The Brain Is For Action: Embodiment, Causality, and Conceptual Learning with Video Games to Improve Reading Comprehension and Scientific Problem Solving

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Dedication

This dissertation is dedicated to you mom and dad.
Abstract

This experiment compares children’s comprehension and problem solving with the same information presented in three different media formats: an embodied video game, a first-person video, and a print narrative. The embodied video game emphasizes interaction and causation, where the player moves the narrative forward by causing change through interaction. According to embodiment theorists, the ability to create knowledge is predicated upon the ability to identify and connect changes, and what causes change in events. Comprehension is measured in this study with the Event-Indexing Model, (EIM). Research on the EIM indicates that identification of causation is often highly correlated to identification of other elements of comprehension, including memory of time, space, objects, and intentions across events. This experiment examines whether media format, which emphasizes embodied interaction and identification of causation, improves comprehension and problem solving. In question 1, this experiment examines whether the embodied video game will lead to superior comprehension and problem solving outcomes compared to the same information presented in a video or a printed text. Question 2 compares comprehension and problem solving when the reading text condition follows playing the game and watching the video. The third question examines the role of causation, which is the ability to identify actions that create changes between narrative events in a text. This dissertation analyzes comprehension and problem outcomes across media: as an embodied video game, a video, or a printed text. Additionally, it examines reading performance across presentation order, and the importance of identification in situation model construction.
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CHAPTER I.

Introduction: The Brain is For Action

This experiment was conducted to compare the quality of comprehension between three media formats—a video game, video, and printed text. It was predicted that an embodied video game would provide better comprehension outcomes compared to viewing information in a video, and reading information from a printed text. The central assumption made was that a media format that emphasized embodied experience would improve the ability to create a mental representation. It is predicted that the physical and mental rehearsal required to play the embodied video game will be more memorable than watching a video, or reading a printed text of the same content. This prediction is based upon a synthesis of research on comprehension and problem solving from cognitive science, discourse-processing psychology, and embodiment research on perceptual processing. Five decades of discourse processing psychology research supports the position that the comprehension process involves the construction of a mental representation as a microworld of an event, or series of events, constructed from memory and experience. This creation of a mental microworld is called a situation model. When a learner can successfully construct a situation model, the learner will have improved recall of goals, space, objects, goals and intentions, and time. Research from embodiment theorists has shown that perceptual knowledge plays a significant role in the creation of a situation model, and thus, comprehension and problem solving. This improved situation model construction should lead to improved academic performance. Research in working
memory has also shown that the ability to comprehend and problem solve is dependent
upon the recency, frequency, and congruent context of prior knowledge. By holding prior
knowledge constant, this experiment should indicate if learners should construct a more
robust situation model from an embodied learning experience like the Tony Hawk RIDE
video game, as measured by classroom assessment activities such as solving a word
problem, multiple-choice questions from the National Assessment of Educational
Progress (NAEP) framework, and a protocol analysis as the construction of a
walkthrough document.

Games have been used in formal classroom settings dating back to Freidrich
Fröbel, who constructed and integrated learning toys and games at the Play and Activity
Institute in 1837 (for further reading, see Fröbel, 2010; or von Marenholtz-Bülow &
Peabody Mann, 2007). In the last five years, more interest has emerged regarding the use
of video games in the classroom (Gee, 2003). Although games have been embraced
through the centuries for education, they are now advocated for primarily by New
Literacies Researchers. However, because skill sets identified in New Literacies research
have not been validated by analysis with perception, memory, and cognitive processing,
no clear link has yet been made with learning transfer for traditional academic
performance. This experiment examines this question of transfer, through an examination
of whether game play may lead to improved comprehension and scientific problem
solving in traditional academic assessment.

Activities such as video game play are considered similar to reading by New
Literacies researchers. New Literacies researchers view reading skills and comprehension
as being constructed in the same way, and look at comprehension as a process of production and interpretation. Thus, comprehension can be achieved with knowledge gained through traditional texts, multimodal texts such as games, television, radio, and even clothing. For New Literacies researchers, all texts are forms of expression, and thus a form of cultural communication (for review, see O’Brien & Dubbels, 2009). By this logic, multimodal texts should be comprehended with the same cognitive processes as traditional academic texts. However, at this point in time, there has been no empirically validated evidence to link New Literacies activities, such as the play and study of video games, to traditional notions of comprehension and problem solving.

Similarly, traditional approaches to instruction have the same problem with internal validity. Although traditional approaches to reading instruction have been shown to have a causal link, such as between spelling and reading (Perfetti, 1989), this link is not a measure of comprehension, and thus lacks internal validity for a causal connection. Empirically researched interventions such as spelling, phonemic awareness, and memorization do not get at the core of what comprehension is, and rather focus on processes abstracted from, but related to comprehension. It is more likely these processes are part of the comprehension process, but not comprehension itself.

The problem with both traditional and New Literacies approaches is that they focus on behaviors and surface-level skills, rather than the cognitive processes of comprehension that underlying them, i.e. perception, processing, and memory. Without basing comprehension and assessment on empirically validated models of memory and processing, the measurement and evaluation of comprehension are questionable. Without a model of perception, memory, and processing, the skills identified for activities and
interventions provide corollaries, and cannot provide a causal link. This creates issues of construct validity, and creates questions about the internal validity in the measures, and provides no causal relationship necessary to evaluate and link both the traditional and new literacies approaches to comprehension.

This dissertation examines the process theorized by embodiment researchers for the transformation of perceptual knowledge into conceptual knowledge. They propose that comprehension and problem solving is a higher order process between incoming perceptual information and prior knowledge to create a mental representation, or situation model. In order to measure comprehension, and provide a description of a situation model, the event-indexing model is used (Zwaan, Langston, & Graesser, 1995; Zwaan & Radvanski, 1998). This model has been developed over four decades of research, and has been reviewed as a valid and reliable measure of comprehension. In order to understand how conceptual knowledge and comprehension are constructed, it is necessary to understand the change of environmental information from a perceptual level and how it becomes conceptual knowledge. Embodiment theory attempts to account for the how and why instruction through multimodal texts may lead to improved comprehension and problem solving. Embodiment theory provides a hypothesis for how perceptual knowledge is involved in the construction, organization, and recall of conceptual knowledge.

This dissertation examines children’s comprehension outcomes with an empirically validated model of comprehension and problem solving, comparing multimodal learning as an embodied video game with reading a printed text, and viewing a video. Discourse processing research on comprehension, through the event-indexing
model combines with embodiment research in this dissertation to examine the potential of multimodal instruction for comprehension and problem solving. Research on instruction that emphasizes congruent sensorimotor experience and visualization has been found to improve the ability to comprehend, read fluently, and solve problems (Glenberg, Brown & Levin, 2007; Glenberg, Gutierrez, Levin, & Japuntich, 2004). In this dissertation I propose that embodied pre-teaching activities such as the video game used in this study, may provide the learner with improved ability to create a situation model and solve related problems.
Statement Of The Research Problem

Comprehension is essential for learning from texts and problem solving. However, emphasis in reading instruction has focused primarily on basic skills related to comprehension. The Reading Excellence Act (1998), brought attention to the need for better reading instruction, but many of the interventions recently advocated by the National Reading Panel’s report of the subgroups for comprehension (National Reading Panel Report, 2000, http://www.nichd.nih.gov/publications/nrp/upload/ch4-II.pdf), emphasized little in comprehension. These reports included few studies on improving comprehension as compared to the numerous studies presented in Chapter 2, which emphasized two subgroup reports on decoding and phonics skills.

An issue of contention regarding the National Reading Panel’s report was that it did not include research from socio-cultural approaches such as multimodal learning and new literacies and is focused instead on processes abstracted from comprehension which are often presented as drill and practice. This is also true for previous what works reports:

- *Learning to Read: The Great Debate* (Chall, 1967);
- *Becoming a Nation of Readers: The Report of the Commission on Reading* (Anderson, Hiebert, Scott, & Wilkinson, 1985);
- *Beginning to Read: Thinking and Learning about Print* (Adams, 1990);
- *Preventing Reading Difficulties in Young Children* (Snow, Burns, & Griffin, 1998, online document).
**Reading is thinking cued by text.**

Almost a century ago, educational psychologists perpetuated the idea that *reading is thinking* (Thorndike, 1917). Although this originated from the empiricist tradition, it also resonates with the socio-cultural approaches of *New Literacies* research. The discourse processing has previously explored and validated this axiom to an extent—that *reading is thinking*—through constructionist/interactionist models (Bransford, Barclay & Frank, 1972; Goodman, 1967; Kintsch & van Dijk, 1978; Piaget, 1969; Rumelhart, 1977; Stanovich, 1980). Although these cognitive researchers lacked the basis for explaining how concepts were developed from perception, they created a foundation for what has been learned about comprehension over the last thirty years. Recently, researchers and theorists have found that comprehension may depend upon perception and the ability to identify action, and potential action; that comprehension and problem solving may depend upon sensorimotor memory, or modal symbol systems—that is, perceptual symbols that are memory networks of perceptual knowledge (Barsalou, 1999; Glenberg, 1997; Glenberg & Robertson, 1999; Zwaan, 1999).

