Use of the isolated elements effect to teach observational gait analysis: the effects on cognitive load and learning outcomes

Kelly J. Sass
University of Iowa

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USE OF THE ISOLATED ELEMENTS
EFFECT TO TEACH OBSERVATIONAL GAIT ANALYSIS:
THE EFFECTS ON COGNITIVE LOAD AND LEARNING OUTCOMES

by

Kelly J. Sass

A thesis submitted in partial fulfillment
of the requirements for the Doctor of Philosophy
degree in Psychological and Quantitative Foundations
in the Graduate College of
The University of Iowa

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Thesis Supervisor: Associate Professor Kathy L. Schuh
This is to certify that the Ph.D. thesis of

Kelly J. Sass

has been approved by the Examining Committee for
the thesis requirement for the Doctor of Philosophy degree
in Psychological and Quantitative Foundations at the May 2016 graduation.

Thesis Committee:

Kathy L. Schuh, Thesis Supervisor

Stephen M. Alessi

Patrick Barlow

Joyce L. Moore

H. John Yack
To Wade, Ben and Emily.
   I love you!
It does not matter how slowly you go as long as you do not stop.

Confucius
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ABSTRACT

The analysis of human walking gait is a complex skill for physical therapy students to learn. As a result, students are at risk for a cognitive overload when confronted with this task. As working memory is limited in its capacity to process new information, it is necessary to manage the cognitive load experienced by the learners. Cognitive load consists of both intrinsic and extraneous loads as well as the germane processes that are required by the learners to process the information in working memory. Intrinsic cognitive load is related to the complexity of the materials that must be learned and cannot be altered by instructional design without sacrificing initial understanding. An isolated elements instructional format purports to reduce the intrinsic cognitive load experienced by learners by isolating the content into the individual elements prior to introducing any complex relationships that may exist between the elements. The purpose of this study was to compare the cognitive load and learning outcome effects of an isolated elements instructional format versus an interacting elements format when teaching observational gait analysis to physical therapy students.

A total of 72 students enrolled in a Doctor of Physical Therapy program participated in this study. Mixed factorial designs assessed both between-group and within-group outcomes. The independent variables were group assignment (isolated or interacting) and time. The dependent variables were cognitive load and learning outcomes. Cognitive load was measured with 7-point Likert-type scales for both mental effort and task difficulty at five separate time points. Learning outcomes were assessed through performance scores and confidence ratings on a posttest and a 1-week follow-up test. Animated videos were used as the medium for instructional delivery. In the isolated elements group, the learners received the content in several separate videos that isolated each of the sub-phases of gait prior to viewing a summary video that
included all of the interacting gait cycle components. Learners in the interacting elements group received the content in one video that included the full gait cycle followed by the same summary video.

Students in the isolated elements group reported lower mental effort ratings immediately after viewing the isolated elements videos than did the interacting group after viewing the interacting video tutorial. However, there were no differences in either mental effort or task difficulty ratings at the four other time points during the lesson or during the assessments. Performance scores and confidence ratings did not differ significantly between the two groups. Within-group analyses found that there were significant changes over time in both groups in task difficulty ratings and confidence ratings. A significant change was noted over time for mental effort and performance scores for only the isolated elements group. The reduction in mental effort ratings immediately following the tutorial content for the isolated elements group lends support to the theory that isolating the individual elements prior to teaching the complex interactions can reduce cognitive load for learners. However, this decrease in cognitive load did not translate into improved test scores or confidence compared to the interacting elements group. Future research is needed to identify instructional methods that can further reduce the cognitive load and increase the learning outcomes of students learning observational gait analysis. In addition, alternative objective methods of assessing cognitive load should be explored.
PUBLIC ABSTRACT

The human brain can only manage so many tasks or ideas at one time. Cognitive load is the term used to describe the amount of information and processing that is required to learn new information or skills. When students are asked to learn complex new skills or information, it can be easy to overwhelm their thinking processes. For physical therapy students, learning to watch people walk and determine if they have an abnormalities in their walking is an example of a complex new skill.

The purpose of this study was to examine two different methods of teaching physical therapy students how to evaluate the walking of their patients. The first method divided the information in the lesson into smaller video portions, while the second method used a single, longer video to provide the same information. Both groups then viewed a summary video. Dividing the content of the lesson into smaller portions was hypothesized to decrease the cognitive load for the students and increase their test scores and confidence in their abilities.

The study found that students taught with the first method did report less mental effort after the tutorial content than those in the second group. Both groups were found to increase their ability to identify abnormal walking, but the groups scored similarly on the tests after the tutorials and a week later. Future studies should further explore the relationship between cognitive load and learning outcomes when teaching walking evaluation to physical therapy students.
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CHAPTER 1: INTRODUCTION

Physical therapists diagnose and manage movement dysfunction to enhance physical and functional abilities (American Physical Therapy Association, 2014). One form of movement that must be assessed by physical therapists on a regular basis is human gait. Human walking gait is defined as a “method of locomotion involving the use of the two legs, alternately, to provide both support and propulsion… [with] at least one foot being in contact with the ground at all times” (Whittle, 2007, p. 48). Walking gait is a very complex activity with eight distinct phases consisting of multiple, highly-interactive elements to be considered simultaneously, including the position of the limb (and the opposite limb), joint range of motion, muscle activation, ground reaction forces, individual joint moments, timing, and critical events that must occur in each of the eight phases (Perry & Burnfield, 2010).

**Gait Analysis**

The gold standard for gait assessment is the use of instrumented tools to provide quantitative kinetic (forces and torques) and kinematic (range of motion) data on an individual’s gait cycle components; however, the use of such tools in the average clinic environment is prohibitive due to cost, time, and inconvenience. Instead, the majority of physical therapists rely on observational gait analysis with their patients in the clinic (Eastlack, Arvidson, Snyder-Mackler, Danoff, & McGarvey, 1991; Ferrarello et al., 2013; Krebs, Edelstein, & Fishman, 1985; Martin et al., 2009; Toro, Nester, & Farren, 2003a; Toro et al., 2003b). Although observational gait analysis is defined simply as the visual inspection of walking; in truth, it is much more complicated. It is the “observer’s capacity to assess body movements… during fast, repetitive gait cycles” (Kawamura et al., 2007, p. 18).
Statement of the Problem

Physical therapy students must learn not only the didactic, classroom information regarding gait and its terminology, but also must be taught to observe gait and recognize deviations from the norm in a learning laboratory sessions. This is a very challenging endeavor for faculty in physical therapy programs (Gronley & Perry, 1984; Pociask, DiZazzo-Miller, & Samuel, 2013; Pociask, Morrison, & Reid, 2013; Seymour & Dybel, 1998). The large amount of information that must be processed to understand the gait cycle has the potential to create an excessive cognitive load for these novice learners (Pociask, Morrison et al., 2013). Therefore, the purpose of this study was to investigate how two different multimedia environments affected perceived cognitive load and student learning outcomes when teaching observational gait analysis.

Cognitive Load Theory

Cognitive load is a multidimensional construct that represents the load that performing a particular task places on the learner’s cognitive system (Paas, Tuovinen, Tabbers, & Van Gerven, 2003). Cognitive load (CL) theory posits that human cognition consists of a working memory, which is limited in its processing capacity, and a theoretically unlimited long-term memory (Sweller, van Merrienboer, & Paas, 1998). According to CL theory, prior knowledge is stored in long-term memory in the form of schemas. Schemas are cognitive constructs that incorporate several elements of information into a single element with a specific function. In order for schemas to be formed, information must first be extracted and processed in the working memory; however, working memory is limited in the amount of information that can be processed at once, so learners are at risk of cognitive overload. Well-developed schemas increase the functional processing capacity of the working memory by allowing multiple pieces
of information to be processed as a single element (Sweller, 2005). Automatization of these schemas allows for subconscious processing and further reduces the burden on the working memory (Paas, Renkl, & Sweller, 2003). For novice learners, who lack such schemas in long-term memory, the working memory must rely on trial and error processes to identify relationships between elements and thus produces a much higher CL (Sweller, 2006). The goal of learning then becomes the development and automatization of such schemas to promote understanding (Kalyuga, 2010). This study investigated the isolated elements instructional method, which is purported to promote schema construction in novice learners when dealing with complex materials, thereby reducing CL.

**Types of Cognitive Load**

According to CL theory, there are multiple sources of load that compete for the limited working memory resources. Intrinsic CL is based on the inherent complexity of the materials to be learned. It is dependent upon the element interactivity of the materials, which is the number of different elements that must be processed concurrently by the learner for understanding to take place (Pollock, Chandler, & Sweller, 2002; Sweller, 2010c). Intrinsic CL is thus dependent on the expertise of the learner. As expertise increases, learners have more schemas available to decrease the load on working memory by reducing the number of independent elements that must be considered at a time (Kalyuga, 2010; Paas, Renkl et al., 2003; Paas, Tuovinen et al., 2003). For example, when considering gait analysis, once the learner has developed schemas to represent each of the sub-phases of gait, he or she may approach the assessment of a person’s gait with only these few interacting elements rather than all of the individual components of each phase.
Cognitive load theory defines extraneous CL as the load on the working memory resources devoted to processing information that is not relevant or productive to learning activities (Kalyuga, 2011; Mayer & Moreno, 2010; Sweller, 2010c). Common sources of extraneous CL are instructional delivery modes that distract the learner rather than enhance learning. The negative effects of extraneous CL are especially pronounced when the intrinsic CL is high and the task complexity exceeds the learner’s expertise (Paas, Renkl et al., 2003; Schnottz & Kürschner, 2007; Sweller, 2010b).

Cognitive load theory also addresses another type of “load” placed on the working memory. This dimension is referred to as germane CL as it describes the working memory resources devoted to learning activities such as managing intrinsic CL, developing schemas, and transferring knowledge to long-term memory for future use (Paas, van Gog, & Sweller, 2010; Sweller, 2010c; Sweller, 2010d). Recent advances in CL theory redefine germane CL in terms of the processing that occurs in working memory that is relevant to those aforementioned activities necessary for intentional learning to occur; these processes are said to be germane to learning (Kalyuga, 2011; Schnottz & Kürschner, 2007; Sweller, 2010c). While learning observational gait analysis, such germane activities would include the creation of schemas for the various sub-phases of gait to be stored in long-term memory and then recalled as the student attempts to understand the complex interactions between the phases.

According to CL theory, intrinsic CL and extraneous CL are additive in nature. Their combined effect, along with the germane resources needed for intentional learning cannot exceed the total working memory capacity available to the learner or understanding will suffer (Kalyuga, 2011; Moreno & Park, 2010; Paas, Renkl et al., 2003; Sweller, 2010c; Sweller 2010d). Reducing either the intrinsic or extraneous CL frees up working memory resources for germane
processes to enhance learning, assuming the learner remains motivated and attentive to the task (Beckman, 2010; Brünken, Seufert, & Paas, 2010; Kalyuga, 2011).

**Isolated Elements Instructional Approach**

Because of its dependence on the complexity of the materials to be learned, intrinsic CL cannot be altered without changing the nature of the task or sacrificing initial comprehension. (Paas, Renkl et al., 2003; Schnitz & Kürschner, 2007; Sweller, 2010c). One means proposed to reduce intrinsic CL is the isolated elements approach. This instructional design method requires the materials to be broken down into simpler, non-interactive elements to be learned prior to presenting the complex interactions of these elements (Kalyuga, 2011; Paas, Renkl et al., 2003; Pollock, Chandler, & Sweller, 2002). The isolated elements approach was found to decrease cognitive load and improve learning outcomes in several areas of study, including electrical engineering (Pollock et al., 2002), mathematics (Ayres, 2006; Clarke, Ayres, & Sweller, 2005), probability theory (Gergets, Scheiter, & Catrambone, 2006), and accounting (Blayney, Kalyuga, & Sweller, 2010). According to the isolated elements approach, the learner sacrifices initial full understanding for eventual deeper understanding of the materials.

**Application of the Isolated Elements Approach to Teaching Gait**

The isolated elements approach was recently studied when teaching healthcare students about the gait cycle in a traditional classroom lecture setting (Pociask, DiZazzo-Miller et al., 2013; Pociask, Morrison et al., 2013). The isolated elements instruction was divided into three phases. Initially, portions of the gait cycle were broken down into individual concepts that could be understood in isolation and processed in a serial manner by the learner. During the final phase, the information was presented in an integrated manner requiring simultaneous processing of all of the concepts for full understanding. The control group received instruction that included
all the interacting elements in a single lecture. Results of this study found that the students in the isolated elements group reported decreased total CL and had better performance on a post instructional exam than their control group peers (Pociask, DiZazzo-Miller et al., 2013; Pociask, Morrison et al., 2013).

**Purpose of this Study**

In physical therapy education, it is common for traditional classroom lectures to be accompanied by interactive, “hands-on” learning laboratory sessions on the topics covered. In the case of gait instruction, following a lecture on human gait components and terminology, the students participate in such a session that would encompass observational gait analysis. Instructional design formats for teaching observational gait analysis have not been previously studied. In addition, Pociask et al. (2013) recommended further research to determine if an isolated elements approach could result in similar findings when utilized for a gait analysis learning laboratory session.

This study focused on the design of animated student tutorials to teach observational gait analysis. When instructing novice students in observational gait analysis, it is typical practice to use videos or animations to represent a person walking, similar to how gait would be assessed in a clinic setting (Eastlack et al., 1991; Ferrarello et al., 2013; Toro et al., 2003a). These videos or animations generally show the entire gait cycle in repetition while describing what the student should be seeing. An isolated elements approach calls for the video or animations to be broken down into smaller portions initially, rather than presenting the entire gait cycle and all the complex interactions simultaneously. Once the student has mastered the content within these individual elements, the elements can be combined so that their full interactions can be understood (Kalyuga, 2011; Paas, Renkl et al., 2003; Pollock et al., 2002). A CL theory
perspective would stipulate that students exposed to an isolated elements instructional approach will report less CL both during and after the lesson than those in the interacting elements group. This decrease in CL is theorized to be due to the formation and storage of schemas in long-term memory that represent the phases of the gait cycle. Retrieval of these schemas from long-term memory then frees up working memory resources for the germane processes required to understand the full gait cycle and all its interacting elements. This ability to hold and process more information in working memory simultaneously is hypothesized to result in both a decreased reported CL and better learning outcomes at the posttest and follow-up test for students in the isolated elements group.

Research Questions and Hypotheses

Research Question 1

Do students who are taught observational gait analysis using an isolated elements instructional format report lower CL ratings than students who are taught in an interacting elements instructional format?

Hypothesis 1. Students in the isolated elements instructional format group will report lower CL ratings than students in the interacting elements instructional format group at the midpoint of the instruction.

Hypothesis 2. Students in the isolated elements instructional format group will report lower CL ratings than students in the interacting elements instructional format group immediately upon completion of the instruction.

Hypothesis 3. Students in the isolated elements instructional format group will report lower CL ratings than students in the interacting elements instructional format group during the posttest immediately following the instruction.
Hypothesis 4. Students in the isolated elements instructional format group will report lower CL ratings than students in the interacting elements instructional format group during the follow-up test one week after completion of the instruction.

Hypothesis 5. Changes in CL ratings over time will be dependent on treatment group assignment.

Research Question 2

Do students who are taught observational gait analysis using an isolated elements instructional format have better learning outcomes on the posttest and follow-up test than students who are taught in an interacting elements instructional format?

Hypothesis 6. Students in the isolated elements instructional format group will have higher performance scores than students in the interacting elements instructional format group on the posttest immediately following the instruction.

Hypothesis 7. Students in the isolated elements instructional format group will have higher performance scores than students in the interacting elements instructional format group on the follow-up test one week after completion of the instruction.

Hypothesis 8. Changes in performance scores over time will be dependent on treatment group assignment.

Hypothesis 9. Students in the isolated elements instructional format group will have higher confidence ratings than students in the interacting elements instructional format group on the posttest immediately following the instruction.

Hypothesis 10. Students in the isolated elements instructional format group will have higher confidence ratings than students in the interacting elements instructional format group on the follow-up test one week after completion of the instruction.
Hypothesis 11. Changes in confidence ratings over time will be dependent on treatment group assignment.

Significance of this Study

Observational gait analysis is a challenging, but critical, skill for physical therapy students to learn. Identifying instructional formats that can decrease the CL experienced by students is an important step in improving learning outcomes for this skill. This study sought to determine if an isolated elements instructional format was superior to an interacting elements instructional format in terms of overall reported CL and learning outcomes for physical therapy students learning observational gait analysis. Although the results did not fully support the hypotheses identified above, important insights were gained with regard to the time points during the lesson when students experienced a decreased CL, and the changes that occurred within the groups over time for CL, performance scores, and confidence ratings. Findings from this study can be used to further explore instructional designs to decrease the CL experienced by learners and improve overall learning outcomes when teaching observational gait analysis.
CHAPTER 2: REVIEW OF THE LITERATURE

All instructional practices have the goal of improved understanding at their root. Multimedia learning environments can provide a powerful tool to attain this goal (Mayer & Moreno, 2002). Animated sequences are one example of multimedia presentations in the educational realm; however, animations can also create an overwhelming environment if the content and pace are not controlled, providing a cognitive overload for the learners. This study investigated the use of two instructional methods to teach observational gait analysis to entry-level physical therapy students. Observational gait analysis is a multi-faceted, complex task that is a challenge for physical therapy educators to effectively teach students (Gronley & Perry, 1984; Pociask, DiZazzo-Miller, & Samuel, 2013; Morrison & Reid, 2013; Seymour & Dybel, 1998).

An isolated elements approach was used to manage the amount of cognitive load (CL) experienced by the learners. It was hypothesized that the learners in the isolated elements group would report a lower CL during both the instruction and during the post-instruction assessments than students in the interacting elements group, and that the learners in the isolated elements groups would demonstrate higher scores and more confidence in their answers on the posttest and follow-up tests than learners in the interacting elements group. In addition, it was hypothesized that there would be changes over time in the CL measures, performance scores, and confidence ratings that would be dependent on group assignment. This chapter will discuss CL theory, human gait instruction, the isolated elements approach to instructional design, the cognitive theory of multimedia learning, measurement of CL, and the use of animation as an instructional tool.
Cognitive Load Theory

Cognitive load is a multidimensional construct that represents the load that performing a particular task enacts on the learner’s cognitive system (Paas, Tuovenin, Tabbers, & Van Gerven, 2003). Cognitive load theory calls for this load to be controlled to allow for effective learning to occur. The following is a discussion on traditional CL theory as well as more recent advances in the theory.

