you choose to withdraw **after** data collection has ended, your data can be removed from the study up to the end of September 2015

I agree to be video-recorded ☐ Yes ☐ No

By signing this form, you do not give up your legal rights and do not release the researchers from their professional responsibilities.

Your signature confirms:

☐ I have read what this study is about and understood the risks and benefits. I have had adequate time to think about this and had the opportunity to ask questions and my questions have been answered.

☐ I agree to participate in the research project understanding the risks and contributions of my participation, that my participation is voluntary, and that I may end my participation.

☐ A copy of this Informed Consent Form has been given to me for my records.

Signature of participant Date

Researcher's Signature:
I have explained this study to the best of my ability. I invited questions and gave answers. I believe that the participant fully understands what is involved in being in the study, any potential risks of the study and that he or she has freely chosen to be in the study.

Signature of Principal Investigator Date

Appendix 4. Summary of dependent measures during transfer test across trials

Variable	***M***	***SE***	***SD***
Time on task			
Test trial 1	105.56 s	12.348s	49.394s
Test trial 3	72.81s	9.700s	38.799s
Test trial 5	71.31s	8.195s	32.780s
SRT			
Test trial 1	.70 s	.036 s	.144 s
Test trial 3	.60 s	.061 s	.246 s
Test trial 5	.58 s	.053 s	.213 s
SRME			
Test trial 1	5.13	.455	1.821
Test trial 3	4.25	.433	1.732
Test trial 5	4.19	.449	1.797