Embodiment Theorists suggest that comprehension entails establishing a relationship between the text and the reader’s background knowledge for the development of conceptual knowledge. This position is known as the *Indexical Hypothesis* (Glenberg, 2004). Additionally, the ability to index prior knowledge as working memory is dependent upon the context, recency, and frequency the child experienced the information (for a review, read Barsalou, 1993). These experiences are mediated between long-term memory, perception, and working memory. This is important for researchers
and educators to know, as the traditional approach to reading instruction is often based upon memorization and amodal instruction, where symbols, words, and syntax are emphasized, and often presented in ways that require memorization and repetition, ungrounded in perception and experience.

For Embodiment theorists (Barsalou, 1999; Glenberg, 1997; Glenberg & Robertson, 1999; Zwaan, 1999), knowledge and memory are grounded in perceptual experience, and perceptual symbols are activated in higher-order cognitive processes like comprehension and problem solving. A perceptual symbol is a network of connected memory information from prior sensorimotor experience. When a concept, such as chair, is activated, prior sensorimotor memories related to chair are activated. These memories work collectively to form a situation model, and work as a perceptual simulation. In essence, a child thinking about chair, may build a mental representation constructed of memory from prior experience, and experience it second-hand as a perceptual simulation. Additionally, the more recent, frequent, and congruent the prior knowledge is with the information to be comprehended, the more likely the child will construct this perceptual simulation and comprehend quickly, accurately, and with coherence as a situation model. Embodiment theorists Glenberg & Robertson (1999) suggest that perceptual symbols are necessary in reading to facilitate the construction of a situation model. This agrees with Zwaan (1999), who argues that amodal and modal systems may not be mutually exclusive; readers may use both types of representation in reading comprehension.
Purpose Of Study

This dissertation examines the role of sensorimotor experience for comprehension outcomes and the ability to problem solve. It is proposed that learning from an embodied video game will be more effective than viewing the same content in a video, or reading about it in a print narrative. Embodiment theory states that prior sensorimotor experience is central to memory and comprehension—that recency, frequency, and context congruence of prior experience will improve comprehension and problem solving when designed in relation to learning objectives. To test this position, this study uses an empirically validated model of comprehension called the event-indexing model to assess comprehension outcomes from a narrative presented as an embodied video game, a video, and a printed text.

Research Questions

1. Will a video game that emphasizes sensorimotor experience provide greater comprehension and problem solving as compared to viewing a video, or reading a printed text?

2. Will performance in the reading condition improve if it follows the game or the viewing condition?

3. How does the identification of causation predict comprehension?
Statement of the Hypothesis

$H_{o1}$: There is no statistically significant difference in recall and problem solving in playing the video game as compared to viewing a video, or reading a printed text as measured by comparing the five dimensions of mental representation from the event indexing model in a walkthrough, as a causal network; through fifteen multiple-choice inventories from the NAEP cognitive target framework; and a STEM word problem adopted from middle school curriculum.

$H_{o2}$: There is no statistically significant difference in the reading condition across treatment order improve as measured by comparing the five dimensions of mental representation from the event-indexing model in a walkthrough, as a causal network; through fifteen multiple-choice inventories from the NAEP cognitive target framework; and a STEM word problem adopted from middle school curriculum.

$H_{o3}$: There is no statistically significant difference in how identification causation predicts building a mental representation as measured by comparing the five dimensions of mental representation from the event-indexing model in the walkthrough, as a causal network.
Definition of Terms

- **Embodiment**: The role of the sensorimotor system, including perceptual modalities such as touch, vision, sound, taste, smell, and motor action such as movement.
- **Comprehension**: The active construction of meaning through the creation of a mental representation.
- **Event Indexing**: Act of monitoring specific dimensions specified by the Event-Indexing Model: Time, space, characters, goals, and causation, across different events.
- **Indexical Hypothesis**: Comprehension may break down when new information is not mapped to prior-experience in long-term memory.
- **Walkthrough**: A map with congruent narrative used to describe multiple routes through a process, usually emphasizing the optimal route.
- **Word problem**: A mathematics/science exercise presented in the form of a hypothetical situation that requires an equation to be solved.
- **NAEP cognitive targets**: Mental processes or kinds of thinking that underlie reading comprehension, as defined by the 2009 Framework Committee of NAEP. The targets are described as: Locate and Recall: When locating or recalling information from what they have read, students may identify explicitly stated main ideas or may focus on specific elements of a story; Integrate and Interpret: When integrating and interpreting what they have read, students may make comparisons, explain character motivation, or examine relations of ideas
across the text. * The third cognitive target was not implemented: Critique and Evaluate.

- **Causation**: the demonstration of how one variable influences (or the effect of a variable) another variable or other variables. When one variable does have an effect on another, you can say that you have “causation.”

- **Sensorimotor System**: pertaining to both sensory and motor nerve functions.

- **Modal**: Having to do with the sensorimotor system.

Scope and Limitations

This experiment was conducted to compare the quality of comprehension between three media formats. It was predicted that an embodied activity, the video game, would provide better comprehension outcomes compared to viewing information in a video, and reading information from a printed text if prior knowledge of content were held constant for recency, frequency, and congruence of context.

The central assumption made was that a media format that emphasized embodied experience, would improve the ability to create a mental representation. When a learner can successfully construct a situation model, the learner will have improved recall of goals, space, objects, and time, and consequently improved performance on the word problem and multiple-choice questions from the NAEP framework.

Students who participated in the study came from the sixth, seventh, and eighth grades at an urban, midwestern middle school, and whose primary language was not
English, and qualified for free and reduced lunch. These students were sampled from students invited for summer school for remediation. One of the primary recommendations for summer school was MCA2 standardized test scores. The majority of students were categorized as ESOL, and scored in the first cut score: does not meet expectations, however there were students from all cut score categories.

In order to control for cognitive ability, measures were taken for visual and auditory working memory, which has been empirically identified as predictive of comprehension. In addition, students were inventoried for prior knowledge of the science and content knowledge, along with media preference.

**Assumptions of the Study**

The experiment was grounded on the following assumptions:

- There was accurate administration, scoring and reporting for all instruments used as outcome measures and independent variables for statistical analyses.
- The data obtained represented each student’s best effort on the measures
- The participants in the study were a representative sample of students who had been identified as in need of reading remediation.
- The instructions and descriptions of the tasks were presented to the students in the same manner.
Chapter II.

REVIEW OF RELATED LITERATURE

Introduction

The first chapter provided a theoretical framework, stated the purpose, the research questions, the hypothesis, definition of terms, limitations and assumptions, and an explanation of the purpose and significance of the study. Chapter two contains a review of relevant literature and research that addresses the construction of a mental representation as it relates to embodied activities, contributions from the perception and action modalities—the sensorimotor system—towards performance in comprehension and problem solving. The review begins with a brief introduction of New Literacies research. This is done to introduce the practice of using multimodal texts such as video games in the classroom. It is also done to introduce the difficulty, and importance of identifying a causal relationship between this example of New Literacies instruction and traditional standardized assessment. The review indicates that both new and traditional literacies have a skill focus rather than a process focus. What is meant by a skill focus is that the action is observable, but has not been reduced to a cognitive process. A process focus is what discourse processing psychology and embodiment theorists have identified as a cognitive process responsible for the observed skills. This is resolved by conducting analysis using an established model of comprehension and information processing from discourse processing and embodiment research.
The theoretical position examined in this study is:

No matter what medium information is presented with, the brain is dependent upon, and utilizes the sensorimotor system to gather perceptual information; and, that the sensorimotor system uses this gathered information as memory, and contributes to comprehension through the construction of a situation model.

Underneath many of the skills identified in new and traditional literacies, comprehension and problem solving have empirically validated processes. This position is supported by decades of work in discourse psychology, embodiment research, and cognitive psychology. This review describes the importance of memory and processing in choosing a model for comprehension, problem solving, assessment, measurement, and evaluation. This is described in relation to the indexical hypothesis, which serves as a bridge between sensorimotor learning and the comprehension process. The connection between perceptual learning and conceptual learning is proposed, and then applied to socio-cultural/constructivist instructional practice to provide a basis for empirical validation.

New and Traditional Literacies

The research often included in “what works” research reports, as described in the problem statement, have historically focused on skills that are capable of predicting future success in learning to read traditional academic texts. However, the nature of the
research in these reports places isolated skills on a pedestal, emphasizing the practice of
skills like spelling and phonological awareness as instructional priorities. This presents a
problem for the learner and the teacher. Skills-based practice can be repetitive and
boring, and kids who struggle are often given more and more repetition without
grounding new concepts in experience; often providing the learning of abstractions,
rather than concepts grounded in action. This approach emphasizes amodal learning, and
“The instructional task is not to 'kill' motivation by demanding drill, but to find tasks that
provide practice while at the same time sustaining interest.” Motivation and engagement
are benefits of a New Literacies approach, which is aligned activating prior knowledge as
literacies, and engaging and sustaining student interest.

The difficulty with many new literacies approaches is that they may not integrate
and emphasize skills from the What Works research to create necessary transfer between
a New Literacies learning experience, and a traditional academic evaluation. Both
approaches should be utilized for instruction. Traditional evaluation should be used to
test whether the student has crystallized reasoning patterns and descriptions of complex
objects and their qualities into concepts, such as scientific terminology. Traditional
assessment draws from a student’s crystallized conceptual knowledge and tests whether
the learner has chunked the skills, qualities, and relations into a term so that the student
can use concept in reasoning and create transfer between learning from texts.
New literacies.