Traditional Cognitive Load Theory

Traditional CL theory is based on the notion that the human cognitive architecture consists of a working memory, which is limited in its processing capacity, and a theoretically unlimited long-term memory (Sweller, van Merrienboer, & Paas, 1998). According to CL theory, prior knowledge is stored in long-term memory in the form of schemas. Schemas are described as cognitive constructs that incorporate several pieces of information into a single element with a specific function. In order for schemas to be formed, information must first be extracted and processed in working memory before being transferred to long-term memory for future retrieval. Well-developed schemas increase the functional processing capacity of working memory by allowing multiple pieces of information to be processed as a single element (Sweller, 2005). Automatization of schema retrieval allows for subconscious processing and further reduces the burden on working memory (Paas, Renkl et al., 2003). In order for learning to occur, the CL placed on working memory must not exceed its limited processing capacity. Traditional CL theory described three types of load that compete for the limited working memory resources available: intrinsic, extraneous, and germane.

Intrinsic cognitive load. In traditional CL theory, intrinsic CL is considered inherent to the materials being learned. It is based on the complexity, or element interactivity, of the subject
(Mayer, 2009; Paas, Renkl et al., 2003). Intrinsic CL is directly related to the expertise and knowledge of the learner. As one develops from a novice to an expert, the amount of intrinsic CL from the materials will decrease accordingly due to additional schema formation (prior knowledge) and automatization of existing schema. This prior knowledge, in the form of schemas, is stored in long-term memory for future retrieval. Automatization of this schema storage and retrieval process frees up working memory capacity for the acquisition of new information and creation of new schemas for future use (Paas, Renkl et al., 2003; Paas, Tuovinen et al., 2003). In this traditional view, intrinsic CL cannot be manipulated by instructional design changes, only by increases in learner expertise.

**Extraneous cognitive load.** Extraneous CL is described as the load due to instructional design formats that distract the learner’s resources away from the tasks involved in learning the materials, such as schema development or automatization (Paas, Renkl et al., 2003; Paas, Tuovinen et al., 2003; Sweller, 2005). Reducing extraneous CL should therefore free up additional working memory resources for learning activities.

**Germane cognitive load.** Germane CL is considered the “effective” cognitive load due to its association with the effort expended in constructing schemas and working to automate them (Paas, Renkl et al., 2003; Paas, Tuovinen et al., 2003; Sweller, 2005). It is the processing used to make sense of the essential elements of the materials, and to organize and integrate the materials in working memory.

In traditional CL theory, these three types of CL were described as discrete and additive in nature, with each contributing to the overall total CL experienced by a learner. If the sum of the CL exceeds working memory capacity, learning will be impaired as the system will be overloaded. However, if a decrease in either intrinsic or extraneous CL is achieved, it is
assumed that available working memory resources will be used for addressing germane CL. Thus the goal of instructional design in traditional CL theory was to increase germane CL by reducing extraneous CL, because intrinsic CL was seen as fixed.

Recent trends in CL theory reject the notion that there are three distinct types of CL (Beckman, 2010; Kalyuga, 2011; Schnotz & Kürschner, 2007). These recent explorations into CL theory argue for a dual framework, rather than one that is triarchic. This dual framework consists of only intrinsic CL and extraneous CL, and asserts that intrinsic CL alone can account for all of the effects traditionally associated with germane CL (Kalyuga, 2011).

**Relationship between intrinsic CL and germane CL.** Traditional CL theory regards intrinsic CL as inherent to the materials to be studied relative to the prior knowledge of the learner. Germanse CL has been described as the load placed on the cognitive system by the processes related to schema acquisition and automatization, or the activities of learning. However, Beckman (2010) proposed that traditional CL theory does not adequately address the kinds of mental activities that the learner is engaged in while working on a learning task. In this view, it is not only the element interactivity of the materials that causes the intrinsic CL experienced by the learners, but it is also the result of the actual cognitive processes in which a learner engages. In other words, it must be recognized that an engaged and motivated learner is also required. The processing of elements in working memory and connecting them with information stored in long-term memory creates the intrinsic CL experienced by the learner, not the materials themselves. It is the load required in “constructing, refining, or automating schematic knowledge structures, making them more flexible and applicable in new situations” (Kalyuga, 2011, p. 10). This processing by traditional definition is the germane CL experienced by a learner and thus the distinction between the two becomes negligible. Total CL then
becomes the sum of the intrinsic CL and extraneous CL, with the intrinsic CL consisting of the
germane processing needed for schema acquisition and the extraneous CL related to instructional
design (Beckman, 2010; Kalyuga, 2011).

**Evolutionary View of Cognitive Architecture**

In addition to a change in the traditional definitions associated with CL, the notion of the
cognitive architecture has transformed as well. An evolutionary approach has been used to
describe how learning occurs and to explain how CL must be managed to allow effective
learning to occur. The evolutionary view describes human cognition in terms of five principles
that mirror the principles of biological evolution.

**Information Store Principle**

The information store principle recognizes that to function in the complex human
environment, a very large amount of information must be stored in long-term memory. This
long-term memory is critical to problem solving and rational thought because as information is
stored for future use, it becomes available to aid in understanding new information presented to
the system (Sweller, 2010b). This principle does not vary from traditional CL theory which
recognized an essentially unlimited long-term memory store. In order for this memory store to
be functional, the information must be kept in organized and retrievable modes, for example, as
schemas.

**Borrowing and Reorganizing Principle**

People most often learn by reading what someone else has written, listening to what
someone else has said, or imitating what someone else has done. In this manner, it can be said
that the large amount of information in the long-term memory is gained almost entirely through
“borrowing” from the long-term memory stores of others. However, because learners typically
do not remember exactly what they have seen or heard from others, the information is reorganized and stored in their own interpretation (Sweller, 2010b). This process is the schema construction that is described in CL theory. Expertise in an area develops when one has multiple, sophisticated, interrelated schemas stored in long-term memory. Automatization of these schemas can allow this processing to occur at a subconscious level, and considerably reduce the CL required to process new information in working memory. From an instructional design standpoint, CL theory is used to develop instructional methods that facilitate the transfer of knowledge from the instructor’s long-term memory to the learner’s long-term memory through schema formation and automatization.

**Randomness as Genesis Principle**

Because not all information can be borrowed from others’ long-term memory stores, there must be a method to learn new information. The evolutionary approach suggests that new information is generated through a random trial and error methodology. When confronted with a problem to solve for which a learner does not have access to any prior knowledge, he or she must make random attempts followed by tests for effectiveness to determine a potential solution (Sweller, 2010b). While this can be an effective way to learn in the absence of information, and perhaps is the source of most human creativity, it most certainly is not an efficient process (Sweller, 2009). In CL theory, random generation processes would be seen as a source of increased CL that can easily overwhelm working memory and hinder learning.

**Narrow Limits of Change Principle**

All successful changes to the long-term memory stores must occur incrementally and slowly. This principle derives from the fact that if left unchecked, random generation processes could exponentially increase the amount of information being transferred to long-term memory.
This flood of information is unlikely to be stored in a useful way. Working memory, with its limited capacity, is the evolutionary method of controlling this influx by limiting the number of elements that can be processed at one time (Sweller, 2010b). From an instructional design standpoint, the narrow limits of change principle suggests that novice learners require more information to be “borrowed” from an instructor rather than randomly generated by the learner to maximize effectiveness (Kirschner, Sweller, & Clark, 2006). This is due to the fact that the borrowed knowledge is presented in some organized fashion rather than requiring random generation of possible answers. The narrow limits of change principle is also the basis for the isolated elements approach to presenting new information, which will be discussed in detail later.

**Environment Organizing and Linking Principle**

The environment organizing and linking principle posits that the organization and storage of information in long-term memory, along with the ability to successfully retrieve and link this prior knowledge with new knowledge, are the main factors that distinguishes experts from novices. Information that has been organized and can be transferred as a single unit of information (schema), rather than multiple units, can be used in working memory with less risk of cognitive overload (Sweller, 2010b). This principle is directly related to the use of formed and automated schema as described in CL theory. Once the information has been randomly generated or borrowed and then organized, a learner is able to use this information to interact effectively with his or her environment, including the learning tasks at hand. From an instructional design standpoint, the instruction should be tailored to the individual learners and the amount of previous information stored (prior knowledge) to determine the teaching methodology and amount of information the learners can effectively process at one time.
The evolutionary view of cognitive architecture provides new insight as to how information is received, processed, and stored for future use. It does not necessarily change CL theory, but instead proposes that the primary goal of CL theory is to …indicate how to present novel information structured according to the narrow limits of change principle to reduce unnecessary working memory load and facilitate change in long-term memory. In turn, changes in long-term memory permit complex actions through the environment organizing and linking principle (Sweller, 2010b, p. 40).

One way that has been proposed to meet this goal is to control the intrinsic CL imposed on the learners through an isolated elements approach.

**Isolated Elements Approach**

Because it is related to the complexity of the materials to be learned, as well as how the learners interact with those materials, intrinsic CL cannot be altered without changing the nature of the task or sacrificing initial comprehension (Paas, Renkl et al., 2003; Schnitz & Kürschner, 2007; Sweller, 2010b). One proposed method to reduce intrinsic CL is the isolated elements approach. The narrow limits of change principle states that the amount of new information coming into working memory for processing must be manageable by the learner.

The isolated elements approach consists of separating the learning of complex materials into two stages. In the first stage, learners are only exposed to individual elements, without including the interactions between these elements. Information is divided into useful chunks that alone do not allow the learner to understand the complex interactions of the materials covered. Instead, lessons are designed to allow novices to develop initial schemas to be stored in long-term memory, an example of the information store principle. In the second stage, the learner is introduced to the interactions between the elements (Kalyuga, 2011; Paas, Renkl et al., 2003;
Pollock, Chandler, & Sweller, 2002). Due to the organizing and linking principle, this stored information can then be used to overcome working memory restrictions imposed by the narrow limits of change principle. More complex interactions can then be introduced to the learners (Sweller, 2010a). In contrast, an interacting elements approach includes all of the interactions between instructional elements as the instruction initially unfolds, rather than in phases.

**Evidence to Support the Isolated Elements Approach**

Several studies support the hypothesis that decreasing intrinsic CL with the isolated elements approach decreases overall CL and improves learning outcomes. In the field of electrical engineering, Pollock et al. (2002) found that novice learners reported a decreased CL in the isolated elements group as opposed to the interacting elements group. Additionally, these same isolated elements group learners had higher efficiency scores, with efficiency being measured as a combined performance and CL score, than those in the interacting elements group. Similar findings were made in the fields of mathematics and accounting with better transfer test scores and decreased CL reported in the isolated elements group (Ayres, 2006; Blayney, Kalyuga, & Sweller, 2010; Clarke, Ayres, & Sweller, 2005). In all of these studies, the positive effects of the isolated elements approach were only found for learners with low prior knowledge of the subject. For high knowledge learners, the effect was reversed, with the interacting elements approach demonstrating superior learning outcomes. Cognitive load measures were not significantly different between the isolated and interacting element groups in the high knowledge learners (Ayres, 2006; Clarke et al., 2005; Pollock et al., 2002). This phenomenon is proposed to occur as the high-knowledge learners already have available schemas in long-term memory, making the isolated elements phase unnecessary.
Three instructional design methods related to the isolated elements approach include the part-whole, modular, and pre-training methods. The part-whole approach is defined as breaking the materials down into simpler tasks and adding more elements and interactions over time (van Merriënboer, 1997; van Merriënboer, Kester, & Paas, 2006). Several studies reported better transfer test performance in part-whole experimental groups that presented the materials in a simple to complex manner, than in groups who were exposed to the full interactions initially (Kester, Kirschner, & van Merriënboer, 2004a; Kester, Kirschner, & van Merriënboer, 2004b; van Merriënboer et al., 2006). In a modular design, the instructional content is broken into individual solution steps as opposed to a molar design with multiple solution steps portrayed at one time (Gergets, Scheiter, & Catrambone, 2006). Gergets et al. (2006) found that learners using modular design examples to solve problems reported decreased CL, a decreased learning time, and solved more problems correctly than learners with molar designed examples. In pre-training designs, learners are introduced to terminology and components prior to presenting how these components will interact within a system (Mayer, 2005b). Learners who were pre-trained demonstrated better transfer performance and superior problem solving performance at the completion of the lesson than those who did not receive the pre-training (Mayer, Mautone, & Prothero, 2002; Mayer & Moreno, 2003).

The need to manage intrinsic CL has also been studied in healthcare education. Professional healthcare education programs (e.g., medicine, physical therapy, physician assistant, dentistry, etc.) are inherently high in intrinsic CL due to the large amount of interacting elements that students are required to learn and then apply in a clinical environment. The isolated elements approach has been advocated as a method to help control intrinsic CL in healthcare education (van Merriënboer & Sweller, 2010; Young, van Merriënboer, Durning, & Ten Cate,
In physical therapy education, human walking gait is an excellent example of a complicated concept that must be taught to novice students.

**Human Gait**

Human gait is a complex biomechanical activity. As an essential part of daily living activities, assessment of proper and safe walking gait is an important aspect of a physical therapy examination. In order to identify any deviations in a patient’s walking gait, a physical therapist must be well versed in the typical gait pattern. As mentioned previously, educating physical therapy students regarding the components of gait analysis is very challenging due to the complexity of the task.

**Normal Gait Cycle**

In its simplest description, a gait cycle consists of a stance phase during which the body weight is borne on the limb, and a swing phase during which the limb is not in contact with the ground and swings forward to take the next step. The stance phase consists of five sub-phases: initial contact, loading response, mid stance, terminal stance, and pre-swing. Initial contact is the moment when the heel hits the floor. Loading response refers to the sub-phase when the body weight is loaded onto a stable outstretched limb. During mid stance, terminal stance, and pre-swing sub-phases, the body propels forward over the planted foot and weight is shifted from the rearfoot to the forefoot to prepare for swing phase.

The swing phase consists of three sub-phases: initial swing, mid swing, and terminal swing. During the initial and mid swing sub-phases, the body weight must be unloaded from the limb and the foot must clear the floor as it swings forward. Terminal swing concludes the gait cycle with the limb outstretched in front of the body and ready to take the next step (Ranchos Los Amigos National Rehabilitation Center, 2001). During every sub-phase, observational gait
analysis requires that the joint positions be considered at each joint of the lower extremity to determine if they are in the optimal position for a typical gait pattern. Figure 1 shows the relationships between the phases and sub-phases of a single gait cycle.

**Teaching Gait to Novice Students**

This is a very large amount of information for a novice, such as a student, to learn and understand. Conventionally, the terminology and content related to the phases and sub-phases of the gait cycle are introduced to students in a traditional classroom setting. This generally consists of one or more lectures, regarding the phases of gait, as well as the concomitant muscle activations and joint range of motion during each of these gait sub-phases. Understanding requires that the student can simultaneously process all of these elements in his or her working memory. In novice learners, with little to no prior knowledge of human gait, this number of interacting elements can easily cause cognitive overload.

The isolated elements effect states that if these elements are taught in isolation initially, learners will form schemas (borrowing and reorganizing principle) that can be stored in long-term memory (information store principle). These schemas, which are composed of multiple components consolidated into a single element, allow for more information to be processed in working memory at once. This freed up capacity in working memory allows the learner to examine the interactions among the elements or phases (Kalyuga, 2011; Paas, Renkl et al., 2003; Pollock et al., 2002).

**Isolated elements approach and gait instruction.** The isolated elements approach has been studied in teaching human gait to novice physical therapist and occupational therapist students in a classroom setting. Traditional classroom instruction on human gait was compared to a three-phase isolated elements instructional approach. The traditional (control) group
Figure 1: Gait cycle components
received an 80 minute lecture that introduced the phases of the gait cycle, including all muscle activations and joint motions, as well as how the phases interact. The experimental approach consisted of three consecutive class sessions of shorter lengths that reorganized the lecture content, such that the relationships between the various gait phases was not included until the final class session (Pociask, DiZazzo et al., 2013; Pociask, Morrison et al., 2013). In other words, the elements of the gait cycle were isolated to allow the learners to master the individual elements prior to trying to understand the relationships between them. In these two studies, it was reported that the experimental groups reported a decreased CL both after completion of the instruction and after completion of the delayed posttest. In addition, students in the isolated elements group scored better on the posttest assessment than those in the control group (Pociask, DiZazzo et al., 2013; Pociask, Morrison et al., 2013). The authors called for further studies to evaluate the transfer of this knowledge to performance in corresponding gait laboratory sessions, as well as to look at strategies to teach the introductory gait laboratory sessions (Pociask, DiZazzo et al., 2013; Pociask, Morrison et al., 2013). These introductory gait lab sessions involve not only using the gait knowledge attained in the classroom regarding each phase and sub-phase, but also teaching novice students to watch and analyze human gait for the presence of any deviations from a normal gait pattern.

**Observational Gait Analysis**

Observational gait analysis is the visual inspection of gait, and requires that the observer assess the body’s movements in multiple planes during quick and repetitive gait cycles (Kawamura et al., 2007). This is typically completed in a laboratory teaching session, and involves the viewing of gait patterns in a cyclic fashion. Students must learn to be able to recognize normal gait patterns, as well as to identify any deviations from the norm. This is a
very complex skill for students to acquire due to all of the interacting elements during each phase and at each joint that must be considered at once.

One method utilized to help students with this visualization is animation. Animations are a “series of frames containing an object or objects so that each frame appears as an alteration of the previous frame in order to show motion” (Baek & Layne, 1988, p.132). In the case of gait analysis, it is possible to create animations of actual subjects walking by using a motion capture system. Such a system uses infra-red markers attached to the extremities, trunk, and head of the human subjects in a gait laboratory. The data collected from these markers can then be translated into an animated model using computer software programs (e.g., Visual 3D, C-Motion Inc., Kingston, Ontario, Canada). These animated depictions of walking gait can be a beneficial means of teaching observational gait analysis to novice learners.

**Cognitive Theory of Multimedia Learning**

Animations are an example of a multimedia learning tool. Multimedia learning is the use of both pictures and words to construct knowledge. Mayer’s (2005a) cognitive theory of multimedia learning is based on three assumptions that derive from cognitive psychology. The first is that there is dual-channel processing, or separate information processing channels for visually presented materials (writing/pictures), and those presented in an auditory (spoken) manner (Baddeley, 1992; Mayer, 2005b; Paivo, 1986). Using both words and pictures promotes efficient use of limited cognitive resources and facilitates learning by maximizing the function of both processing channels (Mayer, 2005a).

The second assumption is that there is a limited capacity for processing information in each of the channels in working memory. This is directly related to CL theory and the narrow limits of change principle. Because of these restrictions, learners are forced to make decisions
about what information to pay attention to and what connections must be made between different pieces of new information, as well as with prior knowledge (e.g., schemas) in long-term memory (Mayer, 2005a). The final assumption is the need for active processing by the learner. These processes include selecting relevant materials, organizing the selected materials, and integrating these selected materials from both channels together and also with their prior knowledge (Mayer, 2005b; 2009). When presented with multimedia instruction, learners must first select the relevant words and/or images to bring into their working memory for further processing. Once in working memory, those words and images must be organized in such a fashion that relationships can be built between them to develop appropriate verbal and pictorial models. Finally, the learner must integrate their schemas, or prior knowledge, from long-term memory with these new models in working memory (Mayer, 2005b; 2009). Figure 2 illustrates the active learning process described in Mayer’s cognitive theory of multimedia learning.

Figure 2: Cognitive theory of multimedia learning model (adapted from Mayer, 2005a).
Understanding occurs when the learner is able to process all of the relevant information in working memory simultaneously. The availability of schemas, particularly those that have been automatized, helps to increase the amount of information that can be processed successfully at one time; therefore, learning can be seen as a change in long-term memory through schema formation, storage, and automatization (Paas, Renkl et al., 2003; Sweller, 2005). An isolated elements approach allows students to develop and automate preliminary schemas that can then be utilized to develop full understanding when complex interactions between elements are introduced later in the instruction.

**Animation as an Instructional Tool**

Animations can be a powerful multimedia instructional tool as they allow the developer to have greater control of the flow of information to the learners and readily depict salient features to the students. Animations are particularly useful in portraying movement or changes over time (Betrancourt & Tversky, 2000; Wouters, Paas, & van Merriënboer, 2008). The ability to depict movement and to manipulate what the learner sees or attends to make animations an excellent tool for teaching observational gait analysis to novice students. However, animations can also be a risk in instructional design.

By definition, animations are transient in nature with a constant flow of images and information. The lack of learning that may occur due to information that has disappeared before a learner has time to adequately process it or link it with either new knowledge or prior knowledge is known as the transient information effect (Sweller, Ayres, & Kalyuga, 2011). Baddeley (1997) described a similar effect, retroactive inhibition, whereby the presentation of new information can interfere with a learner’s recall of information presented earlier in the animation if there has not been time to adequately process and store the information in long-term
memory. Strategies that have been suggested to counteract these potential negative effects include (a) manipulation of the pace of the animation, (b) keeping the presentation simple (c) providing cueing or signaling to relevant information in the animation, and (d) segmenting the animation into smaller components. Each of these will be discussed in more detail in the following sections.

**Pace of the animation.** The apprehension principle states that animations must be presented in a way that can be readily and accurately perceived and comprehended (Tversky, Morrison, & Betrancourt, 2002). It is essential to ensure that the pace of the animation allows the learner adequate time to process new information, because it can be difficult to take in all of the information that may be presented in an animation in real time. This can be accomplished by either slowing the animation or by allowing the learner control over the pace of the information presented. Several studies found that providing the learner control of starting and stopping the animation, the speed of the presentation, and zooming capabilities produced better learning outcomes than animations without such control (e.g., Hasler, Kersten, & Sweller, 2007; Mayer & Chandler, 2001; Tversky et al., 2002). An instructional animation on observational gait analysis can not only be slowed to allow the learner adequate time to perceive the critical events, but control over the speed of the presentation can also be an option.

**Presentation of the animation.** Animations are superior to static pictures when the content involves motion, and particularly when it requires complex element interactivity, such as is seen with observational gait analysis (Betrancourt & Tversky, 2000; Wouters et al., 2008). However, in keeping with the apprehension principle described previously, animations for complex content should be schematic in design rather than either realistic or decorational in nature to provide a more optimal learning environment for novices (Höffler & Leutner, 2007;
Tversky et al., 2002). This effect is thought to be due to less processing demands being placed on working memory because of the simpler presentation. In the case of observational gait analysis, this has implications regarding the choice of schematic representations of walking (e.g., stick figures) versus either a representative avatar figure or a video recording of the gait pattern. For novice learners, stick figures appear to be the most appropriate choice. Transfer of knowledge could then be tested using a more realistic representation of gait such as a video recording.

**Use of cueing or signaling.** Cueing or signaling refers to the “addition of non-content information that captures attention to those aspects that are important to an animation” (de Koning, Tabbers, Rikers, & Paas, 2007, p. 733). A variety of different types of cues include, but are not limited to, the use of motion (including slow motion), arrows, highlighting, color changes, or sounds. Eye tracking studies have demonstrated that signaling draws the learner’s attention to the content that is being emphasized (Kriz & Hegarty, 2007; Ozcelik, Arslan-Ari, & Cagiltay, 2010). In the case of observational gait analysis, slow motion can be used to not only improve perception by the learner, but also to cue the learner to the phase of gait being discussed at the time. Arrows or highlighting could also be added to increase the probability that the learner’s attention is directed to a specific joint or activity being described.

**Segmenting.** When an animation conveys complex information with high element interactivity, the issues related to the transient information effect and retroactive inhibition are amplified (Sweller et al., 2011). Dividing the content up into smaller, more manageable segments allows the learner time to process information before moving on to integrate more new information, and leads to improved learning outcomes over presenting complex information continuously (Hasler et al., 2007; Mayer, 2009; Mayer & Chandler, 2001; Wouters et al., 2008).
The isolated elements approach to instruction calls for content to be initially broken down into individual elements, thus reducing the need for the learner to process complex interactions (Kalyuga, 2011; Paas, Renkl et al., 2003; Pollock et al., 2002). When dealing with observational gait analysis, it would seem plausible to use the natural breakpoints provided by the sub-phases of the gait cycle; however, there are no studies that have addressed this specific content.

**Narration in animation.** An additional consideration when using animations as an instructional tool is the use of narration. According to Mayer’s (2009) modality principle, people learn more deeply from animations with narration than from animations with accompanying text. Because of the dual channel processing, the animated pictures can be processed in the visual channel while the words can be processed in the auditory channel, thus increasing the overall processing capacity rather than overloading the visual channel. Studies have demonstrated improved retention and problem solving skills following narrated animated instruction rather than animation with written text (Mayer & Anderson, 1991; 1992). Therefore, any animation used to teach observational gait analysis should use narration in conjunction with the animated pictures, rather than written text.

The previous discussions regarding the demands placed on the learner due to the content requirements for learning observational gait analysis along with the potential demands that an animation can place on a learner make it clear that a student could easily suffer from a cognitive overload. Instructional design of observational gait analysis learning environments must therefore take measures to control this CL. While CL has been addressed in a classroom setting as students learn the components of human gait, there are no studies available that address a learner’s CL while studying observational gait analysis.
Measurement of Cognitive Load

Cognitive load can be measured by both subjective and objective methods. The most common subjective method is the use of self-reported Likert-type scales. These measures consist of simple questions and rely on a subject’s ability to self-assess their cognitive processes (Paas, 1992; Paas, Tuovenin et al., 2003). The questionnaires address the participant’s perception of their mental effort and task difficulty. Subjective, self-reported ratings may be gathered at specified times during the treatment condition, post-treatment, or during performance assessments. The ratings should always be considered retrospective in nature rather than real time assessments of CL.

Mental Effort Ratings

Mental effort refers to the amount of mental capacity that is allocated to the demands imposed by the instructional tasks (Paas, Tuovenin et al., 2003). Mental effort is considered an indirect method of measuring CL as it relies on learner motivation in addition to CL (Brünken, Plass, & Leutner, 2003). For example, an unmotivated learner may report low mental effort despite highly complex materials. Subjective mental effort scales are widely used in the literature and ask the participants to rate their perceived mental effort on a Likert-type scale. Both 9-point (e.g., Paas, 1992) and 7-point (e.g., Kalyuga, Chandler, & Sweller, 2004) scales are common. The scales provide a good estimate of total cognitive load, are easy to administer, provide strong face validity to participants, and are non-intrusive (Sweller, 2010e; Wiebe, Roberts, & Behrends, 2010). The internal consistency reported for these rating scales is high (Cronbach’s coefficient α = .90, Paas, 1992).
**Task Difficulty Ratings**

A related component of CL is task difficulty. Task difficulty rating scales ask learners to indicate on a 7-point scale how difficult they find the materials. The scale ranges from extremely easy (1) to extremely hard (7) (e.g., Kalyuga, Chandler, & Sweller, 2004). While similar to mental effort ratings, difficulty ratings are purported to provide a more direct measurement of the actual total cognitive load imposed by the learning task itself (as the ratings are not related to motivation), to be sensitive to changes in element interactivity, and were found to be related to error rates in performance measures (Ayres, 2006; Brünken et al., 2003; Sweller, 2010e).

**Learning Outcomes**

Performance score measures are an objective, indirect method of measuring CL. They are considered objective because they measure actual performance, and indirect because they may also be affected by learner traits and the measurement method (Brünken et al., 2003). An additional indirect measure of learning outcomes is the learners’ self-reported confidence in their answers. Expertise and performance in a domain are not only a function of knowledge, but also of confidence. An important consideration is also whether learners are able to discern what they know, and more importantly, perhaps, what they do not know, and for test administrators to determine when a learner may be guessing (Kampmeyer, Matthes, & Herzig, 2015; Kapoor & Natarajan, 2012). Neither learning outcome measures nor subjective ratings of mental effort and difficulty alone can provide the evidence needed to determine if an instructional intervention was successful. Rather, they should be considered in conjunction with each other (Beckman, 2010)
Purpose of this Study

The purpose of this study was to compare the use of an isolated elements approach versus an interacting elements approach with physical therapy students who were learning observational gait analysis. Animations were used as the instructional medium for the lessons. In keeping with the evidence on optimizing CL in animated clips and to control between the two groups, these animations utilized slow motion and stop action frames to control the pace of the information presented to the students, as well as to signal to the learner the segment of the gait cycle that was being discussed. The animations consisted of simplified stick figures walking on-screen using data that were collected using a motion analysis system. The animations had narrated instruction rather than written text. In addition, the content was segmented by sub-phase to prevent a transient information effect.

The isolated elements group initially viewed eight separate animations that depicted each of the sub-phases of gait in isolation, without reference to the remainder of the gait cycle. In a final summary animation, the eight sub-phases were reviewed throughout the entirety of the gait cycle. The interacting elements group received the same content information; however, the eight sub-phases of gait were not isolated. Rather, the entire gait cycle was addressed as is more traditional in instruction, followed by the same summary animation. Between-group and within-group comparisons were made regarding the mental effort and task difficulty reported by the learners during the instruction, following the instruction, and during the learning assessments. Performance scores and confidence levels on the pre-test, posttest, and follow-up were also compared between the groups and over time within the groups.

The first research question addressed whether students who were taught observational gait analysis using an isolated elements instructional format reported lower CL ratings than
students who were taught in an interacting elements instructional format, and whether there was a change in CL ratings over time. The second research question addressed whether the performance scores and confidence ratings for students in the isolated elements group would be higher than those of students in the interacting elements, as well as looking at the change over time.
CHAPTER 3: METHODOLOGY

The purpose of this study was to compare the use of an isolated elements approach versus an interacting elements approach with physical therapy students who were learning observational gait analysis. The first research question examined how these two different instructional approaches impacted student reports of cognitive load (CL) between groups. The perceived CL was measured as mental effort and task difficulty. The second research question investigated how student learning outcomes were affected by the different instructional approaches. Performance scores on pre-, post- and follow-up tests, along with confidence ratings were analyzed between groups. In addition, hypotheses also explored how the two groups changed over time in relation to both the CL and learning outcome variables. In this chapter, the methods and procedures used in this study are presented. Specifically, the study design, participants, instructional materials, survey instruments, data collection procedures, and data analysis methods are described.

Study Design

This section will describe the research designs used for the two research questions presented in this study. The research design for the first question regarding CL was a 2 x 5 mixed factorial design with both between-group and repeated measure within-group comparisons. The first independent variable was the instructional design format and it consisted of two levels: the isolated elements group and the interacting elements group. The second independent variable was time. Cognitive load ratings were gathered at five different time periods throughout the study: (1) during the pretest, (2) mid-instruction, (3) post-instruction, (4) during the posttest, and (5) during the follow-up test. The dependent variable was the CL.
reported by the participants and also consisted of two items: mental effort and task difficulty (Table 1).

Table 1:
2 x 5 Mixed Factorial Design for Cognitive Load Measurements

<table>
<thead>
<tr>
<th>Instructional Format</th>
<th>Cognitive Load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time 1</td>
</tr>
<tr>
<td>Isolated</td>
<td>Mental effort</td>
</tr>
<tr>
<td>Task difficulty</td>
<td>Task difficulty</td>
</tr>
<tr>
<td>Interacting</td>
<td>Mental effort</td>
</tr>
<tr>
<td>Task difficulty</td>
<td>Task difficulty</td>
</tr>
</tbody>
</table>

The research design for the second research question with regard to learning outcomes was a 2 x 3 mixed factorial design with both between-group and within-group comparisons. The independent variables were again the instructional design formats and time. The dependent variables were the performance scores and the confidence levels at the three assessment times: (1) pretest, (2) posttest, and (3) follow-up test (Table 2). These research designs afforded the ability to look at not only the main effects between groups and over time, but also to look at any possible interactions of group and time for each variable.

Table 2:
2 x 3 Mixed Factorial Design for Learning Outcome Measurements

<table>
<thead>
<tr>
<th>Instructional Format</th>
<th>Learning Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time 1</td>
</tr>
<tr>
<td></td>
<td>Performance Score</td>
</tr>
<tr>
<td></td>
<td>Confidence Rating</td>
</tr>
<tr>
<td>Isolated Elements</td>
<td></td>
</tr>
<tr>
<td>Interacting Elements</td>
<td></td>
</tr>
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</table>

Participants

The participants in this study were graduate students enrolled in an entry-level Doctor of Physical Therapy (DPT) program. A power analysis was conducted to determine the number of
participants needed for this study. To achieve power of 0.80, with $\alpha$ set at 0.05, and a medium effect size ($\eta^2 = 0.50$), a total sample size of approximately 50 was required (25 in each group). There was a total of 72 students who participated in the study. Recruitment of these participants is described below.

An invitation to participate in the research study was sent to 77 students in both the first-year (DPT1) and second-year (DPT2) classes. A total of 72 students consented to participate in the study, with 38 (52.1%) in the DPT1 class and 35 (47.9%) in the DPT2 class. There were 32 (43.8%) males and 41 (56.2%) females represented in the sample. This distribution is representative of the male to female ratio in the DPT program as a whole. The mean age of the sample was 23.6 (range 22-34) years. When asked about their previous experience with gait analysis, 10 (13.7%) participants reported no previous experience, 31 (42.5%) reported “a little” experience, 31 (42.5%) reported “some” experience, and only 1 (1.4%) reported “a lot” of previous experience. No students were excluded due to hearing or visual impairments.

Representation between the two experimental groups was similar. The isolated elements group ($n = 37$) comprised 16 (43.2) males, 21 (56.8%) females, 19 (51.4%) DPT1 students and 18 (48.6%) DPT2 students. Four (10.8%) of the students in the isolated elements group reported no previous gait analysis experience, 15 (40.5%) reported “a little” experience, 17 (45.9%) had “some” experience, and 1 (2.7%) reported “a lot” of experience. The interacting elements group ($n = 36$) included 16 (44.4%) males and 20 (55.6%) females, 19 (52.8%) DPT1 students and 17 (47.2%) DPT2 students. Within this group, 6 (16.7%) students reported no previous gait analysis experience, 16 (44.4%) had “a little” experience, 14 (38.9%) had “some” experience, and no students reported that they had “a lot” of experience. The mean age in the isolated elements
group was 23.8 (range 22-34) years, and the mean age in the interacting elements group was 22.3 (range 22-27) years.

There were 10 students who did not complete the one week follow-up test ($n = 63$). These students were evenly split between the two experimental groups and their previous experience with gait analysis. There were 7 males and 3 females in this group, with 8 students in the DPT2 class compared to only 2 students from the DPT1 class.

**Participant Recruitment**

All students enrolled in the two courses that used the tutorial content in regular classroom laboratory activities were invited to participate in the study by email one week before the class was scheduled. One follow-up email was sent to non-responders, with all eventually responding. Students were informed that although the content was required for the course, participation in the study was voluntary and would have no bearing on their grade in the course. Students were provided with a unique identification number for the purposes of the study. To ensure that the identities of those participating or not participating would remain unknown to the instructor of the course, all of the recruitment and group placement activities were completed by a third party. Students were informed that participants who completed the entire study would be entered in a drawing for one of five $10 gift cards.

**Materials**

**Instructional Materials**

Animated instructional tutorials on observational gait analysis that differed in the amount of element interactivity were developed for the tutorials. A motion capture system (Optotrak, Model 3020 NDI, Waterloo, Canada) was used to create animations of people walking. The motion capture system used infra-red markers attached to the extremities, trunk, and head of the
subjects to attain the data points needed to capture the person walking. These data were then translated into an animated model using Visual 3D software (C-Motion Inc., Kingston, Ontario, Canada). Video editing software (Camtasia Studio, v. 8.5.1, Okemos, MI) was used to create the gait tutorial videos that were used for both the isolated elements and interacting elements lessons. All tutorials were web based and housed on the Iowa Courses Online (ICON) website (Desire2learn).

**Tutorial content.** The instructional content of the tutorials was based on the gait analysis work of Dr. Jacquelin Perry (Perry, 2007; Ranchos Los Amigos National Rehabilitation Center, 2001). The focus of the instruction was on the ideal joint range of motion exhibited at the hip, knee, and ankle joints during each gait sub-phase. Content validity of the tutorial content was verified by two physical therapists with extensive gait analysis experience.

The isolated elements group tutorial was designed to limit the amount of element interactivity, thus hypothetically reducing the intrinsic CL experienced by the learner (Kalyuga, 2011; Paas, Renkl, & Sweller, 2003; Pollock, Chandler, & Sweller, 2002). This tutorial was separated into eight discrete animations that each contained instruction on one sub-phase of gait (e.g., initial contact, loading response, mid stance, terminal stance, pre-swing, initial swing, mid swing, or terminal swing). Learners in the interacting elements group viewed a single animation tutorial that contained instruction on all of the phases of gait through an entire gait cycle. Both instructional groups then viewed the same summary animation. The visual displays and narration content were the same between the two groups to keep the extraneous CL within the instructional design constant.

Animations are particularly well suited to teach observational gait analysis due to their ability to portray movement or changes over time (Betrancourt & Tversky, 2000; Wouters, Paas,
& van Merriënboer, 2008). However, animations can also present challenges to the learner due to their transient nature (Baddeley, 1997; Sweller, Ayres, & Kalyuga, 2011). The following design strategies were employed in the development of the tutorial animations to limit these challenges.