New Literacies approaches in the classroom are often predicated upon media for communication (New London Group, 1996), and are currently associated with the digital turn (for a review see Mills, 2010). The digital turn places emphasis on how communications are now digitally mediated, and how members of society are producing and processing text. Although there is much similarity and cohesion in methods and theory in New Literacies research, there are two distinct orientations, Socially Distributed Practices, and Social & Cognitive Language Skills.

Socially distributed practices.

The socially distributed practices approach emphasizes literacy as a social practice. This approach is also thought of as “critical literacy” (Gee, Hull, & Lankshear, 1996; Luke, 2000), and for researchers like Lankshear & Knobel (2006), New Literacies refers to digitally mediated communication, with screens rather than paper pages, and social, highly collaborative interaction as participatory culture (Jenkins, 2006), with critical analysis of culture, power, and message.

In this sense, new literacies refer to emergent, socially mediated ways of generating and negotiating meaningful content through communications encoded specifically from within a group. This group communication has a style, or exhibits a pattern of Discourse. Discourse is presented here with a capital “D” to denote the collective pattern of many voices from a cultural group, a term known as Heteroglossia, to form a cultural collective voice (Bakhtin, 1934). The Social Practice/Critical Literacy researchers encourage the analysis of Discourse based upon literary interpretation and Marxist analysis of culture and power.
The aspects of voice in *Discourse* are identified through semiotic domains, (De Saussure, 1959; Bakhtin, 1981; 1986; Gee, 2001) which are identified as symbolic examples of communication such as vocabulary, clothing, activities, accent, etc. The capital “D” discourse is a cultural style of communication specific to collective group behavior in-context, and how members of groups use a variety of means for expression. What is important for *Social Practice/Critical Literacies* researchers is directing instruction to draw from, and examine, the collective voices of cultural groups to develop critical thinking and empowerment.

**Social & cognitive language skills.**

The *Social & Cognitive Language Skills* theorists touch upon issues of critical cultural analysis, but rather than focusing on the social practice—the interpretation of the different symbol systems, their meanings and context—the *Social & Cognitive Language Skills* theorists focus on the social and cognitive skills, strategies, and dispositions that inform practice in comprehension (for a review see: Leu, Kinzer, Coiro, Cammack, 2004; Leu, Zawilinski, Castek, Banerjee, Housand, Liu, & O’Neil; 2007; O’Brien & Dubbels, 2009).

According to the *Social & Cognitive Language Skills* researchers, language and new digital communications technologies change and evolve quickly. This process is labeled deictic, which means that these processes change continuously, due to the rapidity of changing social media and communications (Leu, 2001; Leu, Kinzer, Coiro, & Cammack, 2004; Coiro, 2003; Coiro & Dobler, 2007)—in the view of New Literacies researchers, too quickly to plan and conduct empirical studies for causal links between New Literacies instruction and standardized testing.
Collectively, both groups of *New Literacies* researchers have stated that traditional approaches to assessment and evaluation of comprehension are not aligned with 21st Century skills, and are thus, not relevant; these tests fail to capture that complex dynamic nature of adapting and using a changing medium and language (Luke, 2008; O’Brien & Dubbels, 2009). However, although the skills and behaviors are constantly changing with new communication styles and media, comprehension, and the cognitive processes that inform it, have remained constant. We still use our sensory modalities to gather and project information, and we still use the same cognitive processes. This continuity may provide an important link between traditional measures of reading, problem solving, and comprehension and *New Literacies*. What is common between the traditional and *New Literacies* is the focus on skills.

**New Literacies and traditional assessment.**

As was stated earlier in this section, the research often included in *What Works* research reports have focused on skills that are capable of predicting future success in reading academic text. However, these reports put isolated skills on a pedestal, establishing practice interventions in spelling and phonological awareness as priorities. This presents a problem for learner and teacher. Skills-based practice can be boring, and kids who struggle are often given more and more skills in drills. According to Anderson, Reder, and Simon, (2000) “The instructional task is not to 'kill' motivation by demanding drill, but to find tasks that provide practice while at the same time sustaining interest.” Motivation and engagement are benefits of a new literacies approach, which is more aligned with student interest.
The difficulty with many new literacies approaches is that they may not integrate and emphasize skills from the “what works” research to create necessary transfer between a new literacies learning experience, and a traditional academic evaluation. Both approaches should be utilized for instruction. Traditional evaluation should be used to test whether the student has crystallized reasoning patterns and complex objects and qualities that have been experienced into concepts, such as scientific terminology. Traditional assessment draws from a student’s crystallized conceptual knowledge and tests whether the learner has chunked the skills, qualities, and relations into a term so that the student can use concept in reasoning and create transfer between learning from texts. There is good reason to promote traditional instructional goals, content, and assessment.

New Literacies provide high interest instructional frameworks for activities to embed traditional academic concepts and skills. The goal is to make the learning engaging, to make the child question and construct views that can be shared and tested in Communities of Practice (Wenger, 1996) and Affinity Groups (Gee, 2001) to increase self-efficacy and Self-Determination (Ryan and Deci, 1985; 2008).

**New Literacies and Discourse Processing.**

According to the Discourse Processing tradition, a field of specialization in psychology that studies memory and processing language in comprehension, the subprocesses of comprehension—perception, action, and cognition process—are fairly stable and predictable across media formats, and comprehension can be measured in all manner of communication artifact or construction based upon the sensory modalities for communication (van den Broek, Kendeou, Kremer, Lynch, Butler, White, & Lorch, 2005).
This is important because the skills, social practices, and language systems identified in new literacies are engaging, as children like to participate in their peer-group culture, and become motivated to engage (Dubbels, 2008). These practices may provide the sustained engagement over time necessary for skill acquisition and some level of mastery. This allows for student ownership of learning while providing criteria for academics. Although this creates some complexity in assessment, there are many texts that surround new literacies instruction, called *paratexts* (Apperly & Beavis, 2011). A paratext can also be a traditional assessment, a walkthrough for a video game, a transcript of group communications, or set of rules or instructions that accompany an activity. Paratexts represent the social practice and the outcome of a process. Paratexts are both the texts and the surrounding materials that frame their consumption, shape the readers’ experience of a text and give meaning to the act of reading. Paratexts can be evaluated for comprehension, just as tests can be evaluated for comprehension.

This dissertation proposes that the same underlying brain functions and structures participate in both approaches. However, there is currently a lack of grounding—for both traditional and new literacies—in scientific research in memory, action, perception, and processing. This lack of grounding can lead to concerns of validity and reliability, as well as replicability and transfer.

The value of grounding instructional measures in a validated research model is that a common valid and reliable measure is provided. If a child participates in a New Literacies activity, the cognitive processes used should be similar to traditional literacies based upon using a human brain, and a human sensorimotor system—there should be transfer if assessment and evaluation are based upon what we know about how the brain
processes information. This is contingent upon recency, frequency, and congruent context for learning (for a review, read Barsalou, 2003). If a child lacks prior experience form the world and/or with the medium, they will struggle to comprehend and problem solve (Goldman, Graesser, & van den Broek, 1999; Zwann, Langston, & Graesser, 1995; Zwann & Radavansky, 1998).

**What Works And Instruction**

Embodiment research has indicated that the sensorimotor system is important for learning assessment and instruction. However, current classroom reading instruction and assessment are often designed around research from *What Works* reports. The reports recommend skills and actions that focus on sub-processes of reading, often excluding the necessary construction of content knowledge and comprehension through hands-on-experience. This kind of instruction is common because action and perception areas of the brain have been typically viewed as non-essential for reading comprehension. However, it is through perceptual knowledge that we create conceptual knowledge. If a child has no experience or understanding with a concept, no amount of practice with phonics, spelling, or fluency are going to help. This is important for educational stakeholders to understand. This is especially true in the regard to the reading interventions that come from *What Works* reports on reading and comprehension.

*What Works* reports recommend research that is abstracted from the comprehension process, such as phonological processing, fluency, symbol recognition, spelling, etc. Although these processes are important for reading and comprehension, they are not comprehension. According to Kintsch & Kintsch (2004), phonological processing, spelling, and writing are all sub processes that inform comprehension, and it
is these sub processes that are often emphasized in instruction. Although these skills are important for reading, prior knowledge is more important. Without prior knowledge, there is no memory with which to link these new skills. As an example, if a child is asked to spell or sound-out an unfamiliar word, and if, perhaps, they have no prior experience with what the word represents, they will have no meaning with which to connect, and construct conceptual knowledge.

The reading interventions from What Works reports provide few interventions to help children with developing conceptual knowledge in the academic content areas. This is likely due to new research, and a limited understanding of how the sensorimotor system is active in comprehension and problem solving. Without prior knowledge, children are memorizing words and definitions, which are not grounded in first-hand experience. As an example, often children are asked to memorize a term as a concept, i.e., children are asked to memorize such concepts as acceleration. So the children are often taught using analogies, such as fast and slow. With this method, children may only guess at their meanings. Children may view a clip, or listen to an example, and are asked to commit the concept to memory. This is not practical based upon what is known about comprehension. Learning concepts not grounded in prior experience can lead to issues of comprehension and transfer. Often after learning a concept through memorization, children have difficulty with transfer.