**Presentation of the animation.** Animations for complex content should be schematic in design rather than either realistic or decorative to lessen the processing demands placed on the working memory (Höffler & Leutner, 2007; Tversky, Morrison, & Betrancourt, 2002). For this study, a stick figure walking in the center of the screen was utilized in the tutorials rather than either an avatar (realistic) or a skeletal (decorational) model.

**Use of cueing or signaling.** Cueing or signaling draws the attention of learners to the content that is being emphasized (Kriz & Hegarty, 2007; Ozcelik, Arslan-Ari, & Cagiltay, 2010). The animated tutorials in this study used several cueing mechanisms to prompt the learners to attend to the appropriate content. The right lower extremity was highlighted in red throughout each animation, as it is the limb of reference in the narration. Slow motion was used to emphasize the segment of the gait cycle that was being discussed, and lines and arrows were drawn on the animation during stop action frames to demonstrate the joint angles that were referenced. Figure 3 is a simulated depiction of the figures used in the tutorial animations.

**Pace of the animation.** To be effective, animations must be presented in a way that can be readily and accurately perceived and comprehended (Tversky et al., 2002). Slow motion was used to not only cue the learner to the portion of the gait cycle being referenced, but also to allow the learner time to perceive and process the position of each joint during that particular phase of gait. Stop action frames were employed when the line and arrow cues were inserted to further increase the time allotted for the learner to process these visual cues.
Narration. According to Mayer’s (2009) modality principle, people learn more deeply from animations with narration than from animations with accompanying text due to dual channel processing in working memory; therefore, the instructional content of the tutorials in this study was presented to the learner through narration that accompanied the animated pictures. Appendix A contains the scripts for the isolated elements group tutorial. Appendix B contains the scripts for the interacting elements group.

![Figure 3](image_url)

*Figure 3:* Simulated picture of the tutorial animations. On the left is a stick figure captured during a walking cycle. On the right is a stop action picture depicting the angles drawn to match the narration.

**Survey Instruments**

**Cognitive load measurement.** Cognitive load was assessed in several ways, including mental effort, difficulty of the materials, and learning outcomes. Paas, Tuovinen, Tabbers, and
van Gerven (2003) defined mental effort as the “cognitive capacity that is actually allocated to accommodate the demands imposed by the task: thus, it can be considered to reflect the actual cognitive load” (p. 64). Mental effort is considered an indirect method of measuring CL as it relies on learner motivation in addition to CL (Brünken, Plass, & Leutner, 2003). For example, an unmotivated learner may report low mental effort despite highly complex materials.

For this study, participants were asked to rate their mental effort at each time point on a 7-point Likert-type scale ranging from extremely low mental effort (1) to extremely high mental effort (7). This rating scale is said to be representative of the total CL experienced by the learner (Brünken et al., 2003; Paas, 1992; Paas & van Merriënboer, 1994). While simplistic in its approach, it is widely used in the CL literature due to its high internal consistency (Cronbach’s α, .90), ease of use, sensitivity to detect small changes in workload, and demonstrated convergent, construct, and discriminant validity (Brünken et al., 2003; Paas, 1992; Paas, Tuovinen et al., 2003; Paas & van Merriënboer, 1994; Sweller, 2010e).

A 7-point Likert-type scale was also used to indicate how difficult the participants found the materials at each measurement time point. The scale ranged from extremely easy (1) to extremely hard (7). While similar to mental effort ratings, difficulty ratings are purported to provide a more direct measurement of the actual cognitive load imposed by the learning task, are sensitive to changes in element interactivity, and are related to error rates in performance measures (Ayers, 2006; Brünken et al., 2003; Sweller, 2010e). Both mental effort and difficulty rating scales have been used successfully with a variety of learner types, including physical therapy students (e.g., Pociask, Morrison, & Reid, 2013) and undergraduate college students (e.g., DeLeeuw & Mayer, 2008).
Subjective CL ratings of mental effort and difficulty gathered at the end of a lesson have been found to be higher than those gathered throughout the lesson (Schmeck, Opfermann, van Gog, Paas, and Leutner, 2015). It was hypothesized that the delayed rating at the end represented the learners’ summative CL over the entire experience, rather than the CL at that moment. For that reason, the mental effort ratings and difficulty ratings were gathered at five different time points throughout the study: (1) baseline, taken during the pretest, (2) mid-instruction, following either the isolated or interacting tutorial portion of the instruction, (3) post instruction, following the gait summary animation, (4) during the posttest, and (5) during the follow-up test.

**Pretest, Posttest, and Follow-up Test**

Cognitive load was also assessed indirectly through learning outcomes. These learning outcomes included performance scores on the pretest, posttest, and follow-up test (Brünken et al., 2003), as well as self-reported confidence levels (Kampmeyer, Matthes, & Herzig, 2015). The pretest was given prior to viewing any of the tutorials to obtain a baseline skill assessment for observational gait analysis and to ensure that the two randomly assigned groups were comparable at the beginning of the study. The posttest was given immediately following the completion of the full tutorial. It consisted of the same animations and videos as the pretest, but the order of the questions was altered. One week after the completion of the tutorials participants took the follow-up test that once again contained the same animations and videos, but the question order reverted back to the pretest. The posttest and the follow-up test were used to assess knowledge and skill acquisition in observational gait analysis.

Five animations and two video recordings of subjects ambulating with gait deviations were used to create the tests. The animations were identical in presentation to the tutorials, using
stick figures created from the motion capture system. The video recordings were of subjects ambulating in a clinical setting. Both animation and video recording formats were used in the testing to allow assessment of observational gait analysis skills in the same environment as the tutorials (animations), as well as to assess the transfer of knowledge to a more authentic clinical environment (video recordings).

Each animation or video in the test was followed by a block of three questions about a specific sub-phase of gait and joint (hip, knee, or ankle). There was a total of 18 blocks of questions in each test. The first question in each block asked the participant to determine if the identified joint demonstrated “close to ideal” or “not ideal” positioning during the stated sub-phase. If “close to ideal” was selected, the student was automatically redirected to the third question concerning his or her confidence rating. If “not ideal” was selected, the student was directed to the second question and asked to indicate whether the deviation was in the form of increased flexion (decreased extension) or increased extension (decreased flexion) at that joint. The third question asked the student to denote his or her level of confidence in the answers given on a 5-point Likert-type scale. Response choices included: (1) extremely confident, (2) moderately confident, (3) somewhat confident, (4) slightly confident, and (5) not at all confident (Kapoor & Natarajan, 2012). All tests were created using an on-line survey software (Qualtrics, LLC, © 2016). Figure 4 shows a screenshot of a sample series of questions in the survey software.
During midstance, the right ankle joint position is:

- Close to ideal
- Not ideal

During midstance, the right ankle joint demonstrates:

- Increased dorsiflexion (Decreased plantarflexion)
- Increased plantarflexion (Decreased dorsiflexion)

What is your level of confidence in your answer?

- Extremely Confident
- Moderately Confident
- Somewhat Confident
- Slightly Confident
- Not at All Confident

*Figure 4*: Screenshot of a sample video and the block questions in the pretest. The same videos and questions were used in each of the assessments.
Data Collection Procedures

Students who chose to participate in the study were randomly assigned to one of the treatment groups (isolated or interacting) through alternating placement based on the order in which they responded to the recruitment email. Students who chose not to participate in the study were placed in a third group (non-study). Study participants were enrolled in one of two ICON courses (OGA1 or OGA2) based on the group to which they had been assigned.

Students in the isolated elements group were placed in the OGA1 course on ICON. The content section of this course consisted of (a) a link to the pretest, (b) eight separate tutorial animations for each of the sub-phases of gait (initial contact, loading response, mid stance, terminal stance, pre-swing, initial swing, mid swing, and terminal swing), (c) a link to the second CL assessment, (d) the gait cycle summary animation, (e) a link to the third CL assessment, and (f) a link to the posttest. Restrictions were placed on the content such that the tutorial animations and the assessments could only be accessed in the order listed above. No restrictions were placed on the ability to return to a previous animation.

Students in the interacting elements group were placed in the OGA2 course on ICON. The content section of this course consisted of (a) a link to the pretest, (b) a single tutorial animation that contained all eight sub-phases of gait, (c) a link to the second CL assessment, (d) the gait cycle summary animation, (e) a link to the third CL assessment, and (f) a link to the posttest. Similar restrictions were placed on the order that the content could be accessed as in the OGA1 course. Total instructional time was similar between groups. All tutorial activities took place during the normally scheduled laboratory class time. One week after completing the tutorials, participants were emailed a link to the follow-up test, along with a reminder of their
identification number for the study. The follow-up test was taken outside of class time. Figure 5 depicts the study protocol.

Figure 5: Diagram of study protocol.
For each block of questions in the tests, performance scores were determined by the number of correct responses to the “close to ideal” versus “not ideal” question in each block. The difference between the joint position demonstrated in the animation or video and the “ideal” joint position was calculated to create the scoring key for each block of questions. Joint position data points from the motion capture information were determined for each sub-phase of the gait cycle within a time normalized (0-100%) gait cycle. The point within each sub-phase where the ideal joint position occurred was determined. For example, the loading response sub-phase occurs during the 1% - 12% portion of the full gait cycle. The ‘ideal” knee joint position that is referenced in the tutorials is 15 degrees of flexion (Ranchos Los Amigos National Center, 2001). This corresponds to the point at 10% of the gait cycle. For the deviant patterns, joint positions were determined around this same point in time. Figure 6 demonstrates a pictorial representation of this process for the knee joint during loading response of an “ideal” gait cycle and during one of the deviated gait patterns.
Figure 6: Knee angles at loading response. The dashed line depicts the ideal the knee range of motion throughout a gait cycle. The solid line is data obtained during a deviated gait trial. The triangle (▲) marks the point during loading response (shaded in gray) referenced in the tutorial (15°). The X marks the corresponding point in the deviated gait pattern.

Because gait is a dynamic process, a single point in time is not the best representation of the joint position. For that reason, a mean was taken for the joint positions for two percentage points above and below the specified point. As per the above example, in the case of the knee during loading response, the mean was taken for the knee joint position recorded at the 8-12% time periods.

A similar process was used to determine joint positions on video data where motion capture data was not available. Sub-phases and joint positions for the video recordings were determined using video editing software (Windows Movie Maker, version 2012). The gait cycle was time-normalized by determining the number of video frames within each gait cycle. The
frames associated with each gait sub-phase were identified. Still pictures representing the interval of interest (from the example above, 8-12%) were printed and the joint position in each picture was measured with a universal goniometer. From these measurements, a mean range of motion was calculated for each specified sub-phase and joint.

For both the animations and the video recordings, the difference between the demonstrated value and “ideal” value was calculated for each block of questions. If the difference was greater than or equal to five degrees, the joint position demonstrated in the animation or video recording was considered to be “not ideal” due to the inability for the human eye to detect changes in range of motion of less than five degrees during walking (Groth & Novak, 1999).

A total of 18 question blocks were used in each assessment. Of these, 11 represented a joint position that was “not ideal” and seven were considered ideal. Of those that were “not ideal, four demonstrated increased extension/plantarflexion and seven increased flexion/dorsiflexion. There were six of the blocks that pertained to the hip joint, five to the knee joint, and seven to the ankle joint. The mean of the non-ideal range of motion values was 15.2 degrees, with a range from 6-33 degrees. Appendix C contains a table that includes all of the data used to create the scoring key for the pretest, posttest, and follow-up test.

**Data Analysis**

Preliminary data analysis consisted of data cleaning to identify any missing data and to test the statistical assumptions, including normality, outlying values, homogeneity of variance, and sphericity. Item difficulty and item-total correlations were calculated for the pre-, post- and follow-up tests. A description of the primary data analyses for the research questions follows below.
Question 1: Do students who are taught observational gait analysis using an isolated elements instructional format report lower CL ratings than students who are taught in an interacting elements instructional format?

The data collected for the first research question consisted of the mental effort and task difficulty ratings gathered over five time points (pretest, mid-instruction, post-instruction, posttest, and follow-up test). Because CL theory presumes a lower load on the working memory in the isolated elements group, it was hypothesized that there would be a difference in the CL ratings reported between these groups at each time point after the baseline measurement. In addition, because CL is additive in nature, it was also hypothesized that there would be a differential change in CL over time. Independent t-tests were conducted to analyze any between-group differences in both mental effort ratings and task difficulty ratings at each time point. A 2-way multivariate analysis of variance (MANOVA) was used to evaluate how both group and time affected the CL ratings. Because both mental effort and task difficulty measure the same construct (CL), the MANOVA allowed assessment of the impact of group assignment and time on the combined CL measure, as well as each separate component.

Question 2: Do students who are taught observational gait analysis using an isolated elements instructional format have better learning outcomes on the posttest and follow-up test than students who are taught in an interacting elements instructional format?

The second research question hypothesized that the students in the isolated elements group would have higher scores on the post-instruction assessments than the interacting elements group due an increased ability to form, store, and retrieve schemas for observational gait analysis. In addition, it was predicted that there would be a change over time for both groups in their posttest and follow-up test performance scores and confidence ratings. Independent t-tests
were conducted to analyze any between-group differences for the performance scores and the confidence ratings at each assessment time point. Because the objective performance score and the subjective confidence rating are measuring two distinctly separate constructs, a 2-way analysis of variance (ANOVA) was used to assess differences in performance and confidence both between groups and within groups across time. Table 3 provides a summary of the research hypotheses, sources of data, and primary analyses conducted. Chapter 4 presents the detailed findings from these analyses.
### Table 3:
**Summary of the Primary Analyses Completed**

<table>
<thead>
<tr>
<th>Study Hypotheses</th>
<th>Data Sources</th>
<th>Analysis Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students in the isolated group will report lower CL ratings than students in the interacting group at the midpoint of the instruction.</td>
<td>• Mental effort rating scale&lt;br&gt;• Task difficulty rating scale</td>
<td>Independent t-tests</td>
</tr>
<tr>
<td>Students in the isolated group will report lower CL ratings than students in the interacting group immediately upon completion of the instruction.</td>
<td>• Mental effort rating scale&lt;br&gt;• Task difficulty rating scale</td>
<td>Independent t-tests</td>
</tr>
<tr>
<td>Students in the isolated group will report lower CL ratings than students in the interacting group during the posttest immediately following the instruction.</td>
<td>• Mental effort rating scale&lt;br&gt;• Task difficulty rating scale</td>
<td>Independent t-tests</td>
</tr>
<tr>
<td>Students in the isolated group will report lower CL ratings than students in the interacting group during the follow-up test one week after completion of the instruction.</td>
<td>• Mental effort rating scale&lt;br&gt;• Task difficulty rating scale</td>
<td>Independent t-tests</td>
</tr>
<tr>
<td>Changes in CL ratings over time will be dependent on treatment group assignment.</td>
<td>• Mental effort rating scale&lt;br&gt;• Task difficulty rating scale</td>
<td>2-way MANOVA</td>
</tr>
<tr>
<td>Students in the isolated group will have higher performance scores than students in the interacting group on the posttest immediately following the instruction.</td>
<td>• Posttest score</td>
<td>Independent t-tests</td>
</tr>
<tr>
<td>Students in the isolated group will have higher performance scores than students in the interacting group on the follow-up test one week after completion of the instruction.</td>
<td>• Follow-up test score</td>
<td>Independent t-tests</td>
</tr>
<tr>
<td>Changes in performance scores over time will be dependent on treatment group assignment.</td>
<td>• Pretest scores&lt;br&gt;• Posttest scores&lt;br&gt;• Follow-up test scores</td>
<td>2-way ANOVA</td>
</tr>
<tr>
<td>Students in the isolated group will report higher confidence in their performance than students in the interacting group on the posttest immediately following the instruction.</td>
<td>• Posttest confidence ratings</td>
<td>Independent t-tests</td>
</tr>
<tr>
<td>Students in the isolated group will report higher confidence in their performance than students in the interacting group on the follow-up test one week after completion of the instruction.</td>
<td>• Follow-up test confident ratings</td>
<td>Independent t-tests</td>
</tr>
<tr>
<td>Changes in confidence ratings over time will be dependent on treatment group assignment.</td>
<td>• Pre-test confidence ratings&lt;br&gt;• Posttest confidence ratings&lt;br&gt;• Follow-up test confidence ratings</td>
<td>2-way ANOVA</td>
</tr>
</tbody>
</table>
CHAPTER 4: RESULTS

The purpose of this study was to examine the effects of two instructional design formats on cognitive load (CL) and learning outcomes. Students in the isolated elements format group were introduced to observational gait analysis through a series of tutorial videos that presented each gait sub-phase independently before they were exposed to the entire gait cycle. In contrast, the tutorial for students in the interacting elements format group addressed the full gait cycle in one video.

The first research question posited whether students in the isolated elements group would report lower CL ratings, in the form of mental effort and task difficulty ratings, than students in the interacting elements group at each time point or over time. Mental effort data were gathered as a subjective, indirect measure of CL (Brünken, Plass, & Leutner, 2003), while task difficulty data were measured as a subjective, direct method of measuring CL (Ayers, 2006; Brünken et al., 2003; Sweller, 2010e). Independent t-tests were used to analyze the CL data for between-group comparisons. A 2-way multivariate analysis of variance (MANOVA) was used to evaluate how both group and time affected the CL ratings. Because both mental effort and task difficulty measure the same construct (CL), the MANOVA allowed assessment of the impact of group assignment and time on the combined CL measure, as well as each separate component.

The second research question asked whether students in the isolated elements group would have higher performance scores and confidence ratings than students in the interacting elements group at each time point and over time. Learning outcomes are considered objective, indirect measures of CL (Brünken et al., 2003). Independent t-tests were used to analyze the learning outcomes data for between-group comparisons. A 2-way analysis of variance (ANOVA) was used to assess differences in performance and confidence both between the
groups and within the groups over time due to the dependent variables measuring two distinct constructs (objective performance scores and subjective confidence ratings).

In this chapter, the results of the statistical analyses used to answer the research questions are presented. The results are organized into the following sections: preliminary analyses, primary analyses, and a summary of the results.

**Preliminary Analyses**

**Data Cleaning**

All data was analyzed with SPSS (version 23). Preliminary review of the data exposed 16 duplicate identification numbers on the posttest, and one each on the pretest, follow-up test, second CL assessment, and third CL assessment. Further investigation revealed that one of students entered a wrong identification number in each of the instruments. Computer IP number tracking allowed the scores to be reassigned to a different identification number. The other 15 duplicate numbers on the posttest were students who retook the posttest in error rather than the follow-up test. This was indicated by the date that the test was completed. The content of the posttest and follow-up test was identical, but in a different question order. Performance scores of those in the isolated elements group that mistakenly took the posttest \( (M = 12.88, SD = 1.27) \) did not differ significantly from those in the isolated group who took the true follow-up test \( (M = 11.74, SD = 4.93) \), \( t(29) = 1.36, p = 0.18 \). Interacting elements group scores for the posttest taken in error \( (M = 11.75, SD = 2.25) \) also did not differ significantly from the scores of those who took the true follow-up test \( (M = 11.85, SD = 4.36) \), \( t(29) = -0.09, p = 0.93 \), thus these posttest scores were included in the final analyses of the follow-up test.