We depend upon action and perception systems to make sense of the world. We chunk these experiences into conceptual categories, abstracting information until an idea is crystallized. To comprehend, a child must create the concept, which can take more time than learning to sound out the word with phonics instruction, i.e., just imagine
sounding-out the word *obtuse*, and then trying to explain the word. It is much more likely that a child will quickly comprehend a concept when they have prior experience, as compared to when they can decode and fluently express it orally.

This instructional practice comes from research predicated upon the *AAA Model* of cognition. The *AAA Model* means: Arbitrary, Amodal, and Abstract. It refers to how memory is organized and activated for comprehension and reasoning. It is assumed that information is structured through logic and syntax, but this does not account for semantic relations necessary for comprehension. The *AAA Model* comes from theoretical linguistics and cognitive science research, and is based upon syntax, logic, and computer models. It presents a possible obstacle to children who have not been exposed to a range or depth of experience. When children do not come from a childhood full of rich developmental experiences, they may suffer as instruction becomes more abstract and predicated on reading, listening, and watching to learn.

**The AAA Model of Learning and Instruction**

Academic content like Science, Literature, and Mathematics are often taught using simple symbols representing quantities, concepts, and qualities. In Mathematics, children are asked to use symbols in abstracted conceptual processes and functions such as *logs, sine, cosine*, and even simple ideas like *addition, multiplication, ratios, and division*. This is also true for Language Arts, where students are taught such conceptual patterns as plot with constituent parts: *introduction, rising action, conflict, climax, falling action, and denouement*. Often children have traditionally been taught through lecture, drills and skills with worksheets, or reading to learn. This instructional method has been
reinforced through a history of practice and research, but success of lecture or reading assignments depend upon the learner having prior knowledge to link to the new concepts.

For a time, computers were considered similar to brains. Computers were like brains, and thus brains were treated like computers. The problem with this analogy is that you cannot just reprogram a person. This analogy was popular when little was known about the brain. Computers are programmed. They do not learn from perception and action like living creatures. So much of the early research on learning was based upon computer models of the brain were programmed with memory processing, organization, and location were Arbitrary in location and connection, unrelated to sensory and action modalities—Amodal, and not connected to any grounded experience from learning—Abstract. These models were derived from logic and transformational grammar.

The AAA Model treats language as a symbol manipulation system, where language conveys meaning by using abstract, amodal, and arbitrary symbols (i.e., words) combined by syntactic rules (e.g., Burgess & Lund, 1997; Chomsky, 1980; Fodor, 2000; Kintsch, 1998; Pinker, 1994). This approach has led to decades of research on learning, assessment, and instruction. However, it does not account for how environmental information, in the form of things we experience and perceive, are crystallized into concepts such as *run, accelerate, and abruptly stop.*

The AAA model promotes the view that comprehension and reasoning are syntax-driven, which leads to erroneous assumptions about learning. Systems of syntax and symbols are not just programmed into the mind like a computer—although this view has been very popular over the last sixty years and began with Shannon (1948) and Turing (1950) stating that the brain is like a computer. Similarly, educational approaches to
comprehension have been oriented towards symbol memorization, such as phonics instruction and conceptual learning through memorization of definitions espoused in print-text mediums.

**The Role of Prior Knowledge**

Prior knowledge is the best predictor of the ability to comprehend and problem solve (Goldman, Graesser, & van den Broek, 1999; Zwann, Langston, & Graesser, 1995; Zwann & Radavansky, 1998). *The Event Indexing-Model* (Graesser, Millis, & Zwaan, 1997; Kintsch, 1998; Zwaan & Radvansky, 1998) provides a robust description of how prior knowledge interacts with new information. It is essential that assessment and evaluation be grounded in research about how learning happens in the brain. The combination of Embodiment Theory research and research from Discourse Processing psychology provide a clear and coherent model for how information from texts and actions become learned conceptual information. The importance of this is so that when instruction and learning evaluation are planned, there is a coherent and valid model for measuring comprehension, so that the key measures are not biased through culture-specific content . . . such as testing kids from the city on content about farming. It is not only important to understand the importance of prior knowledge, and how some tests will be biased towards cultural experience, but also to design testing and instruction with awareness of knowledge acquisition through cognitive processing, memory, and the role of the sensorimotor system. By using an empirically validated model, it is possible to examine which kinds of media experiences promote the greatest construction of prior knowledge, which is then accessed for recall and problem solving.
Additionally, Embodiment theory provides a description that describes how the brain encodes actions and perceptual experience into conceptual knowledge and symbols that eventually become conceptual knowledge, from perceptual knowledge. According to embodiment researchers, the sensorimotor system, which is responsible for perception and action, is also active in creating mental representation. The brain uses the sensorimotor system as a simulation of actual experience . . . *we visualize with our eyes closed, what we might wish to see with our eyes.* This phenomenon is known as a perceptual simulation, where the sensorimotor system keeps memories of prior experience as perceptual symbol systems, which are active during, recall, construction, and organization of memory. When studies have investigated the comprehension, contributions from the perceptual system, or *perceptual traces,* were identified (Fischer & Zwaan, 2008; Richardson, Spivey, Barsalou, & McRae, 2003; Wu & Barsalou, 2003; Zwaan et al., 2003, 2004), meaning that the way that we take in environmental information is simulated when we retrieve and review memory, i.e., the same brain areas are active in seeing and remembering an event.

This dissertation examines the differences in comprehension problem solving when information is presented through an embodied video game, a video, and a printed narrative with the same content. By integrating theoretical models of comprehension and the sub processes of comprehension, such as how perceptual information is transformed into conceptual information, measures of comprehension and problem solving will avoid the test bias from testing cultural knowledge such as language and prior experience.
Discourse Processing Psychology

As was described in earlier sections of this dissertation, both traditional and new literacies instruction depend upon the ability to mentally represent textual information as a situation model. A situation model is a mental representation—a mental microworld of the text constructed in the mind’s eye. It is widely accepted in discourse psychology that readers construct situation models as they attempt to comprehend text (Graesser, Millis, & Zwaan, 1997; Kintsch, 1998; Zwaan & Radvansky, 1998). In a situation model, the reader visualizes the microworld represented in the text. A situation model is a composite of characters’ actions or the obstacles they face as events in the narrative. These goals and obstacles may be conflicts between characters, methods of resolving conflicts, orientation, and even emotional reactions to the events and conflicts. In order for successful comprehension, time, motivation, and prior knowledge are necessary to create a situation model.

Adults can construct situation models with relative ease for narrative texts. This is because situation models have a close correspondence to everyday experiences. In contrast, it is more difficult to construct a situation model from informational texts, such as an expository text in a science. If given a test item on a concept such as acceleration, a successful reader would be able to construct a mental model. If the question is on the acceleration of a skateboard, they should be able to create a situation model of the components of the text, causal chains, and processes that compose it, along with the scientific concept so they can visualize and make an informed answer. However, this is
very difficult or impossible when the reader has little prior world knowledge to furnish the content needed to construct the mental model.

Discourse psychologists also widely acknowledge that an explicit text does not sufficiently constrain or determine what information is constructed in a situation model. Constraints are important, as they limit the range of possibilities, i.e., chair as compared to lawn chair – lawn chair, being more constrained in a range of possibilities.

With this view, comprehension can be viewed as a complex function or mechanism that considers Representation, Text, Reader, and Goal interactions. Prominent examples of these cognitive models in discourse psychology include the construction integration model (Kintsch, 1988, 1998; Schmalhofer, McDaniel, Keefe, 2002; Singer & Kintsch, 2001), the constructionist theory (Graesser, Singer, & Trabasso, 1994; Singer, Graesser, & Trabasso, 1994), the structure building framework (Gernsbacher, 1997), the event indexing model (Zwaan, Langston, & Graesser, 1995; Zwaan & Radvansky, 1998), memory-based resonance models (Lorch, 1998; O’Brien, Rizzella, Albrecht, & Halleran, 1998), and the landscape model (van den Broek, Everson, Virtue, Sung, & Tzeng, 2002).

**Situation models and the event-indexing model.**

The Event-Indexing Model is used here because it provides a broad framework grounded in empirical studies for understanding the comprehension process. This framework integrates and builds upon many of the discoveries of previous models for cognitive processing in comprehension, and also provides an accessible model for designing instruction around. The Event-Indexing Model accounts for prior knowledge and long-term memory, and the construction of new conceptual categories and content.
The model also accounts for issues in different levels of problem solving, and makes a clear connection to sensorimotor processing and conceptual processing.

The strength of the model has been the ability to link incoming information with prior memory across the dimensions of mental representation called a *Situation Model*. The term, *Situation Model*, was introduced by Kintsch & van Dijk (1978), which offered a departure from current comprehension research—moving the study of comprehension from research of descriptive systems, to process models, which are characterized by rich experimental and theoretical frameworks. Although these models have revealed much about memory, reasoning, processing, and perception, most instructional models are not guided by this research, but are rather still predicated upon descriptive, and culturally driven comprehension frameworks such as observable skills in both new literacies and traditional literacies.