There were 10 students who did not complete the one week follow-up test \( (n = 63) \). These students were evenly split between the two experimental groups and in regard to their
previous experience with gait analysis. There were 7 males and 3 females in this group, with 8 students in the DPT2 class compared to only 2 students from the DPT1 class.

**Analysis of the Testing Instruments**

The instruments used for the pre-test, posttest, and follow-up test were analyzed for item difficulty, item discrimination, and test-retest reliability. Item difficulty was assessed using the percentage of participants who answered the “close to ideal” or “not ideal” question correctly. The average item difficulty was calculated across the three tests for each question. For the 18 questions, the range of percent correct ranged from 35.5% to 91.87%, with a mean of 67.87% correct. This is less than the reported ideal item difficulty for a 2-response question of 75%, indicating that the items were somewhat more difficult than the ideal for the participants (Thorndike, R. M, Cunningham, Thorndike, R.L., & Hagen, 1991). Item discrimination was tested using an item-total correlation. Across the three assessments, these correlations ranged from -0.05 to 0.49, with the majority of the questions demonstrating good item discrimination (Ebel & Frisbie, 1986).

Test-retest reliability analysis found that the posttest scores significantly and positively correlated with the follow-up scores, $r(62) = 0.347$, $p = 0.005$. Higher posttest scores were associated with higher follow-up test scores, and lower posttest scores were associated with lower follow-up scores. Appendix D contains a table summarizing the item difficulty and item-total correlations for the three assessments.

**Pre-test Comparisons**

To validate subsequent between-group comparisons, pre-test analyses were completed to assure the two treatment groups were similar prior to the intervention. Table 4 contains the pre-test means, standard deviations, and $p$-values for the two treatment groups on the following
variables: baseline CL ratings (mental effort and task difficulty), ability to detect “close to ideal” versus “not ideal” joint positions, and confidence ratings. There were no significant differences between the isolated elements and interacting elements groups for these variables during the pretest assessments.

Table 4:
*Independent t-test Results Comparing the Treatment Groups at Pretest*

<table>
<thead>
<tr>
<th></th>
<th>Group Mean (SD)</th>
<th>t(df)</th>
<th>p-value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Isolated Elements Group</td>
<td>Interacting Elements Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mental Effort</td>
<td>4.47 (0.74)</td>
<td>4.58 (1.13)</td>
<td>-0.49 (60.16)</td>
<td>0.623</td>
</tr>
<tr>
<td>Task Difficulty</td>
<td>4.78 (0.96)</td>
<td>4.69 (1.01)</td>
<td>0.36 (70)</td>
<td>0.721</td>
</tr>
<tr>
<td>Raw Test Score</td>
<td>11.0 (1.48)</td>
<td>11.48 (1.37)</td>
<td>-1.46 (71)</td>
<td>0.149</td>
</tr>
<tr>
<td>Confidence Rating</td>
<td>2.90 (0.49)</td>
<td>2.84 (0.65)</td>
<td>0.17 (71)</td>
<td>0.862</td>
</tr>
</tbody>
</table>

*Notes:* CI = confidence interval; Confidence rating scale: 1 = extremely confident, 2 = moderately confident, 3 = somewhat confident, 4 = slightly confident, and 1 = not at all confident

**Primary Analyses**

**Cognitive Load Analyses**

Mental effort and task difficulty ratings were gathered at five time points: (1) during the pretest, (2) at the midpoint of instruction, following either the isolated or interacting videos, (3) at the completion of the instruction, following the gait summary video, (4) during the posttest, and (5) during the follow-up test. Table 5 contains the descriptive statistics for the between-group comparisons of the CL variables. At the midpoint of the instruction, students in the isolated elements group reported a statistically significant lower mental effort rating ($M = 3.65$, $SD = 1.42$) than the students in the interacting elements group ($M = 4.54$, $SD = 1.09$). At all other
time points, there was no statistically significant difference reported between the two groups for either mental effort or task difficulty.

Table 5:

*Independent t-test: Between-Group Comparisons for the Cognitive Load Variables*

<table>
<thead>
<tr>
<th>Time</th>
<th>Group Mean (SD)</th>
<th>t(df)</th>
<th>p-value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Isolated Elements Group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interacting Elements Group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mental Effort</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>4.47 (0.74)</td>
<td>-0.49</td>
<td>0.623</td>
<td>[-0.561, .339]</td>
</tr>
<tr>
<td>Midpoint Instruction</td>
<td>3.65 (1.42)</td>
<td>-2.98</td>
<td>0.004*</td>
<td>[-1.492, -.296]</td>
</tr>
<tr>
<td>Post Instruction</td>
<td>4.03 (1.12)</td>
<td>-1.31</td>
<td>0.194</td>
<td>[-0.796, 0.164]</td>
</tr>
<tr>
<td>Posttest</td>
<td>4.59 (1.04)</td>
<td>0.18</td>
<td>0.856</td>
<td>[-0.389, 0.467]</td>
</tr>
<tr>
<td>Follow-up Test</td>
<td>4.23 (0.84)</td>
<td>-0.26</td>
<td>0.799</td>
<td>[-0.621, 0.48]</td>
</tr>
<tr>
<td><strong>Task Difficulty</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>4.78 (0.96)</td>
<td>0.36</td>
<td>0.721</td>
<td>[-0.380, 0.546]</td>
</tr>
<tr>
<td>Midpoint Instruction</td>
<td>3.70 (1.10)</td>
<td>-1.07</td>
<td>0.286</td>
<td>[-0.767, 0.230]</td>
</tr>
<tr>
<td>Post Instruction</td>
<td>3.92 (1.14)</td>
<td>0.13</td>
<td>0.898</td>
<td>[-0.483, 0.055]</td>
</tr>
<tr>
<td>Posttest</td>
<td>4.38 (1.11)</td>
<td>0.07</td>
<td>0.941</td>
<td>[-0.450, 0.484]</td>
</tr>
<tr>
<td>Follow-up Test</td>
<td>4.16 (0.82)</td>
<td>0.81</td>
<td>0.422</td>
<td>[-0.239, 0.561]</td>
</tr>
</tbody>
</table>

*Note: * = statistically significant p-value

A 2-way multivariate analysis of variance (MANOVA) was used to evaluate how both group and time affected the combined CL ratings. A significant multivariate main effect for time was found, $F(8, 47) = 6.29, p < 0.001$, partial $\eta^2 = 0.52$. However, there was not a significant
multivariate main effect for the groups, $F(2, 53) = 1.28, p = 0.288$, partial $\eta^2 = 0.05$, or for the group * time interaction, $F(8, 47) = 1.37, p = 0.236$, partial $\eta^2 = 0.19$. Univariate results for the changes in CL over time are shown in Table 6. As the table demonstrates, significant univariate main effects were seen for task difficulty ratings over time for the full sample and for each of the treatment conditions. Significant univariate main effects were found for mental effort over time for the full sample and the isolated elements group, but not for the interacting elements group.

Table 6:  
*Univariate Main Effects for Changes in Cognitive Load Over Time*

<table>
<thead>
<tr>
<th>Main Effect</th>
<th>$F$-Statistic (df)</th>
<th>Partial $\eta^2$</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Sample</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulty</td>
<td>12.48 (3.26,176)</td>
<td>0.24</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Mental Effort</td>
<td>5.88 (4.0,189.72)</td>
<td>0.10</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Interacting Elements Group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulty</td>
<td>6.7 (2.92,72.93)</td>
<td>0.21</td>
<td>0.001*</td>
</tr>
<tr>
<td>Mental Effort</td>
<td>1.1 (2.86,71.45)</td>
<td>0.04</td>
<td>0.353†</td>
</tr>
<tr>
<td>Isolated Elements Group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulty</td>
<td>10.71 (4.0,116.0)</td>
<td>0.27</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Mental Effort</td>
<td>6.38 (2.91,84.37)</td>
<td>0.18</td>
<td>0.001*</td>
</tr>
</tbody>
</table>

*Note:* * = statistically significant $p$-value, † = Greenhouse-Geisser statistic was used to correct for violating sphericity.

There was a significant cubic trend in the way mental effort changed for members of the isolated elements group, $F_{\text{trend}}(1,29) = 15.82, p < 0.001$, partial $\eta^2 = 0.35$. Figure 7 shows this cubic waveform, with two inflection points demonstrating a high amount of mental effort at the baseline measurement, followed by a large drop in mental effort mid-instruction, a return to the baseline mental effort at the posttest, and finally a decreased mental effort at the follow-up test. A similar waveform can be seen for mental effort scores in the interacting elements group and for task difficulty measurements in both treatment groups (Figure 8). However, these waveforms did not reach a level of statistical significance.
Figure 7: Change in cognitive load mental effort measure over time for both the interacting and isolated treatment groups. A significant cubic trend, with two inflection points, can be seen for the mental effort ratings in the isolated elements group.

Figure 8: Change in cognitive load task difficulty measure over time for both the interacting and isolated treatment groups. Although the cubic waveform is seen for this data as well, it did not reach statistical significance.
Learning Outcome Analyses

The learning outcomes analyzed include the performance scores on the first question and the confidence ratings for each block of questions. The performance scores were based on the ability to determine if the 18 joint positions presented in the blocks were “close to ideal” or “not ideal”. Confidence ratings were scored on a 5-point Likert-type scale, ranging from “extremely confident” (1) to “not at all confident” (5), with a lower score indicating more confidence. The results for the between-group comparisons of test scores and confidence ratings are displayed in Table 7. There were no statistically significant differences between the group means on either performance scores or confidence ratings for any of the assessments.

Table 7: *Independent t-test: Between-Group Comparisons for the Test Scores and Confidence Ratings*

<table>
<thead>
<tr>
<th>Time</th>
<th>Mean (SD)</th>
<th>t(df)</th>
<th>p-value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Isolated Elements Group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw Performance Score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>11.0 (1.48)</td>
<td>-1.46 (71)</td>
<td>0.149</td>
<td>[-1.18, 0.18]</td>
</tr>
<tr>
<td>Posttest</td>
<td>11.65 (1.44)</td>
<td>-1.76 (71)</td>
<td>0.084</td>
<td>[-1.46, 0.09]</td>
</tr>
<tr>
<td>Follow-up</td>
<td>12.13 (2.11)</td>
<td>0.56 (61)</td>
<td>0.580</td>
<td>[-0.74, 1.31]</td>
</tr>
<tr>
<td></td>
<td>Interacting Elements Group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>11.48 (1.37)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posttest</td>
<td>12.07 (1.92)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow-up</td>
<td>11.85 (2.09)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Confidence Rating</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>2.90 (0.49)</td>
<td>0.17 (71)</td>
<td>0.862</td>
<td>[-0.23, 0.27]</td>
</tr>
<tr>
<td>Posttest</td>
<td>2.48 (0.40)</td>
<td>1.04 (71)</td>
<td>0.301</td>
<td>[-0.10, 0.32]</td>
</tr>
<tr>
<td>Follow-up</td>
<td>2.37 (0.45)</td>
<td>0.69 (56)</td>
<td>0.491</td>
<td>[-0.17, 0.34]</td>
</tr>
</tbody>
</table>

Notes: CI = confidence interval; Confidence rating scale: 1 = extremely confident, 2 = moderately confident, 3 = somewhat confident, 4 = slightly confident, and 5 = not at all confident

A 2-way ANOVA was used to analyze both performance scores and confidence ratings between-groups and within-groups. There was a significant main effect for time, \( F(4, 53) = \)
24.86, $p < 0.001$, partial $\eta^2 = 0.65$. However, there was no significant main effect for the
treatment group, $F(2, 55) = 0.43, p = 0.653$, partial $\eta^2 = 0.02$. There also was no significant
group by time interaction, $F(2,122) = 1.24, p = 0.294$, partial $\eta^2 = 0.02$. Both the descriptive
statistics and the ANOVA results indicate that although there was a significant change over time
within-groups for both test scores and confidence, the groups did not differ significantly from
each other in either score or confidence at any time point.

The results of the ANOVA for changes in the learning outcomes over time are shown in
Table 8. Significant main effects were seen for the full sample and the isolated elements
treatment group over time for both the performance scores and confidence ratings. In the
interacting elements group, there was a significant main effect for the confidence ratings, but not
the test score. Figures 9 and 10 graphically depict the group means for each variable over time
and it can been seen that the group means are very close at each time point, but do show
significant changes over time for the isolated elements group in both performance scores and
confidence ratings.

Table 8:

Univariate Main Effects for Changes in Score and Confidence Over Time

<table>
<thead>
<tr>
<th>Main Effect</th>
<th>$F$-Statistic (df)</th>
<th>Partial $\eta^2$</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Sample</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test Score</td>
<td>4.05 (1.97,112)</td>
<td>0.07</td>
<td>0.021*</td>
</tr>
<tr>
<td>Confidence</td>
<td>60.19 (1.68,112)</td>
<td>0.52</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Interacting Elements Group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test Score</td>
<td>1.35 (2,52)</td>
<td>0.05</td>
<td>0.268</td>
</tr>
<tr>
<td>Confidence</td>
<td>29.00 (2,52)</td>
<td>0.53</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Isolated Elements Group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test Score</td>
<td>3.67 (2,60)</td>
<td>0.11</td>
<td>0.031*</td>
</tr>
<tr>
<td>Confidence</td>
<td>31.27 (2,60)</td>
<td>0.51</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>

Note: * = statistical significant $p$-value, † = Greenhouse-Geisser statistic was used to correct for
violating sphericity
Figure 9: Mean test performance scores over time. Within group comparisons were significant over time for the isolated elements group. Between-group comparisons of the two treatment groups were not statistically significant.

Figure 10: Mean confidence ratings over time. Within group comparisons for confidence ratings did show a significant increase in confidence over time for both treatment groups (lower score indicates increased confidence). There was no significant difference in confidence ratings between groups.
Additional Analyses

Four video recordings of patients were included in the post-instructional assessments to investigate whether the students’ ability to identify ideal joint positions during gait transferred from the animated stick figures to an actual person walking. On the posttest, the number of participants who answered the “close to ideal”/”not ideal” question correctly for the video recordings ($M = 29.15, SD = 7.85$) was significantly higher than for the animated stick figure questions ($M = 21.71, SD = 8.59$), $t(2) = 2.19, p = 0.036$. On the follow-up test, the mean for the video recordings ($M = 25.50, SD = 8.38$) was still higher than for the animated clips ($M = 21.14, SD = 6.03$), but was not statistically significant.

The second question in each block in the assessments asked the learners to determine if the deviation they identified was in the direction of flexion or extension. The assessment design made detailed analysis of the results of the question difficult due to the fact that the question only appeared to the learner if they selected “not ideal” in the first question. “Not ideal” was the correct response for 11 of the 18 questions. As a result, question 2 was only analyzed for those learners who had correctly selected “not ideal” on those 11 questions. There was no statistically significant difference between students in the isolated elements group ($M = 0.90, SD = 0.02$) and the interacting elements group ($M = 0.86, SD = 0.04$), $t(20) = 0.64, p = 0.53$, when identifying the direction of the deviation.

Summary of Results

The purpose of this study was to determine whether a difference existed in reported CL or learning outcomes based on assignment to either an isolated elements instructional format or an interacting elements instructional format to learn observational gait analysis. The results of this study found that with the exception of the mental effort rating at the mid-instructional time point,
there were no significant differences between the two treatment groups on CL, test scores, or confidence. However, within-group analyses confirmed that there were significant differences found over time within each group for the task difficulty and confidence rating variables. Mental effort ratings and test scores were found to change significantly over time for the isolated elements group, but not for the interacting elements group. The mental effort ratings in the isolated elements group demonstrated a significant cubic trend such that the participants reported high initial mental effort, lower time 2 mental effort, a return to near baseline effort at time 4, and followed by a return to a lower mental effort rating at time 5. These findings will be further explored in Chapter 5 as they relate to the significance of this study.
CHAPTER 5: DISCUSSION

Cognitive overload can hamper the learning process when teaching complex materials to novice students. The purpose of this study was to investigate how two different instructional design formats affected the cognitive load experienced by the learners and their learning outcomes. The content of the lesson was focused on observational gait analysis, which has been identified as a very challenging skill for physical therapy students to learn (Gronley & Perry, 1984; Pociask, DiZazzo-Miller, & Samuel, 2013; Pociask, Morrison, & Reid, 2013; Seymour & Dybel, 1998). It was hypothesized that using an isolated elements approach, with the content broken down into individual elements, would lead to lower CL ratings and higher learning outcome scores than an interacting elements approach. It was also hypothesized that both the isolated elements and the interacting elements groups would see changes in their reported CL, performance scores, and confidence ratings over time. Chapter 5 discusses the findings related to these hypotheses, the limitations of this study, and suggestions for future research related to this topic.

Cognitive Load Findings

Cognitive load was measured subjectively using two Likert-type rating scales that asked the students to rate their mental effort and the task difficulty at five different time points during the study. It was hypothesized that the participants in the isolated elements group would report lower mental effort and task difficulty ratings at each of the time points after the pre-test than those in the interacting elements group. However, it was only at the mid-instruction time point that this difference was found to be statistically significant and then only for mental effort. The mid-instruction time point immediately followed the viewing of either the isolated elements tutorial videos or the single interacting elements tutorial video. This finding lends support to the
theory that isolating the elements of instruction within a complex lesson can lower the CL experienced by students, as the reduction in reported mental effort occurred immediately following the portion of the instruction that was isolated rather than integrated. These findings were similar to the findings of Pociask, Morrison et al. (2013) in their post-instruction measurement of mental workload when teaching gait analysis in a classroom in both the reduction of CL, as well as the magnitude of the mean CL scores in the isolated elements groups immediately following the isolated instructional component (Current study: $M = 3.65$, $SD = 1.42$; Pociask, Morrison et al.: $M = 3.56$, $SD = 0.51$). The between-group task difficulty ratings were virtually identical at all stages during the study and did not support the hypothesis that there would be a difference between the groups.