*The Event-Indexing Model* represents a point of validation, provides a predictive model of memory, processing, and construction of new knowledge. This is important for instruction and assessment. The model offers clear connection to classroom instruction and assessment for reading comprehension and academic concepts in Language Arts and English Literature. The Event Indexing Model is important because the five levels identified in the event indexing model (Zwaan, Langston, & Graesser, 1995; Zwaan, Magliano, & Graesser, 1995; Zwaan & Radvansky, 1998) offer an empirically validated framework for different levels of analysis for reading, reasoning, and comprehension:

1. Surface, or Text-Decoding Level—where the letters, symbols, words, and sentences are processed into sounds and meaning. This includes the exact wording and grammar of the sentences.
2. Propositional Level—where concepts represented in the surface level group into propositions. The meaning of the verbs and nouns as clauses that are explicitly mentioned in the text. Concepts group into propositions, the smallest units of communication. Propositions in turn group into statements, statements into paragraphs, paragraphs into sections. This process continues until finally one arrives at the entire discourse.

3. Situation Model Level—this is the mental representation level. The ideas or microworld of what the text is about. Inferences based on world knowledge are needed to construct the mental model; that is, the meaning in the mental model goes beyond the explicit text. Information is represented as a situational framework, linking events as: temporality, spatiality, character/objects, intentionality, and causality,

4. Genre Level—textual characteristics and criteria that indicate a format, structure, and content in the composition of how information is organized for meaning in communication. The category of the text. The major genre categories are narrative, expository, persuasive, and descriptive texts, but some texts are combinations of these basic categories. Each genre has its own rhetorical structure.

5. Author Communication Level—Specific stylistic elements that indicate a specific voice in communication. This level describes the act of communication between the reader and writer, or narrator and audience. Such acts of communication normally require a global theme, message,
point, or purpose in writing the text. The ground rules for the communication differ among the various genres, such as arguments, tutoring sessions, jokes, and newspaper articles. A text is coherent when there are connections, overlap, and continuity of textual elements within levels and between levels.

When readers comprehend text, they mentally build meaning representations at multiple levels. Each level has its own special characteristics, and children need to master each of these levels in to become a proficient reader. They need to learn the meaning of the words, the grammatical forms, the subject matter, the rhetorical structure, and the communication conventions. Moreover, it may not be enough merely to learn all of this; they may have to overlearn it. That is, they may need extensive practice, in diverse contexts, so the codes, structures, and processing skills become automatic (Perfetti, 1985). A child becomes proficient with a level of representation when they know what the code is (called awareness), they can mental build the code reliably (called mastery), they know when to construct the code, and they can know how to execute and monitor the construction of code very quickly.

**The indexical hypothesis**

The indexical hypothesis (Glenberg, 2004) is central to embodiment theory and comprehension research. It states that when a learner listens or reads, and they cannot connect the words to prior experience, they will not construct an accurate mental representation. The importance of the IH is the role of indexes, or the dimensions listed in the Event-Indexing Model. Research from the past three decades describes an accurate
mental representation as measured with the five dimensions or indexes, of the Event Indexing Model: Goals, Causation, Space, Time, and Protagonist (Zwaan, Langston, & Graesser, 1995; Zwaan & Radvanski, 1998). These five dimensions are dependent upon the sensorimotor system for constructing and organizing new information, as well as activating prior knowledge (Zwaan, 1999).

### Comprehension as Mental Representation and Event Indexing

In order for an individual to successfully comprehend, it is necessary for them to construct a mental representation called a situation model. A situation model is a coherent mental representation of the events, states, and actions depicted in a text (van Dijk & Kintsch, 1983).

In order to measure mental representation in discourse processing, the causal network analysis model is used (Trabasso & van den Broek, 1985, van den Broek, P., Kendeou, P., Kremer, K., Lynch, J. S., Butler, J., White, M. J., & Lorch, E. P., 2005). This causal network model provides a basis for analysis of how semantic and conceptual elements underlie grammatical structures and comprehension. This model led to development of the constructionist theory of inference generation (Graesser, Singer, & Trabasso, 1994). This was important because it offered predictions about what kinds of knowledge-based inferences are generated when readers construct a situational model for a text. According to this theory, children will seek to establish explanatory coherence for narrative information by making both local and global inferences. Even if there are explicit local connections between narrative events, comprehenders are naturally inclined to make inferences that provide explanations at deeper levels to make global inferences, and use the local causal connections and motivations/goals of the narrative’s protagonist.
to construct a global view of the narrative. This process is important for teachers to understand, as it indicates that children will look at the information as idea-units, taking each proposition and comparing it to long-term memory for the construction of a situation model—prior knowledge is important for understanding new information; and prior knowledge influences how new information is processed and comprehended.

The constructionist theory of inference generation model led to the event-indexing model (Zwaan, Langston, & Graesser, 1995; Zwaan & Radvansky, 1998), which is used here in this study. This constructionist theory of inference generation model was developed in response to emphasis that had been placed on causality in comprehension (Langston & Trabasso, 1999; Trabasso & Sperry, 1985; Trabasso & van den Broek, 1985).

The event-indexing model proposed that narratives are composed of five situational dimensions (time, space, character, goals, and causation) that operate together to form a situation model (Zwaan, Langston, & Graesser, 1995; Zwaan & Radvansky, 1998). This model is important for understanding that these dimensions often work together. That each event experienced from a text is constructed as a mental representation, and as changes occur, the model is updated. This is predicated upon the idea that children monitor each dimension for changes to update the situation model across a series of events. The following paragraphs present research exploring the role of these dimensions as they relate to narrative discourse processing.

Causation. An event can cause or enable the occurrence of another event if the preceding event is both necessary and sufficient. Such causal relations are important for narratives to be coherent (Trabasso et al., 1989; van den Broek, 1994). Because events
can have multiple causes and consequences, causal connections are often depicted as a complex network (Trabasso & van den Broek, 1985). The number of connections and the degree of necessity and sufficiency affects the strength of a causal connection (Langston & Trabasso, 1999; Trabasso & Sperry, 1985); the more causal connections that are identified and overlap, the more memorable they likely to be.

Adults regularly monitor causation, and when events are highly connected the events are read more quickly (Bloom, Fletcher, van den Broek, Reitz, & Shapiro, 1990); the events are remembered more accurately (Trabasso & van den Broek, 1985); the events are recalled more quickly (O’Brien & Myers, 1987); and the events are considered more important (Trabasso & van den Broek, 1985).

Causal understanding develops early in development:

- Four-year-olds can recall highly connected events from stories (van den Broek et al., 1996) and incorporate causal relations into retellings (Goldman & Varnhagen, 1986; Trabasso & Nickels, 1992).
- Six-year-olds can recall events with many causal connections more often than other events (Trabasso et al., 1984; van den Broek, 1988; 1989).
- Eight-year-olds make causal connections across episodes when cognitive demands are low and if they have enough background knowledge (Casteel, 1993; Inman & Dickerson, 1995).
- By junior high, children have a solid grasp of causal relations within and between episodes and respond to questions with answers that reflect the global causal structure of a text (Goldman & Varnhagen, 1986; van den Broek, 1989). They also use abstract causal logic and make causal
inferences (Casteel, 1993; Casteel & Simpson, 1991; van den Broek, 1997).

With age, children increasingly remember important parts of stories that are also highly causally connected. Children also increasingly notice when the canonical order, the story grammar, of a narrative has been violated (Yussen, 1982). Such evidence supports the notion that children monitor causation in narratives—something that happened in one event caused the next event.

In addition, elementary-aged children are able to reinstate causal information when cognitive demands are low (Casteel, 1993; Inman & Dickerson, 1995). This suggests that working memory may play a role in monitoring causal events. Studies with preschoolers show that they have developed in their ability to focus on events that are causally central. Pre-school children are able to do this through suppressing irrelevant information (e.g., Durston et al., 2002; Lorsbach & Reimer, 1997; Zelazo, 2004). This ability to attend to important information and suppress non-essential information indicates a possible dependence upon working memory—but this may not be as important as children become more automatic with language and understanding narrative schemas, thus freeing up mental resources to focus on connecting causes with consequences (e.g., Johnson et al., 2003; Pascual-Leone & Baillargeon, 1994).

Character Dimension. This dimension indicates awareness of entities such as people, objects, and ideas. Characters are the agents that cause events to occur, and their actions are often goal-motivated (Perner & Wimmer, 1987; Trabasso & Nickels, 1992). By age four, children can introduce characters in relation to one another, recall character goals at a higher rate than other events, and judge a character’s satisfaction based on goal
fulfillment (Trabasso & Nickels, 1992, Yuill, 1984). When kindergarteners learn about a character (e.g., the character is nice, is a bully, or neutral information), their recall includes information that is consistent with the trait. Children also attempt to update their representation upon learning information that conflicts with the initial trait, suggesting that kindergarteners build and update character models (Greenhoot, 2000). By the age of 9, children can use pronouns and definite expressions that are consistent with the character’s perspective during story narrations (Vion & Colas, 1999).