Cognitive load can be measured subjectively or objectively, and either directly or indirectly. Brünken, Plass, and Leutner (2003) described mental effort ratings as a subjective, indirect method of measuring CL. Self-reporting leads to the subjective classification, while the affective components involved in a learner’s effort leads to the indirect label. In other words, mental effort may also be related to such factors as motivation or fatigue within a learner, not just CL. In contrast, they described task difficulty ratings as a subjective, direct method to assess CL. Again, these are self-reported, but are instead considered to be direct as they are the learner’s own perceived difficulty of the materials and are not reliant on affective components. To explain the differential findings for the mental effort ratings and the task difficulty ratings in this study, it is necessary to further assess what these ratings are actually measuring.

Many claim that these types of subjective measures can only reliably measure total CL (e.g., Sweller, 2010e; Wiebe, Roberts, & Behrends, 2010); however, others propose that they can be used to measure the different types of CL. DeLeeuw and Mayer (2008) found that mental
effort ratings were related to the complexity of the materials being presented and thus are most closely aligned with intrinsic CL. Task difficulty ratings were found to be related to test performance, and thus the germane CL or processes used for deeper processing and transfer of learning. The findings of the current study lend further support to this theory on CL measurement. Isolating the content into individual elements is theorized to lower the intrinsic CL (Kalyuga, 2011; Paas, Renkl et al., 2003; Pollock, Chandler, & Sweller, 2002). The isolated elements group reported a decreased mental effort following the isolated instructional component as compared to their peers who viewed the interacting instruction. Additional support for DeLceuw and Mayer’s (2008) theory regarding the ability to measure different types of CL comes from the finding that task difficulty ratings were similar between groups throughout the study and that both groups scored similarly on both the posttest and follow-up tests. When analyzed through the lens of their findings, the results of this study point to the students in the isolated elements group experiencing a lower intrinsic CL than those in the interacting elements group, yet both groups found the germane processes necessary to learn and apply the information to be equally taxing from a CL (task difficulty) standpoint.

When analyzing the CL results over time, a cubic trend was seen in the isolated elements group for both mental effort and task difficulty. A cubic relationship is one in which when the dependent variable means are graphed against the levels of the independent variable two inflection points can be seen. Specifically, the students reported high CL during the pretest, their lowest level of CL immediately after the isolated elements tutorial videos, a return to a higher rating at the posttest, and then a lower rating one week later on the follow-up test. A similar trend was seen for the interacting element group, but did not reach statistical significance. Previous studies have shown that a delayed CL measurement tends to be higher than ratings.
gathered immediately following each task (Schmeck, Opfermann, van Gog, Paas, & Leutner, 2015; Van Gog, Kirschner, Kester, & Paas, 2012). It has been postulated that this may be due to the student’s “perception of ‘the learning task’ as a whole; that is, when being asked to give delayed estimations of their cognitive load, participants take the total number of problems or the total time into account rather than simply remembering each (or the most difficult) problem…” (Schmeck et al., 2015, p. 112). In the case of this study, it is possible that the higher cognitive load ratings seen following the gait summary video and during the posttest indicate the students’ cumulative CL rather than the actual cognitive load at that time. The decrease in CL ratings seen during the follow-up test, which was one week later, lends further credence to the summative nature of the ratings, as CL was only measured once during the test and not at the end of the assessment, but in the middle. Fatigue for the activities could also very well play a factor in the higher CL ratings at the end of the lesson and during the posttest, as the ratings were similar between groups and the time spent in each lesson was equivalent.

Learning Outcome Findings

The learning outcomes analyzed in this study included performance scores and confidence ratings. Performance scores are considered to be an objective, indirect measure of CL. They are considered objective as they measure actual performance, and indirect due to the fact that they depend on the schema acquisition and retrieval processes that are dependent on CL (Brünken et al., 2003). Performance scores were determined by the number of times the student could correctly identify if the joint position demonstrated in either the animation or video was “close to ideal” or “not ideal” compared to the position described in the tutorial. There were no significant differences found between the two treatment groups on performance scores on the pretest, posttest, or follow-up test. This task proved to be very challenging to both groups with
test means ranging from only 61% - 67% percent correct on any given test, and a mean item difficulty of 0.68. An optimal item difficulty for a 2-response question would be 0.75 (Thorndike, R. M, Cunningham, Thorndike, R.L., & Hagen, 1991). These results indicate that perhaps the task itself was too difficult to measure any true difference in performance outcomes based on group assignment alone. The students’ report of above average task difficulty during the tests also seems to support this notion.

The second question in each block of questions on the assessments only appeared to the participants if they answered “not ideal” to the first question regarding the joint position, making meaningful analysis of the results challenging. The second question asked the students to indicate whether the joint demonstrated increased flexion or increased extension relative to the ideal position identified in the tutorials. Although students had difficulty consistently identifying whether a joint position was “ideal” or “not ideal” as discussed previously, those who correctly identified a deviation from that norm were more accurate in identifying the direction of that deviation. The isolated elements group correctly identified the direction of the deviation 90.14% of the time, while the interacting elements group was correct 85.65% of the time, but this difference was not statistically significant. Further exploration is needed in this area to determine whether these results could be actually indicative of a difference between the groups in their ability to determine the direction of the deviation.

Performance scores did increase over time for both the sample as a whole and for the isolated elements group, but the increase was not statistically significant for the interacting group alone. In other words, overall the tutorial content did appear to increase the students’ ability to distinguish whether there was a deviation in the joint position present compared to their pretest performance. Those in the isolated group were also more likely to see this difference in their
score than those in the interacting group, even if the difference between the group means was not found to be statistically significant. This is suggestive of the isolated format providing an environment that was more conducive to learning observational gait analysis. This may be due to a decreased CL, but given that performance is an indirect measure of CL, and the nonsignificant findings between groups, it is in need of further investigation.

Stick figure animations were used in the tutorial due to their ability to portray movement over time, their simplicity in design, and the ability to cue the learner to the salient features of the animation through arrows, slow motion, and stop action frames (Betrancourt & Tversky, 2000; de Koning, Tabbers, Rikers, & Paas, 2007; Tversky, Morrison, & Betrancourt, 2002). The transfer of knowledge (schemas) from this animated stick figure environment to a video recording of a person walking is an essential, but challenging task for clinical practice. In this study, the investigation into the transfer of the observational gait analysis skills from an animated stick figure to a video recording of a patient walking in the clinic found surprising results at first glance. On both the posttest and the follow-up test, the mean number of students who answered the “close to ideal”/“not ideal” question correctly was higher for the questions with a video recording than those with an animated stick figure. However, further exploration of the data revealed that the average deviation from the normal joint position was 21.5 degrees for the video recordings and 9.86 degrees for the animated clips. This unintended bias made the discernment of a deviation much easier to identify in the video recordings than the animations. Interestingly, however, the difference between the mean number correct for the videos versus the animations only reached statistical significance on the posttest, but not the follow-up test. Further investigation is warranted into the transfer of observational gait analysis skills from an animated tutorial to a clinical environment.
Confidence ratings were also assessed as a learning outcome. There were no significant differences between the two groups for the confidence ratings on the pretest, posttest, or follow-up test. Repeated measures analysis showed significant changes in the confidence scores over time, within both groups. As hypothesized, the confidence increased from pre-test to posttest to follow-up test for both groups. Figure 10 depicts how the changes over time in mean confidence ratings were virtually identical for both groups, and mirror the changes seen in performance scores, with the exception of the follow-up test score in the interacting elements group, although this exception was not statistically significant (Figure 9). The results of this study show that as CL decreased and knowledge increased over time, the learners’ confidence in their answers increased as well. Expertise and performance in a domain are not only a function of knowledge acquisition, but also of confidence. A learner who is knowledgeable but not confident may be unable to apply that knowledge (Kampmeyer, Matthes, & Herzig, 2015). However, a certain amount of distrust in one’s knowledge can be beneficial in a healthcare field to encourage seeking out additional or new knowledge for clinical problems. The goal is for clinicians to demonstrate appropriate confidence, such that their confidence is high when they correct and low when they are not, rather than to be over or under confident (Friedman, Gatti, Elstein, Franz, Murphy, & Wolf, 2001).

Limitations

As with any research study, there were limitations in this project. The tutorials used in this study consisted of video animations of stick figures walking. The isolated elements tutorial videos were subdivided into the eight different sub-phases of gait. The isolated elements effect calls for content with high element interactivity to be reduced to smaller elements for initial schema formation prior to introducing the full interactions of the elements. As was discussed in
Chapter 2, the breakdown of elements in relation to observational gait analysis has not been described. Performing a task analysis could help identify the number of interacting elements involved in the skill of observational gait analysis (Sweller, 2010c). From this task analysis, it could be determined whether the eight gait sub-phases were the best division of the content into isolated elements.

Several instructional approaches were used to cue the learners to important content, but there was very limited learner interactions with the media or the content. Simply guiding someone’s attention to specific content in an animation does not guarantee that improved comprehension of the material will occur (Kriz & Hegarty, 2007; de Koning, Tabbers, Rikers, & Paas, 2009). As identified by the cognitive theory of multimedia learning, learners must also be actively engaged in processing the information (Mayer, 2005a). The passive learning approach used in the current study may not have yielded enough “instructional power” to lead to any differences between groups. Adding learner interactions, such as questioning that provides feedback to the learner, would afford a better learning environment for the student overall and perhaps then differentiate between the two groups (Lin, 2011). In addition, the students were exposed to a large amount of information in one sitting rather than spreading it out over two or more days to allow for further organizing of the information learned. Information that has been organized and can be transferred as a single unit of information (schema), rather than multiple units, can be used in working memory with less risk of cognitive overload (Sweller, 2010b). The one day time frame may have also played into student fatigue with the lesson and the materials over time.

The tests consisted of all dichotomous-answer questions which allowed for guessing to go undetected more readily. In addition, the second question in each block only appeared to the
learner only if the answer “not ideal” was chosen for the first question. This design did not allow for full interpretation of these data in the current study, but could be rectified in future work by including the content of question two within the answer choices for question one. For example, the question could read “During (gait sub-phase), the (joint) position is: (a) ideal, (b) not ideal, demonstrating increased flexion, or (c) not ideal, demonstrating increased extension. The addition of more answer choices in the first question would also reduce the possibility of guessing the correct answer. Finally, the timing of the follow-up test for the DPT2 students coincided with their finals week for the fall semester. This led to a greater drop rate from the study for the DPT2 students and may have interfered with their motivation to perform well on the follow-up test.

**Conclusion and Future Research Suggestions**

This research study provided information in regard to student perceptions of their CL while learning observational gait analysis in two different instructional environments. The first research question queried how CL might vary between and within the treatment groups. This study supported the first hypothesis that the isolated elements group would report lower CL ratings than the interacting elements group at the mid-instruction point. This point in the instruction immediately followed the “treatment” portion of the study. The remaining between-group comparisons of CL at the other time points did not result in statistically significant findings. Within-group comparisons of CL demonstrated significant changes in both the mental effort and task difficulty variables over time for the sample as a whole. When looking at the two treatments, the isolated elements group exhibited significant changes over time for both mental effort and task difficulty, whereas the interacting elements group had significant changes only for the task difficulty ratings.
The second research question concerned how learning outcomes would differ between the two treatment groups and change over time within the groups. Between-group analyses found that performance scores and confidence ratings were not statistically different between the groups at any assessment point. An analysis of the two individual treatments found that the isolated elements group had significant changes over time for both performance scores and confidence ratings, while the interacting elements group had significant changes for the confidence rating, but not the performance scores.

This study was to able confirm that an isolated elements approach can decrease the mental effort reported by learners at certain times during the instruction. Future research should seek to identify additional instructional design methods that can not only further decrease the CL experienced by the learners, but also facilitate schema formation, storage, and retrieval. Examples of such strategies include incorporating learner control over the pace of the animations (e.g., Tversky, Morrison, & Betrancourt, 2002), providing opportunities for practice and feedback (e.g., Lin, 2011), and spreading out the tutorial lessons over several days, rather than in a single lesson, as was utilized by Pociask, Morrison et al. (2013) in a classroom setting.

This study utilized self-reported CL measures as the primary means of determining CL. However, future studies should consider using alternative objective methods such as dual-task assessment (DeLeeuw & Mayer, 2008), physiological monitoring such as heart rate variability, pupillary dilation-tracking, task evoked brain potentials, or blink rate (Paas, Tuovenin, Tabbers, & Van Gerven, 2003), or neuroimaging techniques such as fMRI studies (Brünken et al., 2003). These methods provide a more objective measure of CL and may be able detect differences in experienced CL between treatment groups that subjective measures cannot (Kalyuga, 2009).
Identifying learning environments that can control CL, prevent cognitive overload, and promote schema acquisition and automation remains an important educational need for the future.
APPENDIX A

ISOLATED ELEMENTS TUTORIAL SCRIPTS

VIDEO 1: INTRODUCTION – PHASES OF GAIT

These gait tutorials were developed to improve your ability to analyze walking gait. Observational gait analysis requires you to understand ideal gait and be able to identify when deviations from the ideal occur. The focus of the tutorials will be on recognizing the ideal joint positions of the hip, knee, and ankle during each of the phases of a gait cycle. These phases include:

1) Initial contact
2) Loading response
3) Mid Stance
4) Terminal stance
5) Pre-swing
6) Initial swing
7) Mid Swing
8) Terminal Swing

New screen

(Have a video of the stick figure walking while the following is read)

Each tutorial will consist of a video clip of a stick figure walking. A gait cycle is defined as the time from right heel contact to the next right heel contact (As this is read, use a cue to show right heel contact to right heel contact). For each phase of gait, slow motion and freeze frames will be used to highlight the portion of the gait cycle that is being discussed.

The instruction will focus on the right leg only and it has been drawn in red for ease in viewing. You will not be able to stop or rewind a video clip once it has been started. You will need to watch each of the video clips in order, but you may go back and repeat a video after you have viewed it, if you wish. You will be asked occasionally to stop and answer two brief questions regarding your mental effort and the difficulty of the materials.

VIDEO 2: INITIAL CONTACT

(Text at the beginning of the video on black background)

OBSERVATIONAL GAIT ANALYSIS – INITIAL CONTACT

(New screen-Entire video should have INITIAL CONTACT in the upper left hand corner to identify which video they are watching. Have the video run through at least one full gait cycle and then have the initial contact phase in slow motion as the following is read)

This video will focus on the initial contact phase of gait, which is shown in slow motion. Initial contact marks the beginning of the gait cycle as the foot hits the ground.
(Freeze the video at heel contact while you read the following).

During initial contact, it is critical that the heel makes the first contact with the ground rather than other parts of the foot. The ankle joint should be in a neutral position with 0 degrees of either dorsiflexion or plantarflexion and it appears to be at a 90 degree angle (Draw lines over the video to indicate that the ankle is at neutral).

(Remove the arrows at the ankle)

The knee at initial contact is in a straightened position with 0 degrees of either flexion or extension. (Draw lines over the video to indicate that the knee is in a straight position)

(Remove the arrows at the knee)

At initial contact, the hip will be in a position of about 20 degrees of flexion as the limb is outstretched for the next step. (Draw lines over the video to indicate that the hip is at 20 degrees of flexion--the lines will be a vertical dashed line towards the floor and along the femur. Put in an angle indicator)

(Restart the video through a several more gait cycles with initial contact phase in slow motion as the following is read)

Here is the entire gait cycle once again with the Initial Contact phase shown in slow motion.

(Fade out)

VIDEO 3: LOADING RESPONSE
(Text at the beginning of the video on black background)

OBSERVATIONAL GAIT ANALYSIS – LOADING RESPONSE

(New screen-Entire video should have LOADING RESPONSE in the upper left hand corner to identify which video they are watching. Have the video run through at least one full gait cycle and then have the loading response phase in slow motion--from heel contact until the foot is flat on the floor--as the following is read)

This video will focus on the loading response, which is the second phase of gait. It begins immediately after the heel contacts the ground. During this phase, the foot is lowered to the ground and the weight of the body is transferred to this forward leg.

(As the following is read, freeze the video at the moment the foot becomes flat on the ground).

Once the foot is flat on the ground, the ankle joint should be in approximately 5 degrees of plantarflexion (draw lines to indicate that the ankle is at approximately 5 degrees of plantarflexion using a dashed line to show the 0 degree (neutral) position and the bottom of the foot. Add an angle marker and label it as 5 degrees).

(Remove the arrows at the ankle).
The knee should in a position of approximately 15 degrees of flexion to help provide shock absorption during loading response. (Draw lines over the video to indicate that the knee is now in a position of 15 degrees of flexion--include a dashed line to show where 0 degrees would be and an angle indicator)

(Remove the arrows at the knee).

The hip remains at 20 degrees of flexion relative to a vertical line. (Draw lines over the video to indicate that the hip is at 20 degrees of flexion--the lines will be a vertical dashed line towards the floor and along the femur. Put in an angle indicator)

(Restart the video through a several more gait cycles with the loading response phase in slow motion as the following is read)

Here is the entire gait cycle once again with the Loading Response phase shown in slow motion.

(Fade out)

VIDEO 4: MID STANCE

(Text at the beginning of the video on black background)

OBSERVATIONAL GAIT ANALYSIS – MID STANCE

(New screen-Entire video should have MID STANCE in the upper left hand corner to identify which video they are watching. Have the video run through at least one full gait cycle and then have the mid stance phase in slow motion - from foot flat until the foot is directly under the body --as the following is read)

This video will focus on mid stance, which is the third phase of gait. Mid stance is when the body moves forward over the leg that is planted on the ground. It is essential that the leg can support the weight of the body as the tibia is moving forward over the foot.

(As the following is read, freeze the video at the moment the foot is under the body or just behind it).

The ankle moves from the plantarflexed position of loading response to 5 degrees of dorsiflexion as the tibia moves forward. (Draw lines to indicate that the ankle is at approximately 5 degrees of dorsiflexion using a dashed line to show the 0 degree (neutral) position and the bottom of the foot. Add an angle marker and label it as 5 degrees).

(Remove the arrows at the ankle).

The knee should move to a position of approximately 5 degrees of flexion to provide shock absorption. (Draw lines over the video to indicate that the knee is now in a position of 5 degrees of flexion--include a dashed line to show where 0 degrees would be and an angle indicator)

(Remove the arrows at the knee).
The hip moves from the flexed position of loading response to a more vertical or neutral position as the body moves over the planted foot. (*Draw arrow to show the direction of movement*)

(*Restart the video through several more gait cycles with the mid stance phase in slow motion as the following is read*)

Here is the entire gait cycle once again with the mid stance phase shown in slow motion

(*Fade out*)

**VIDEO 5: TERMINAL STANCE**

(*Text at the beginning of the video on black background*)

**OBSERVATIONAL GAIT ANALYSIS – TERMINAL STANCE**

(*New screen-Entire video should have TERMINAL STANCE in the upper left hand corner to identify which video they are watching. Have the video run through at least one full gait cycle and then have the Terminal Stance phase in slow motion -- from mid stance to just before the heel rises --as the following is read*)

This video will focus on terminal stance, which is the fourth phase of the gait cycle. Terminal stance is when the body moves forward past the forefoot and the heel prepares to rise off of the ground. As in mid-stance, you can see the tibia continue to move forward over the planted foot, until it reaches a maximum of 10 degrees of ankle dorsiflexion at the end of terminal stance. This dorsiflexion can be seen as the tibia sitting forward of a vertical line through the ankle. (*Freeze the video at the moment the heel is just about to start to rise. Draw lines to indicate that the ankle is in approximately 10 degrees of dorsiflexion using a dashed line to show the 0 degree (neutral) parallel to the bottom of the foot and another dashed line showing the vertical position. Add an angle marker between the vertical line and the tibia and label it as 10 degrees—something similar is shown below).*

![10° Dorsiflexion](image)

(*Remove the arrows at the ankle)*

The knee remains in about 5 degrees of flexion from mid stance through terminal stance. (*Draw lines over the video to indicate that the knee is in a position of 5 degrees of flexion--include a dashed line to show where 0 degrees would be and an angle indicator)*. (*Remove the arrows at the knee)*
The hip moves from the neutral position found in mid stance towards a maximum of 20 degrees of extension relative to a vertical line. (Draw lines over the video to indicate that the hip is at 20 degrees—the lines will be a vertical dashed line towards the floor and along the femur. Put in an angle indicator).

( Restart the video through several more gait cycles with the terminal stance phase in slow motion as the following is read).

Here is the entire gait cycle once again with the terminal stance phase shown in slow motion.

(Fade out)

**VIDEO 6: PRE-SWING**

(Text at the beginning of the video on black background)

**OBSERVATIONAL GAIT ANALYSIS – PRE-SWING**

(New screen-Entire video should have PRE-SWING in the upper left hand corner to identify which video they are watching. Have the video run through at least one full gait cycle and then have the pre-swing phase in slow motion -- from heel rise to just before toe off --as the following is read).

This video will focus on pre-swing, which is the fifth phase of the gait cycle. During the pre-swing phase, the heel rises and the knee flexes while the forefoot remains on the ground. The heel rise and knee flexion are caused by the forward momentum of the body as the weight is transferred to the other foot.

(As the following is read, freeze the video at the moment just before the forefoot lifts off the ground).

As the heel rises off the floor, the ankle reaches a maximum position of approximately 15 degrees of plantarflexion. (Draw lines to indicate that the ankle is in approximately 15 degrees of plantarflexion—something similar is shown below).

(Remove the arrows at the ankle).
The knee flexes to about 40 degrees during Pre-Swing in preparation for the swing phase. (*Draw lines over the video to indicate that the knee is in a position of 40 degrees of flexion--include a dashed line to show where 0 degrees would be and an angle indicator*).

(*Remove the arrows at the knee*).

The hip begins to move forward during pre-swing to a position of about 10 degrees of extension relative to a vertical line. (*Draw lines over the video to indicate that the hip is at 10 degrees—the lines will be a vertical dashed line towards the floor and along the femur. Put in an angle indicator*).

(*Restart the video through several more gait cycles with the pre-swing phase in slow motion as the following is read*).

Here is the entire gait cycle once again with the pre-swing phase shown in slow motion.

(*Fade out*)

**VIDEO 7: INITIAL SWING**

(*Text at the beginning of the video on black background*)

OBSERVATIONAL GAIT ANALYSIS – INITIAL SWING

(*New screen-Entire video should have INITIAL SWING in the upper left hand corner to identify which video they are watching. Have the video run through at least one full gait cycle and then have the initial swing phase in slow motion -- from toe off to about 15 degrees of hip flexion --as the following is read*)

This video will focus on initial swing, the sixth phase of the gait cycle. During the initial swing phase, the hip flexes forward and the knee continues to bend, causing the foot to come off of the ground.

(*As the following is read, freeze the video at the moment when the hip is flexed to approximately 15 degrees*)

As the foot is lifted from the ground to begin the step forward, the ankle moves to a position of approximately 5 degrees of plantarflexion. (*Draw lines to indicate that the ankle is in approximately 5 degrees of plantarflexion—something similar is shown below*).
(Remove the arrows at the ankle).

The knee flexes to 60 degrees during the initial swing phase. (Draw lines over the video to indicate that the knee is in a position of 60 degrees of flexion--include a dashed line to show where 0 degrees would be and an angle indicator)

(Remove the arrows at the knee).

During the initial swing phase, the hip moves from an extended position to approximately 15 degrees of flexion. (Draw lines over the video to indicate that the hip is at 15 degrees of flexion— the lines will be a vertical dashed line towards the floor and along the femur. Put in an angle indicator).

(Restart the video through several more gait cycles with the initial swing phase in slow motion as the following is read).

Here is the entire gait cycle once again with the initial swing phase in slow motion.

(Fade out)

VIDEO 8: MID-SWING

(Text at the beginning of the video on black background)

OBSERVATIONAL GAIT ANALYSIS – MID SWING

(New screen-Entire video should have MID-SWING in the upper left hand corner to identify which video they are watching. Have the video run through at least one full gait cycle and then have the mid swing phase in slow motion -- from about 15 degrees of hip flexion to 25 degrees of hip flexion --as the following is read).

This video will focus on mid-swing, the seventh phase of the gait cycle. During the mid-swing phase, the hip continues to flex forward, and the knee now begins to extend toward a straightened position.

(As the following is read, freeze the video at the moment when the hip becomes flexed to 25 degrees and the knee is flexed about 25 degrees).

As the leg progresses forward, the ankle is positioned in a neutral position of 0 degrees of either dorsiflexion or plantarflexion (Draw lines to indicate that the ankle is in a neutral position).

(Remove the arrows at the ankle).

The knee begins to extend or straighten and moves from 60 degrees of flexion to a position of approximately 25 degrees of flexion at the end of the mid swing phase. (Draw lines over the video to indicate that the knee is in a position of 25 degrees of flexion--include a dashed line to show where 0 degrees would be and an angle indicator).

(Remove the arrows at the knee).
During the mid-swing phase, the hip continues to flex forward to a position of 25 degree of flexion. (Draw lines over the video to indicate that the hip is at 25 degrees of flexion—the lines will be a vertical dashed line towards the floor and along the femur. Put in an angle indicator).

(Restart the video through several more gait cycles with the mid swing phase in slow motion as the following is read).

Here is the entire gait cycle once again with the mid-swing phase shown in slow motion.

(Fade out)

**VIDEO 9: TERMINAL SWING**

(Text at the beginning of the video on black background)

**OBSERVATIONAL GAIT ANALYSIS – TERMINAL SWING**

(New screen-Entire video should have TERMINAL SWING in the upper left hand corner to identify which video they are watching. Have the video run through at least one full gait cycle and then have the terminal swing phase in slow motion -- from mid swing position to knee extended position—as the following is read).

This video will focus on terminal swing, the final phase of the gait cycle. During the terminal swing phase, the hip remains flexed as the knee straightens out to prepare to take the next step.

(As the following is read, freeze the video at the moment when the hip is flexed to about 20 degrees and the knee is fully extended).

As the leg finishes its forward progression, the ankle is positioned in neutral with 0 degrees of either dorsiflexion or plantarflexion to prepare for the next initial contact phase (Draw lines to indicate that the ankle is in a neutral position.)

(Remove the arrows at the ankle).

The knee continues to straighten until it reaches a fully extended position at 0 degrees. (Draw lines over the video to indicate that the knee is in a position of 0 degrees of flexion).

(Remove the arrows at the knee).

At terminal swing phase, the hip assumes a position of approximately 20 degrees of flexion. (Draw lines over the video to indicate that the hip is at 20 degrees of flexion—the lines will be a vertical dashed line towards the floor and along the femur. Put in an angle indicator).

(Restart the video through several more gait cycles with the terminal swing phase in slow motion as the following is read).

Here is the entire gait cycle once again with the terminal swing phase shown in slow motion.

(Fade out)
VIDEO 10: COMPLETE GAIT CYCLE SUMMARY

(Observational Gait Analysis: Complete Gait Cycle)

The previous videos described the ideal range of motion requirements during each of the 8 phases of the gait cycle. This video will now combine these phases into one complete gait cycle while reviewing the ideal range of motion present during each phase at the hip, knee, and ankle.

The gait cycle begins with Initial Contact as the foot hits the ground. During initial contact, the ankle joint should be in a neutral position with 0 degrees of either dorsiflexion or plantarflexion, the knee is in a straightened position, and the hip is flexed to approximately 20 degrees.

Following initial contact, the foot is lowered to the ground and the weight of the body is transferred to this forward leg during the loading response phase. Once the foot is flat on the ground, the ankle joint should be in approximately 5 degrees of plantarflexion, the knee will be flexed to approximately 15 degrees, and the hip remains at 20 degrees of flexion relative to a vertical line.

Once the foot is on the ground, the body moves forward over this planted foot during the mid-stance phase. As a result, the ankle moves from the plantarflexed position of loading response to 5 degrees of dorsiflexion, the knee moves to a position of approximately 5 degrees of flexion, and the hip moves from a flexed position to a more vertical or neutral position.

Terminal stance is when the body moves forward past the forefoot and the heel prepares to rise off of the ground. As in mid-stance, you can see the tibia continue to move forward over the planted foot. The ankle reaches a maximum of 10 degrees of ankle dorsiflexion at the end of terminal stance, the knee remains in about 5 degrees of flexion, and the hip moves from the neutral position found in mid stance towards a maximum of 20 degrees of extension.
The pre-swing phase is characterized by the heel rising from the floor and the knee beginning to flex. (*Freeze the video at the moment just before the forefoot lifts off the ground and write PRE-SWING under the stick figure*). As the heel rises off the floor, the ankle reaches a maximum position of approximately 15 degrees of plantarflexion, the knee flexes to about 40 degrees in preparation to swing forward, and the hip begins to move forward to about 10 degrees of extension.

(*Restart the video, without the pre-swing words on the screen*).

Initial swing phase begins when the foot is lifted from the ground. During this phase, the hip continues to flex forward and the knee continues to bend to allow the foot to clear the floor as it swings forwards.

(*As the following is read, freeze the video at the moment when the hip is flexed to approximately 15 degrees and write INITIAL SWING under the stick figure*). As the foot is lifted from the ground, the ankle moves to a position of approximately 5 degrees of plantarflexion, the knee flexes to 60 degrees, and the hip moves from an extended position to approximately 15 degrees of flexion.

(*Restart the video, without the initial swing words on the screen.*)

The focus will now be on mid swing, the seventh phase of the gait cycle. During the mid swing phase, the hip continues to flex forward, and the knee begins to extend toward a straightened position.

(*As the following is read, freeze the video at the moment when the hip becomes flexed to 25 degrees and the knee is flexed about 25 degree and write MID SWING under the stick figure*). As the leg progresses forward, the ankle is positioned in a neutral position, the knee begins to straighten, and moves to a position of approximately 25 degrees of flexion, and the hip moves forward to a position of 25 degree of flexion.

(*Restart the video, without the mid swing words on the screen.*)

The final phase of the gait cycle is terminal swing. During the terminal swing phase, the hip remains flexed as the knee straightens out to prepare to take the next step. (*Freeze the video at the moment when the hip is flexed to about 20 degrees and the knee is fully extended and write TERMINAL SWING under the stick figure*). The ankle is positioned in neutral with 0 degrees of either dorsiflexion, the knee continues to straighten until it reaches a fully extended position, and the hip assumes a position of approximately 20 degrees of flexion.

(*Restart the video, without the terminal swing words on the screen and play the stick figure walking while the following is read*).

These tutorial videos demonstrated the ideal range of motion during the gait cycle at the hip, knee and ankle during each of the 8 phases of gait. An understanding of the typical or ideal ROM requirements for each phase of the gait cycle is a crucial step in learning observational gait analysis. These videos may viewed as many times as you like prior to taking the posttest.
APPENDIX B

INTERACTING ELEMENTS TUTORIAL SCRIPTS

VIDEO 1: INTRODUCTION

(Have this text on the screen as you read this paragraph)

This gait tutorial was developed to improve your ability to analyze walking gait. Observational gait analysis requires you to understand ideal gait and be able to identify when deviations from the ideal occur. The focus of the tutorial will be on recognizing the ideal joint positions of the hip, knee, and ankle during each of the phases of a gait cycle. These phases include:

1) Initial contact
2) Loading response
3) Mid Stance
4) Terminal stance
5) Pre-swing
6) Initial swing
7) Mid Swing
8) Terminal Swing

NEXT SCREEN

(Have a video of the stick figure walking while you read the following)

The tutorial consists of videos of a stick figure walking. A gait cycle is defined as the time from right heel contact to the next right heel contact (As this is read, use a cue to show right heel contact to right heel contact). For each phase of gait, slow motion and freeze frames will be used to highlight the portion of the gait cycle that is being discussed.

The instruction will focus on the right leg only and it has been drawn in red for ease in viewing. You will not be able to stop or rewind the video once it has been started, but you may go back and repeat the video if you wish. You will be asked occasionally to stop and answer two brief questions regarding your mental effort and the difficulty of the materials.

VIDEO 2: INTERACTING ELEMENTS – ALL COMPONENTS

(Text at the beginning of the video on black background)

OBSERVATIONAL GAIT ANALYSIS

(Then add in the following words below it)

INITIAL CONTACT
The first phase of the gait cycle is Initial Contact, which is being shown in slow motion at this time. Initial contact marks the beginning of the gait cycle as the foot hits the ground. (Freeze the video at heel contact while you read this).

During initial contact, it is critical that the heel makes the first contact with the ground rather than other parts of the foot. The ankle joint should be in a neutral position with 0 degrees of either dorsiflexion or plantarflexion and it appears to be at a 90 degree angle. (Draw lines over the video to indicate that the ankle is at neutral).

The knee at initial contact is in a straightened position with 0 degrees of either flexion or extension. (Draw lines over the video to indicate that the knee is in a straight position).

At initial contact, the hip will be in a position of about 20 degrees of flexion as the limb is outstretched for the next step. (Draw lines over the video to indicate that the hip is at 20 degrees of flexion--the lines will be a vertical dashed line towards the floor and along the femur. Put in an angle indicator).

Here is the entire gait cycle once again with the initial contact phase shown in slow motion. 

Loading response, which is being shown in slow motion now, is the second phase of gait. It begins immediately after the heel contacts the ground. During this phase, the foot is lowered to the ground and the weight of the body is transferred to this forward leg. (As the following is read, freeze the video at the moment the foot becomes flat on the ground).

Once the foot is flat on the ground, the ankle joint should be in approximately 5 degrees of plantarflexion. (Draw lines to indicate that the ankle is at approximately 5 degrees of plantarflexion using a dashed line to show the 0 degree (neutral) position and the bottom of the foot. Add an angle marker and label it as 5 degrees).
(Remove the arrows at the ankle).

The knee should in a position of approximately 15 degrees of flexion to help provide shock absorption during loading response. (Draw lines over the video to indicate that the knee is now in a position of 15 degrees of flexion--include a dashed line to show where 0 degrees would be and an angle indicator).

(Remove the arrows at the knee)

The hip remains at 20 degrees of flexion relative to a vertical line. (Draw lines over the video to indicate that the hip is at 20 degrees of flexion--the lines will be a vertical dashed line towards the floor and along the femur. Put in an angle indicator).

(Restart the video through several more gait cycles with the loading response phase in slow motion as the following is read).

Here is the entire gait cycle once again with the loading response phase shown in slow motion.

(Fade out)

(Fade back in with this text on black background)

OBSERVATIONAL GAIT ANALYSIS: MID STANCE

(New screen-Entire video should have MID STANCE in the upper left hand corner to identify which video they are watching. Have the video run through at least one full gait cycle and then have the mid stance phase in slow motion--from foot flat until the foot is directly under the body--as the following is read).

The third phase of gait is mid stance and is being shown in slow motion at this time. Mid stance is when the body moves forward over the leg that is planted on the ground. It is essential that the leg can support the weight of the body as the tibia is moving forward over the foot.

(As the following is read, freeze the video at the moment the foot is under the body or just behind it).

The ankle moves from the plantarflexed position of loading response to 5 degrees of dorsiflexion as the tibia moves forward. (Draw lines to indicate that the ankle is at approximately 5 degrees of dorsiflexion using a dashed line to show the 0 degree (neutral) position and the bottom of the foot. Add an angle marker and label it as 5 degrees).

(Remove the arrows at the ankle).

The knee should move to a position of approximately 5 degrees of flexion to provide shock absorption. (Draw lines over the video to indicate that the knee is now in a position of 5 degrees of flexion--include a dashed line to show where 0 degrees would be and an angle indicator).

(Remove the arrows at the knee)
The hip moves from the flexed position of loading response to a more vertical or neutral position as the body moves over the planted foot. (Draw arrow to show the direction of movement.)

(Restart the video through several more gait cycles with the mid stance phase in slow motion as the following is read).

Here is the entire gait cycle with the mid stance phase shown in slow motion.

(Fade out)

(Fade back in with this text on black background)

OBSERVATIONAL GAIT ANALYSIS – TERMINAL STANCE

(New screen-Entire video should have TERMINAL STANCE in the upper left hand corner to identify which video they are watching. Have the video run through at least one full gait cycle and then have the terminal stance phase in slow motion -- from mid stance to just before the heel rises --as the following is read).

This portion will focus on terminal stance, which is the fourth phase of the gait cycle, and is being shown in slow motion at this time. Terminal stance is when the body moves forward past the forefoot and the heel prepares to rise off of the ground. As in mid-stance, you can see the tibia continue to move forward over the planted foot, until it reaches a maximum of 10 degrees of ankle dorsiflexion at the end of terminal stance. This dorsiflexion can be seen as the tibia sitting forward of a vertical line through the ankle. (Freeze the video at the moment the heel is just about to start to rise. Draw lines to indicate that the ankle is in approximately 10 degrees of dorsiflexion using a dashed line to show the 0 degree (neutral) parallel to the bottom of the foot and another dashed line showing the vertical position. Add an angle marker between the vertical line and the tibia and label it as 10 degrees—something similar is shown below).

(10° Dorsiflexion)

(Remove the arrows at the ankle).

The knee remains in about 5 degrees of flexion from mid stance through terminal stance. (Draw lines over the video to indicate that the knee is in a position of 5 degrees of flexion--include a dashed line to show where 0 degrees would be and an angle indicator).

(Remove the arrows at the knee).

The hip moves from the neutral position found in mid stance towards a maximum of 20 degrees of extension relative to a vertical line. (Draw lines over the video to indicate that the hip is at 20
degrees—the lines will be a vertical dashed line towards the floor and along the femur. Put in an angle indicator)

(Restart the video through several more gait cycles with the terminal stance phase in slow motion as the following is read).