The developmental literature examining character understanding is tied closely to goal understanding. Therefore it is difficult to measure goals and character as independent factors. However, when children are asked to take the perspective of a protagonist, they are capable of using language that is consistent with the protagonist’s point of view (Rall & Harris, 2000; Ziegler et al., 2005).

*Goal Dimension*. Recall for the *goal* dimension indicates awareness of the protagonist’s goals and motivation to act in the narrative. When children are able to link the protagonist’s goals across events, the children construct coherence across events. The *goals* dimension is often linked with the *space, time, and causal* dimensions in regard to relational information showing ownership, kinship, and social interaction. To assess goal understanding, studies often investigate how children retell stories by assessing the organization, quantity of recalled information, and the inclusion of goal information (e.g. Brown, 1975; Trabasso & Stein, 1997). This work shows that 4-year-olds’ retellings often focus on concrete actions, general descriptions, neutral outcomes, state changes unrelated to a goal, and do not reliably include goal-action-outcome episodes (Thompson & Myers, 1985; Trabasso & Nickels, 1992; Trabasso & Stein, 1997; van den Broek,
1997; van den Broek et al., 1996). However, 4- through 6-year-old children can link a character’s actions with the goal of obtaining a concrete object (Trabasso, Stein, Rodkin, Munger, & Baughn, 1992; Trabasso et al., 1984; van den Broek et al., 1996). By 8-years, children recognize that goals are important across episodes (van den Broek, 1997), and can make inter-episodic connections between goals, actions, and outcomes by 9-years (Trabasso & Nickels, 1992). From age ten through high school, children have a relatively sophisticated understanding of the importance of goals, and use goals to create titles (van den Broek et al., 2003).

*Time.* As children age, they increasingly include temporal markers in story narrations. This may be because of developments in general language skills, memory, and comprehension skills, or even just an understanding of time as a concept (Chang, 2004). At 7-years, children begin to understand seriation and duration intervals, which are necessary for comprehending time (Piaget & Inhelder, 1969). However, children still rely on other cues more than time. For example, contextual cues are more helpful when asking children to retell personal events (Pearse, Powell, & Thomson, 2003). This may occur because elementary-aged children experience deficits in sequencing (Buss, Yussen, Mathews, Miller, & Rembold, 1983).

By age ten, children are more able to choose appropriate temporal and causal conjunctions (Cain, Patson, & Andrews, 2005). They also reliably remember temporal events in different media (Hoffner, et al., 1988), although performance is still facilitated by causation (Hsu et al., 1987). It is possible that general comprehension skills play a role in children’s ability to monitor and understand time. As children develop in their
knowledge of story schemas (Hudson & Shapiro, 1991), this should help them develop more concrete understandings of time.

*Space.* In adulthood, the location of characters and objects can affect moment-by-moment reading and the resulting memory representation. When events occur in the same location, reading times decrease (de Vega, 1995). Adults spend less time reading about and more quickly recognize objects that are close to a protagonist than objects located farther away (Glenberg, Meyer, & Lindem, 1987). However, adults do not consistently monitor the spatial dimension (Zwaan et al., 1998).

The likelihood that adults will monitor spatial information can be increased by having adults study a map prior to reading about a protagonist moving through a spatial setting. Adults more quickly remember objects located in rooms that the protagonist is located in or moving towards. This includes rooms that are more accessible to the protagonist, such as adjacent rooms, and also objects in a room that a protagonist is thinking about (Haenggi, Kintsch, & Gernsbacher, 1995; Morrow, Bower, & Greenspan, 1989).

It is more likely that adults will monitor spatial information when it is directly relevant to another dimension. For example, causal relevance affects the spontaneity with which adults engage in constructing, maintaining, and updating spatial models (Jahn, 2004; Sundermeier, van den Broek, & Zwaan, 2005; Zwaan & van Oostendorp, 1993). Character relevance is also important, as adults perform better when identifying whether an object is in the same location as a character (Wilson, Rinck, McNamara, Bower, & Morrow, 1993). Adults also monitor space as a function of time (e.g., Magliano, Miller, & Zwaan, 2001). Salience can also increase the likelihood that spatial information will be
monitored. If a location is still salient after a spatial shift, reading times do not immediately increase for information following the shift (Levine & Klin, 2001). This suggests that salience can facilitate spatial integration.

The developmental literature documenting children’s understanding of the spatial dimension is relatively sparse in the elementary and middle school years, although rich in the infancy years (e.g., Newcombe et al., 1998, 1999). There may be an implicit assumption that children understand the spatial dimension in narratives. For example, when 2nd- and 7th-grade children tell stories based on pictures, they give detailed accounts of the scenes described in the pictures, but lack clear statements about the characters’ goals, actions, and the connections between different pictures in the story (Buss, Yussen, Mathews, Miller, & Rembold, 1983). Because spatial understanding seems to be tied closely to causation, characters, and time, as in deitics, it is difficult to assess whether development in the ability to understand and monitor space is a byproduct of other dimensions. Children’s propensities towards monitoring space may be a result of their ability to differentiate it from other dimensions. This would suggest that working memory could play a role in children’s ability to attend to the spatial dimension, albeit only when relevant or salient.

Perceptual and motor experiences may play a role in monitoring the five dimensions of a situation model in event indexing. As was described, earlier in this review, development plays a key role in what dimensions are monitored. It may be that dimensions such as time require conceptual understanding. Four themes emerged form this review of research:
• Through every dimension, working memory is implicated in the ability to recall each aspect of a situation model.

• The five dimensions interact and may co-vary depending on the narrative, it may be difficult in some instances to differentiate one dimension from another.

• Learners are better at monitoring each dimension with development through age and experience.

• Salience is important. The form and content of a story, as well as the learners goals can influence which dimensions are best recalled.

• Situation models are built from perceptual symbols (Zwaan, 1999). Each of the five dimensions is predicated upon sensorimotor activity redescribed as a situation model and conceptual categories.

**Working Memory and Situation Model Construction**

Discourse processing researchers have found that readers monitor five specific dimensions that affect moment-by-moment awareness of a situation: time, space, characters, causation, and goals. However, the research literature reviewed in this chapter suggests that monitoring each dimension may be determined by cognitive/conceptual development, working memory, and salience.

Working memory refers to the ability to simultaneously manipulate multiple pieces of information in memory (Baddeley, 1986), which is limited (Miller, 1956/1994; van Geert, 1998). Assuming that children are less automatic at understanding language (e.g., Bloom, 1990, Gleason, 2001), and have less experience with narrative schemas (e.g., Hudson & Shapiro, 1991), they must allocate extra cognitive resources to such
tasks. This should leave fewer resources for attending to dimensions of a situation model.

For example, preschool- and elementary-aged children tend to focus on only one aspect of a problem rather than on multiple components (Piaget & Inhelder, 1969). In late elementary school, sentence and digit-span tasks of working memory explain independent variance in reading comprehension for 8-, 9-, and 11-year-olds (Cain, Oakhill, & Bryant, 2004). Such data suggest that children may not have the cognitive resources to focus on multiple aspects of a problem simultaneously, and that working memory could play a role in children’s ability to monitor multiple dimensions of a narrative.

Of special interest is the suggestion that working memory may play a role in children’s ability to create a situation model (Casteel, 1993; Durston et al., 2002; Inman & Dickerson, 1995; Lorsbach & Reimer, 1997; Johnson et al., 2003; Pascual-Leone & Baillargeon, 1994; Zelazo, 2004). Although working memory is often implicated in processing deficits, it may be more likely that prior sensorimotor experience is better explanation. Embodiment theorists propose that an individual learns through sensorimotor experience from situations in the environment, and, that sensorimotor memory is used to create perceptual simulations to build situation models. Prior memory of congruent sensorimotor experience may be more important than observations regarding working memory. According to Barsalou (1993), accessibility is the basis of working memory. Accessibility is based upon three factors:

1. Recency of prior experience
2. Frequency of prior experience
3. Context of prior experience
Thus, working memory has more to do with accessing long-term memory, with current experience. Successful comprehension is predicated upon how recently a child experienced a similar phenomena; how frequently they have been exposed to that phenomena; and in what context they have experienced that phenomena. This Aligns with Baddeley (2001) who has provided evidence for a verbal, spatial, and episodic working memory loops.

The indexical hypothesis states that when a learner listens or reads, and they cannot connect the words to sensorimotor experience, they will not construct an accurate mental representation. This may lead to the increased processing times often attributed to working memory deficits, which may be due to recency, frequency, and congruent context.

Embodiment theorists propose that we create meaning based upon action, and we create meaning through assigning attribution of action and potential actions to objects in the environment, thus creating conceptual categories predicated upon perceptual knowledge. Thus, if an individual cannot draw previous sensorimotor experience from memory, they may have to construct a situation model from contextual information and approximation, rather than retrieving congruent sensorimotor experience from memory. For this reason, working memory may be implicated in comprehension and problem solving. However, from the perspective of embodiment theorists, working memory may be a less significant factor than prior experience, and the ability to activate patterns of prior experience similar to current experience based upon recency, frequency, and congruence of context for prior experience.
Embodiment Theory

Embodiment theory is a culmination of research from a variety of fields including neuroscience, cognitive psychology, social psychology, developmental psychology, computer science, and a sub-field of cognitive science called discourse processing. According to Wilson (2002), embodiment theory seeks to explain how an individual's perceptual experiences may influence memory and problem-solving components of cognition. An important element of embodiment theory is the phenomena of perceptual grounding in cognition, or grounded cognition (Barsalou, 2007, 2010). The grounded cognition approach posits that the human conceptual system contains knowledge that supports all cognitive activities, including perception, memory, language and thought. Researchers report that re-enactments of states in modality-specific systems underlie conceptual processing.