Here is the entire gait cycle again with the terminal stance phase in slow motion.

(Fade out)

(Fade back in with this text at the beginning of the video on black background)

OBSERVATIONAL GAIT ANALYSIS – PRE-SWING

(New screen-Entire video should have PRE-SWING in the upper left hand corner to identify which video they are watching. Have the video run through at least one full gait cycle and then have the pre-swing phase in slow motion -- from heel rise to just before toe off --as the following is read).

The fifth phase of the gait cycle is pre-swing and is being shown in slow motion now. During the pre-swing phase, the heel rises and the knee flexes while the forefoot remains on the ground. The heel rise and knee flexion are caused by the forward momentum of the body as the weight is transferred to the other foot.

(As the following is read, freeze the video at the moment just before the forefoot lifts off the ground).

As the heel rises off the floor, the ankle reaches a maximum position of approximately 15 degrees of plantarflexion. (Draw lines to indicate that the ankle is in approximately 15 degrees of plantarflexion—something similar is shown below).

(Remove the arrows at the ankle).

The knee flexes to about 40 degrees during Pre-Swing in preparation for the swing phase. (Draw lines over the video to indicate that the knee is in a position of 40 degrees of flexion--include a dashed line to show where 0 degrees would be and an angle indicator).

(Remove the arrows at the knee).
The hip begins to move forward during pre-swing to a position of about 10 degrees of extension relative to a vertical line. **(Draw lines over the video to indicate that the hip is at 10 degrees—the lines will be a vertical dashed line towards the floor and along the femur. Put in an angle indicator).**

**(Restart the video through a few more of the pre-swing cycles in slow motion as the following is read)** Here is the entire gait cycle once again with the pre-swing phase shown in slow motion.

**(Fade out)**

**(Fade back in with this text on black background)**

OBSERVATIONAL GAIT ANALYSIS – INITIAL SWING

**(New screen-Entire video should have INITIAL SWING in the upper left hand corner to identify which video they are watching. Have the video run through at least one full gait cycle and then have the initial swing phase in slow motion -- from toe off to about 15 degrees of hip flexion --as the following is read).**

Initial swing is the next phase of the gait cycle and is being shown in slow motion now. During the initial swing phase, the hip flexes forward and the knee continues to bend, causing the foot to come off of the ground.

**(As the following is read, freeze the video at the moment when the hip is flexed to approximately 15 degrees).**

As the foot is lifted from the ground to begin the step forward, the ankle moves to a position of approximately 5 degrees of plantarflexion. **(Draw lines to indicate that the ankle is in approximately 5 degrees of plantarflexion—something similar is shown below).**

**(Remove the arrows at the ankle).**

The knee flexes to 60 degrees during the initial swing phase. **(Draw lines over the video to indicate that the knee is in a position of 60 degrees of flexion--include a dashed line to show where 0 degrees would be and an angle indicator).**

**(Remove the arrows at the knee).**
During the initial swing phase, the hip moves from an extended position to approximately 15 degrees of flexion. (Draw lines over the video to indicate that the hip is at 15 degrees of flexion— the lines will be a vertical dashed line towards the floor and along the femur. Put in an angle indicator).

(Restart the video through several more gait cycles with the initial swing phase in slow motion as the following is read).

Here is the entire gait cycle once again with the initial swing phase shown in slow motion.

(Fade out)

(Fade back in with this text on black background)

OBSERVATIONAL GAIT ANALYSIS – MID SWING

(New screen-Entire video should have MID-SWING in the upper left hand corner to identify which video they are watching. Have the video run through at least one full gait cycle and then have the mid swing phase in slow motion -- from about 15 degrees of hip flexion to 25 degrees of hip flexion --as the following is read).

The focus will now be on mid swing, the seventh phase of the gait cycle. During the mid-swing phase, the hip continues to flex forward, and the knee now begins to extend back toward a straightened position.

(As the following is read, freeze the video at the moment when the hip becomes flexed to 25 degrees and the knee is flexed about 25 degrees).

As the leg progresses forward, the ankle is positioned in a neutral position of 0 degrees of either dorsiflexion or plantarflexion. (Draw lines to indicate that the ankle is in a neutral position).

(Remove the arrows at the ankle)

The knee begins to extend or straighten and moves from 60 degrees of flexion to a position of approximately 25 degrees of flexion at the end of the mid swing phase. (Draw lines over the video to indicate that the knee is in a position of 25 degrees of flexion--include a dashed line to show where 0 degrees would be and an angle indicator).

(Remove the mid-swings at the knee).

During the mid-swing phase, the hip continues to flex forward to a position of 25 degree of flexion. (Draw lines over the video to indicate that the hip is at 25 degrees of flexion— the lines will be a vertical dashed line towards the floor and along the femur. Put in an angle indicator).

(Restart the video through several more gait cycles with the mid-swing phase in slow motion as the following is read).

Here is the entire gait cycle with the mid swing phase shown in slow motion.

(Fade out)
OBSERVATIONAL GAIT ANALYSIS – TERMINAL SWING

This video will focus on terminal swing, the final phase of the gait cycle. During the terminal swing phase, the hip remains flexed as the knee straightens out to prepare to take the next step.

As the leg finishes its forward progression, the ankle is positioned in neutral with 0 degrees of either dorsiflexion or plantarflexion to prepare for the next initial contact phase. Draw lines to indicate that the ankle is in a neutral position.

The knee continues to straighten until it reaches a fully extended position at 0 degrees. Draw lines over the video to indicate that the knee is in a position of 0 degrees of flexion.

At terminal swing phase, the hip assumes a position of approximately 20 degrees of flexion. Draw lines over the video to indicate that the hip is at 20 degrees of flexion— the lines will be a vertical dashed line towards the floor and along the femur. Put in an angle indicator.

Here is the entire gait cycle once again with the terminal swing phase shown in slow motion.

This tutorial video demonstrated the ideal range of motion during the gait cycle at the hip, knee and ankle at each of the 8 phases of gait. An understanding of the typical or ideal range of motion requirements for each phase of the gait cycle is a crucial step in learning observational gait analysis. This video may be viewed as many times as you like prior to taking the posttest.

VIDEO 3: COMPLETE GAIT CYCLE SUMMARY

This tutorial video demonstrated the ideal range of motion during the gait cycle at the hip, knee and ankle at each of the 8 phases of gait. An understanding of the typical or ideal range of motion requirements for each phase of the gait cycle is a crucial step in learning observational gait analysis. This video may be viewed as many times as you like prior to taking the posttest.
The previous videos described the ideal range of motion requirements during each of the 8 phases of the gait cycle. This video will now combine these phases into one complete gait cycle while reviewing the ideal range of motion present during each phase at the hip, knee, and ankle.

The gait cycle begins with Initial Contact as the foot hits the ground. (Freeze the video at heel contact while you read this and write INITIAL CONTACT under the stick figure). During initial contact, the ankle joint should be in a neutral position with 0 degrees of either dorsiflexion or plantarflexion, the knee is in a straightened position, and the hip is flexed to approximately 20 degrees.

Following initial contact, the foot is lowered to the ground and the weight of the body is transferred to this forward leg during the loading response phase. (As the following is read, freeze the video at the moment the foot becomes flat on the ground and write LOADING RESPONSE under the stick figure). Once the foot is flat on the ground, the ankle joint should be in approximately 5 degrees of plantarflexion, the knee will be flexed to approximately 15 degrees, and the hip remains at 20 degrees of flexion relative to a vertical line.

Once the foot is on the ground, the body moves forward over this planted foot during the mid-stance phase. (As the following is read, freeze the video at the moment the foot is under the body or just behind it and write MID STANCE under the stick figure). As a result, the ankle moves from the plantarflexed position of loading response to 5 degrees of dorsiflexion, the knee moves to a position of approximately 5 degrees of flexion, and the hip moves from a flexed position to a more vertical or neutral position.

Terminal stance is when the body moves forward past the forefoot and the heel prepares to rise off of the ground. As in mid-stance, you can see the tibia continue to move forward over the planted foot. (Freeze the video at the moment the heel is just about to start to rise and write TERMINAL STANCE under the stick figure). The ankle reaches a maximum of 10 degrees of ankle dorsiflexion at the end of terminal stance, the knee remains in about 5 degrees of flexion, and the hip moves from the neutral position found in mid stance towards a maximum of 20 degrees of extension.

The pre-swing phase is characterized by the heel rising from the floor and the knee beginning to flex. (Freeze the video at the moment just before the forefoot lifts off the ground and write PRE-SWING under the stick figure). As the heel rises off the floor, the ankle reaches a maximum position of approximately 15 degrees of plantarflexion, the knee flexes to about 40 degrees in preparation to swing forward, and the hip begins to move forward to about 10 degrees of extension.
(Restart the video, without the pre-swing words on the screen)

Initial swing phase begins when the foot is lifted from the ground. During this phase, the hip continues to flex forward and the knee continues to bend to allow the foot to clear the floor as it swings forwards.

(As the following is read, freeze the video at the moment when the hip is flexed to approximately 15 degrees and write INITIAL SWING under the stick figure). As the foot is lifted from the ground, the ankle moves to a position of approximately 5 degrees of plantarflexion, the knee flexes to 60 degrees, and the hip moves from an extended position to approximately 15 degrees of flexion.

(Restart the video, without the initial swing words on the screen.).

The focus will now be on mid swing, the seventh phase of the gait cycle. During the mid swing phase, the hip continues to flex forward, and the knee begins to extend toward a straightened position.

(As the following is read, freeze the video at the moment when the hip becomes flexed to 25 degrees and the knee is flexed about 25 degrees and write MID SWING under the stick figure). As the leg progresses forward, the ankle is positioned in a neutral position, the knee begins to straighten, and moves to a position of approximately 25 degrees of flexion, and the hip moves forward to a position of 25 degree of flexion.

(Restart the video, without the mid swing words on the screen).

The final phase of the gait cycle is terminal swing. During the terminal swing phase, the hip remains flexed as the knee straightens out to prepare to take the next step. (Freeze the video at the moment when the hip is flexed to about 20 degrees and the knee is fully extended and write TERMINAL SWING under the stick figure). The ankle is positioned in neutral with 0 degrees of either dorsiflexion, the knee continues to straighten until it reaches a fully extended position, and the hip assumes a position of approximately 20 degrees of flexion.

(Restart the video, without the terminal swing words on the screen and play the stick figure walking while the following is read).

These tutorial videos demonstrated the ideal range of motion during the gait cycle at the hip, knee and ankle during each of the 8 phases of gait. An understanding of the typical or ideal ROM requirements for each phase of the gait cycle is a crucial step in learning observational gait analysis. These videos may viewed as many times as you like prior to taking the posttest.
### APPENDIX C

**SCORING DATA**

Table 9:

*Summary of the Data Used to Create the Answer Key for the Pretest, Posttest, and Follow-up Tests*

<table>
<thead>
<tr>
<th>PRETEST QUESTION #s</th>
<th>POSTTEST QUESTION #s</th>
<th>FOLLOW-UP QUESTION #s</th>
<th>JOINT</th>
<th>SUB-PHASE</th>
<th>ROM SHOWN IN TUTORIAL (IN DEGREES)</th>
<th>IDEAL ROM (IN DEGREES)</th>
<th>IDEAL/NOT IDEAL (DIFF)</th>
<th>DIRECTION OF DEVIATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>12,15, 108-2, 112-2</td>
<td>12, 15</td>
<td>hip</td>
<td>initial contact</td>
<td>10</td>
<td>20</td>
<td>not ideal (10)</td>
<td>increased extension</td>
<td></td>
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<td>24,26, 116-2, 120-2</td>
<td>24, 26</td>
<td>knee</td>
<td>initial swing</td>
<td>64</td>
<td>60</td>
<td>ideal</td>
<td></td>
<td></td>
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<td>29,31, 132-2, 136-2</td>
<td>29, 31</td>
<td>ankle</td>
<td>mid stance</td>
<td>6</td>
<td>5</td>
<td>ideal</td>
<td></td>
<td></td>
</tr>
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<td>34,36, 140-2, 142-2</td>
<td>34, 36</td>
<td>hip</td>
<td>terminal stance</td>
<td>-8</td>
<td>-20</td>
<td>not ideal (12)</td>
<td>increased flexion</td>
<td></td>
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<tr>
<td>39,41, 148-2, 150-2</td>
<td>38, 41</td>
<td>ankle</td>
<td>mid stance</td>
<td>13</td>
<td>5</td>
<td>not ideal (8)</td>
<td>increased dorsiflexion</td>
<td></td>
</tr>
<tr>
<td>44,46, 164, 166</td>
<td>44, 46</td>
<td>ankle</td>
<td>initial contact</td>
<td>-7</td>
<td>0</td>
<td>not ideal (7)</td>
<td>increased plantarflexion</td>
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<td>49,51, 172, 174</td>
<td>49, 51</td>
<td>knee</td>
<td>terminal stance</td>
<td>8</td>
<td>5</td>
<td>ideal</td>
<td></td>
<td></td>
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<td>54-2, 56-2</td>
<td>knee</td>
<td>loading response</td>
<td>12</td>
<td>15</td>
<td>ideal</td>
<td></td>
<td></td>
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<td>54-1, 56-1</td>
<td>hip</td>
<td>initial contact</td>
<td>10</td>
<td>20</td>
<td>not ideal (10)</td>
<td>increased extension</td>
<td></td>
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<td>66,69, 104, 106</td>
<td>66, 69</td>
<td>hip</td>
<td>pre-swing</td>
<td>-6</td>
<td>-5</td>
<td>ideal</td>
<td></td>
<td></td>
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<td>72,74, 120, 122</td>
<td>72, 74</td>
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<td>terminal stance</td>
<td>-3</td>
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<td>not ideal (8)</td>
<td>increased extension</td>
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<td>mid swing</td>
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<td>0</td>
<td>ideal</td>
<td></td>
<td></td>
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<td>82,84, 136, 138</td>
<td>82, 84</td>
<td>ankle</td>
<td>initial contact</td>
<td>0</td>
<td>0</td>
<td>ideal</td>
<td></td>
<td></td>
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<tr>
<td>87,89, 152, 154</td>
<td>87, 89</td>
<td>hip</td>
<td>terminal stance</td>
<td>6</td>
<td>-20</td>
<td>not ideal (14)</td>
<td>increased flexion</td>
<td></td>
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<td>95,97, 124-2, 126-2</td>
<td>95, 97</td>
<td>ankle</td>
<td>mid swing</td>
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<td>0</td>
<td>not ideal (21)</td>
<td>increased dorsiflexion</td>
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<tr>
<td>101,103, 156-2, 158-2</td>
<td>101, 103</td>
<td>knee</td>
<td>mid stance</td>
<td>31*</td>
<td>5</td>
<td>not ideal (26)</td>
<td>increased flexion</td>
<td></td>
</tr>
<tr>
<td>106,108, 112, 114</td>
<td>106, 108</td>
<td>hip</td>
<td>terminal stance</td>
<td>13*</td>
<td>-20</td>
<td>not ideal (33)</td>
<td>increased flexion</td>
<td></td>
</tr>
<tr>
<td>111, 113, 144, 146</td>
<td>111, 113</td>
<td>ankle</td>
<td>mid stance</td>
<td>11*</td>
<td>5</td>
<td>not ideal (6)</td>
<td>increased dorsiflexion</td>
<td></td>
</tr>
</tbody>
</table>

*Note: * = video recording in clinic setting rather than animated stick figure
### APPENDIX D

#### ITEM ANALYSIS

Table 10: *Item Difficulty and Item-Total Correlations for Gait Assessment Items at Pretest, Posttest, and Follow-up Tests*

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Item Difficulty (Item-Total Correlation)</th>
<th>Mean Item Difficulty</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest</td>
<td>Posttest</td>
</tr>
<tr>
<td>During initial contact, the right hip joint position is:</td>
<td>56.9% (0.36)</td>
<td>98.6% (0.06)</td>
</tr>
<tr>
<td>During initial swing, the right knee joint position is:</td>
<td>51.4% (0.48)</td>
<td>63.4% (0.19)</td>
</tr>
<tr>
<td>During mid swing, the right ankle joint position is:</td>
<td>88.9% (-0.03)</td>
<td>50.7% (0.35)</td>
</tr>
<tr>
<td>During mid stance, the right ankle joint position is:</td>
<td>86.1% (0.29)</td>
<td>47.9% (0.29)</td>
</tr>
<tr>
<td>During terminal stance, the right hip joint position is:</td>
<td>66.7% (0.03)</td>
<td>94.4% (0.16)</td>
</tr>
<tr>
<td>During mid stance, the right ankle joint position is:</td>
<td>65.3% (0.01)</td>
<td>47.9% (0.29)</td>
</tr>
<tr>
<td>During mid stance, the right knee joint position is:</td>
<td>93.1% (0.22)</td>
<td>87.3% (0.24)</td>
</tr>
<tr>
<td>During initial contact, the right ankle joint position is:</td>
<td>95.8% (0.17)</td>
<td>50.7% (0.16)</td>
</tr>
<tr>
<td>During terminal stance, the right knee joint position is:</td>
<td>59.7% (0.28)</td>
<td>69% (0.27)</td>
</tr>
<tr>
<td>During loading response, the right knee joint position is:</td>
<td>18.1% (0.13)</td>
<td>50.7% (0.46)</td>
</tr>
<tr>
<td>During initial contact, the right hip joint position is:</td>
<td>6.9% (0.16)</td>
<td>98.6% (0.06)</td>
</tr>
<tr>
<td>During pre-swing, the right hip joint position is:</td>
<td>66.7% (0.19)</td>
<td>74.6% (0.31)</td>
</tr>
<tr>
<td>During terminal stance, the right hip joint position is:</td>
<td>90.3% (0.2)</td>
<td>94.4% (0.16)</td>
</tr>
<tr>
<td>During terminal stance, the right knee joint position is:</td>
<td>36.1% (0.27)</td>
<td>69% (0.27)</td>
</tr>
<tr>
<td>During mid swing, the right ankle joint position is:</td>
<td>43.1% (0.11)</td>
<td>50.7% (0.35)</td>
</tr>
<tr>
<td>During initial contact, the right ankle joint position is:</td>
<td>54.2% (0.19)</td>
<td>50.7% (0.16)</td>
</tr>
<tr>
<td>During mid stance, the right ankle joint position is:</td>
<td>47.2% (0.34)</td>
<td>47.9% (0.29)</td>
</tr>
<tr>
<td>At terminal stance, the right hip joint position is:</td>
<td>87.5% (-0.05)</td>
<td>91.5% (0.12)</td>
</tr>
</tbody>
</table>
REFERENCES