Grounded cognition is in contrast to most contemporary theories of how conceptual knowledge is formed. Contemporary theories of conceptual development propose the conceptual categories undergo a redescription from the modal system in to an amodal representation, and that conceptual reasoning is done without support from the sensorimotor (modal) system once a concept has been coded into memory.

In amodal approaches, sensorimotor representations are transduced into an amodal representation, such as a feature list, semantic network, or frame. Amodal representations are described as residing outside of sensorimotor systems, and that a process of redescription transduces the sensorimotor states into a conceptual symbol. Once amodal redescriptions of sensorimotor states exist as conceptual symbols, all cognitive processes operate on them as conceptual symbols to achieve their functions – not on memories of
the original sensorimotor states.

Alternatively, embodiment theorists propose that perceptual states are re-enacted from long-term memory; that the body’s modal systems, are activated and contribute as aspects of conceptual symbols. Thus, the sensorimotor system re-enacts, or simulates the experiences described in a text by activating modal memory; and that the ability to successfully comprehend a text, and to engage in conceptual learning like scientific problem solving, will improve if a congruent embodied experience precedes the targeted text and conceptual learning (Glenberg et al., 2004).

**Neuroscience.**

Neuroscience research has indicated that the perceptual (modal) system becomes active as people perform tasks that involve long-term memory content knowledge such as problem solving and reasoning with language (Martin, 2001, 2007; Pulvermuller, 1999, 2005; Thompson-Schill, 2003). Neuroimaging research further confirms that perceptual simulation plays a central role in conceptual processing (Martin 2001, 2007). When conceptual knowledge about objects is represented, brain areas that represent their properties during perception and action become active; when conceptual knowledge of animals are presented, visual areas are especially active; when knowledge of objects and artifacts from the environment are presented, such as a hammer, motor areas become active (e.g., Kiefer 2005; Martin 2001, 2007; Thompson-Schill 2003). Similarly, when conceptual knowledge of food is presented gustatory areas become active (e.g., Simmons et al. 2005). When conceptual knowledge of smell are presented, olfactory areas become active (e.g., Gonzalez et al. 2006). Additionally, the property areas just noted are often segregated by category (Martin 2007). Within the motion processing system, for
example, distinct areas represent motion related conceptually for animals versus artifacts. In Glenberg et al. (2008) action systems were demonstrated through fMRI during comprehension of concrete language—through this study Glenberg et al (ibid) provided neurophysiologic evidence for modulation of motor system in the same manner as Fischer & Zwaan (2008) to support embodiment theory and grounded cognition.

**Cognitive psychology.**

Theories of grounded cognition and embodiment theory arose in response to the Amodal Arbitrary, and Abstract (AAA) theories of language and conceptual development. Researchers such as Gibson (1986) theorized that cognition was situated; that the environment plays a central role in shaping cognitive mechanisms. Theories of situated action focus on the link between perception and action during goal achievement (e.g., Clark 1997, W. Prinz 1997, Thelen & L. Smith 1994, Steels & Brooks 1995), and social interaction (e.g., Breazeal 2002). These theories came about in reactions to AAA theories of syntax, (e.g. Chomsky 1957; Lakoff & Johnson, 1980, 1999; Gibbs 1994), meaning that there was no explanation for the process of sensorimotor experience as it becomes conceptual knowledge, called transduction—the redescription of perceptual information into conceptual information.

For embodiment theorists in the cognitive tradition, brains evolved to control action, and AAA models do not account for how we learn from the environment. The importance of action and perception in comprehension has been demonstrated empirically (e.g., Barsalou, 2008a; de Vega, Glenberg, & Graesser, 2008; Gibbs, 2006; Pecher & Zwaan, 2005; Semin & Smith; 2008). Motor and perceptual processes are active in reading and language comprehension (Barsalou, 1999, 2003; Glenberg, 1997, 1999, Zwaan, 2004),
and linguistic meaning is grounded in bodily activity (e.g., Barsalou, 1999; Fincher-Kiefer, 2001; Glenberg, 1997; Glenberg & Robertson, 1999, 2000; Lakoff, 1987; McNeill, 1992; Stanfield & Zwaan, 2001). Consider the example presented by Harnad (1990; in Glenberg & Kaschak, 2002, pg.1):

A person lands at an airport in a foreign country (perhaps China) whose language she does not speak. At her disposal is a dictionary written solely in that language. Upon disembarking, she sees a sign with a sentence in logograms, and she wishes to determine the meaning of the sentence. She looks up the first logogram (an abstract symbol) in the dictionary, only to find that its definition is given by its relations to additional abstract symbols. To determine the meaning of the first symbol in the definition, she looks it up in the dictionary only to be faced with additional abstract symbols. No matter how many of these abstract symbols she relates to one another, she is never going to determine the meaning of the sentence. The lesson is that the abstract symbols of language must be grounded, or mapped, to the world if they are to convey meaning.

For Glenberg and Kaschak, the lesson is that symbols must be grounded, or mapped to the world if they are to convey meaning. The importance of this example is that meaning is based in the sensorimotor system of our bodies. As stated previously, the \textit{indexical hypothesis} proposed that meaning is based upon action and perception, and we create meaning through assigning the qualities, action and potential actions to objects in the environment, thus creating conceptual categories predicated upon perceptual knowledge.

The creation of conceptual categories is thought to happen through two processes called grounding and transduction. Grounding and Transduction provide the basis for the
construction, organization, and retrieval of information for creating situation models, and do so with the aid of the sensorimotor system.

*Transduction.* Transduction is the transformation of environmental energy into electrical, or neural energy. It describes the process through which our sensorimotor system experiences the environment and takes input. This is not to be confused with Piaget’s description of transductive reasoning, which is a description of making sense of a stimulus. However, the two are related in that transductive reasoning is dependent upon transduction.

Transduction is a term used to describe how perceptual knowledge from the environment becomes conceptual knowledge (for a review, read Barsalou, 1999). Transduction is essential for understanding how new information is processed and organized. According to Barsalou (ibid), transduction is made possible through the extraction of perceptual symbols, where “perception refers to the capture of symbolic content, not the content itself (ibid, p. 65). Thus transduction, for Barsalou is based upon the activation of memory networks that include memory of movement, perception, and action related to the memory of content when it was acquired.

*Grounding.* Grounding refers to how words get their meanings. Words are defined based upon the things they describe. Words are a symbol system that can be deemed as abstract, arbitrary, and amodal (the *AAA model*) combined to create meaning with syntactic rules (e.g., Birgess & Lund, 1997; Chomsky, 1980; Fodor, 2000; Kintsch, 1988; Pinker, 1994). What this means, according to Glenberg and Kaschak (2002) is that words are abstract because they can refer to similar, but different objects, i.e., “big chairs and little chairs”. They are amodal as the same word is used when chairs are spoken or
written about; and words are arbitrary, as they have no phonemic, orthographic characteristics related to the actual physical or functional relationship of the word’s referent (ibid, pg. 1).

Additionally, cognitive psychology researchers found that sensory-motor variables affect diverse tasks associated with perception, action, memory, knowledge, language, and thought, implicating the brain’s modal systems throughout cognition. (Glenberg, 1997; Zwaan, 2004, 2008; Gibbs, 2006; Hegarty, 2004; W. Prinz, 1997; Wilson, 2002; Wilson and Knoblich, 2005; Rubin, 2006; Barsalou, 2008a, 2010).

**Developmental psychology.**

The study of infancy and cognitive processing in early childhood has presented an embodied approach to how human beings move from perceptual awareness and knowledge to conceptual knowledge, beginning with Piaget’s (1952) theory of sensorimotor development. This theory posited that young children create mental representations of the world, and this is called an image schema.

For Piaget, the image schema is the basis for conceptual development—but Piaget believed that perceptual knowledge preceded conceptual development, and is predicated upon physical maturation of the sensorimotor areas—thus, as the infant matured physically, they would be capable of greater conceptual learning.

Piaget (1952, 1954) also suggested that children make mental connections between action and semiotic representations, but never specified how this occurred. Building upon this, Mandler (1992, 1998, 2000) indicated that perceptual and motor function (sensorimotor function) may be innate, and not developmental; and that human beings are able to use sensorimotor function to develop image schemas as early as infancy; and, that
infants engage in conceptual learning—specifically through identification of causation, action, and potential action (Mandler, 2000).

For example, newborn infants imitate the facial expressions and bodily movements of adults, simulating the actions that they see physically (Meltzoff & Moore 1983). Researchers have demonstrated that conceptual development depends upon bodily states (e.g., L. Smith 2005b) and situated action (e.g., L. Smith & Gasser 2005), and that motor actions performed while learning a category influence the visual features abstracted into its representation (L. Smith 2005a). In general, extensive amounts of learning occur between perception, action, and cognition as development progresses (e.g., Greco et al. 1990, Rochat & Striano 1999).

Embodiment theory and the event-indexing model.

As was described previously in this review, the construction of a situation model is considered a perceptual simulation. Embodiment theorists propose that when an individual creates a situation model, the sensorimotor system simulates actual perceptual experiences from memory in order to visualize or imagine. When studies have investigated the construction of a situation model, contributions from the perceptual system, or perceptual traces, were identified (Fischer & Zwaan, 2008; Richardson, Spivey, Barsalou, & McRae, 2003; Wu & Barsalou, 2003; Zwaan et al., 2003, 2004), meaning that the way that we take in environmental information is simulated when we retrieve and review memory, i.e., the same brain areas are active in seeing and remembering an event.
CHAPTER III.

METHODOLOGY

Research and Hypothesis

Chapter one introduced the research problem and explained the purpose, the hypothesis, possible limitations, and assumptions of this study. Chapter two presented a review of relevant literature and research that addressed the role of embodied learning in comprehension and problem solving for designing effective classroom instruction. In this chapter, I restate the research questions and null hypothesis, I describe the experimental design, and I explain the methods and procedures used in the study. Chapter three also includes a description of the measures used to collect and analyze the data.

Research questions.

• Will a video game that emphasizes sensorimotor experience provide greater recall and problem solving as compared to viewing a video, or reading a printed text?
• Will performance in the reading condition improve if it follows the game or the viewing condition?
• How does the identification causation predict building a mental representation and problem solving?
Summary

This study was designed to assess the importance of grounding learning in sensorimotor experiences for improved performance in reading comprehension and problem solving. When students are asked to read and listen for learning, they are dependent on whatever prior experiences they can draw from to create a situation model. Research from working memory states that the ability to comprehend is predicated upon prior experience that was experienced recently, frequently, and in a congruent context. Working memory and embodiment theory predict through the Indexical Hypothesis, that the more recent, frequent, and congruent the learner’s prior experiences, and more involved their sensorimotor memory experience, the more likely it is that they will have the ability to connect incoming information with their prior memory and create a relevant mental representation for improved problem solving.

The students in the embodied video game condition should have greater sensorimotor memory, rely less on prior experience to interpret the media narrative, as compared to the video and printed narrative, and do better in problem solving on the word problem and multiple-choice test.

This is supported by evidence presented in the literature review, that perceptually-based processes can be best explained in the form of a perceptual symbol system (Barsalou, 1999), that working memory depends upon frequency, recency, and congruence of context (for a review, see Barsalou, 2003); that perceptual experience structures the use of language (Zwaan, 2004), and uses constructs such as affordances (Glenberg, 1999) to aid in the construction of mental representation from perceptual memory to facilitate conceptual development.
In order to test the efficacy of these positions, this experiment made the prediction that students would be more successful in creating mental representation and problem solving after playing an embodied video game as compared to viewing a video, or reading a printed text media.

In addition, it was predicted that if an embodied activity such as the video game, preceded the reading condition, the outcomes from the comprehension and problem solving measures would improve. Comprehension is measured here using the Event-Indexing Model (Zwaan et al., 1995a; 1995b). This model has shown that specific dimensions are monitored as specified by the Event-Indexing Model: Time, space, characters, goals, and causation. The developmental literature suggests that children develop in their understandings of time, space, characters, goals, and causation. It is predicted here that performance in these categories will improve if the assessment measure is preceded by sensorimotor experience, which emphasizes causation. The more abstract the presentation of information or memory, i.e., viewing or reading, the less likelihood for an accurate mental representation.

What informs this view is the role of causation. The opportunity to act and rehearse for action may be the most important dimension in constructing a mental representation. Causation has been found to be predictive of other dimensions, and causal relations are important for narratives to be coherent (Trabasso et al., 1989; van den Broek, 1994). The ability to identify causation is commonly accepted as developmentally appropriate for children this age (Goldman & Varnhagen, 1986; van den Broek, 1989). Additionally, Glenberg et al. (2004) identify causation as central to comprehension and problem solving. When Glenberg et al (Ibid) used a manipulation activity for comparing mental...
representation, as compared to re-reading, the manipulation activity yielded significantly better performance. In a second order experiment, Glenberg et al (Ibid) and the secondary activity, visualization. The subsequent improvement in outcomes may have been a result of mental rehearsal in off-line processing, identifying causality—or what action led to what change in the narrative.

It is therefore hypothesized that embodied activities that require imaginative rehearsal in off-line processing (planning and practice) based upon causation, such as the video game, will outperform viewing and reading conditions; and, that causation will predict performance in the creation of a mental representation in the walkthrough, the word problem, and the multiple choice questions. In the study, the children were asked to play an embodied video game called Tony Hawk RIDE. They were told to ride their virtual skateboard on the Venice Beach Speed Run challenge from the beginning to end in the shortest amount of time.

In the study, the children were asked to play an embodied video game called Tony Hawk RIDE. They were told to ride their virtual skateboard on the Venice Beach Speed Run challenge from the beginning to end in the shortest amount of time.

In addition to the embodied video game, students experienced the same narrative content as a video and a print narrative. After each media narrative experience, the learner was asked to recall the narrative through the creation of a walkthrough, and then answer multiple choice questions and solve a word problem. The walkthrough was analyzed as a causal network using the five dimensions for a situation model operationalized in the event-indexing model.
After the walkthrough, the children were asked to answer a STEM word problem related skateboarding and answer 15 multiple-choice items. The multiple-choice questions were also based upon the five dimensions of a situation, as well as scientific problem solving as defined by the NAEP cognitive targets.

After each media/data collection condition, the learner experienced the other two media conditions in a randomized presentation order. Through this method, the role of embodied narrative experience in comprehension and problem solving can be compared to viewing and reading, as well as the effect of embodied experience if it comes before reading.

The three media conditions offer different advantages and considerations. The video game offers much more opportunity for physical interaction to segment events and identify causal relations. The children are more likely to recall causal relations in the embodied video game, because they cause the narrative to move to the next event through their physical actions. The video game also offers immediate feedback so the learner can test their beliefs about how the narrative works. Additionally, the game provides rapid basic skill acquisition for proficiency in the skateboarding activity. So rather than having to master basics of skateboarding, like balance and pushing the skateboard, the learner has their actions augmented by the game so they can learn to be strategic in how they meet the narrative goal structure.

The video offers an image and action to identify what causes the narrative to move. The video offers much more sensory input for the creation of a situation model than a printed text. With a video, or an image, the learner can view and construct viewed experiences with the objects, actions, and ideas. Watching a video can provide a clear
connection between concept and what it describes. In essence, a video of an elephant will provide more information than the word “elephant” or a stylized abstract representation or symbol Kress (2001).

Although a game and video can present more information to inform concept development, actual text may offer greater specificity, especially when combined with a graphic or interactive software/game. If the learner has already created prior knowledge with the content, and they have the ability to create a situation model from printed text, printed text can present more specific information through narrative focus.

This dissertation seeks to examine the role of embodied learning for comprehension and problem solving performance. This may provide educators insight into planning instruction for children who lack the range of sensorimotor experience that inform the concepts presented in instruction. Presenting sensorimotor experience prior to conceptual learning may expedite success. Using an embodied experience like a video game may provide greater success in situation model construction—increasing comprehension and problem solving.

Research findings on the role of causality in reading comprehension have established that causal relations aid the development of a reader's coherence of text through the generation of inferential processes that link text information with other text and background information. These inferential processes can result in the development of a coherent, unified representation of text meaning (Albrecht & Myers, 1995; Graesser, Millis, & Zwaan, 1997; Kintsch, 1998; McKoon & Radcliff, 1992) and may imply a connection between causal and perceptual properties in text comprehension (Stanfield & Zwaan, 2000; Zwaan, Stanfield, & Yaxley, 2002).
To test whether the embodied activity will improve mental representation and problem solving, several predictive factors were gathered as potential covariates. Although the covariates were chosen as factors in the ability to comprehend and problem solve: auditory and visual working memory, standardized test reading scores (MCA2), media preference, and prior knowledge of the science and activity concepts. However, this study was designed using random assignment, and the influence of the covariates should be non-existent or minimal.

Working memory has been shown to be predictive of information processing difficulties and the ability to construct a mental representation (Kinstch & Kintsch, 2004). Because the in off-line processing, the participant must orally recall the auditory information in the proper sequence, the digit span task is often described as a sequencing task (Sattler, 1992). Average WM scores for digit span as four digits. WM memory might be a factor in the sample population, as these students have been chosen for lack of performance. The expected analysis may result in a digit span, or the ability to chunk four digits, or chunks (Cowan, 2001).

This is an important corollary, as the students were chosen for the sample based upon lack of performance on the MCA2, Minnesota Comprehension Assessment. This assessment seeks to test students on certain literary constructs, and the scores are normalized across grade level using a vertical score table from the Minnesota Department of Education. For this reason, working memory data were collected to investigate working memory as a factor in comprehension.

In addition, research in prior knowledge has shown that individuals with prior experience and knowledge will perform better in building a more robust mental
representation for comprehension and problem solving. For this reason, students were surveyed with five questions for each category related to the tasks: prior knowledge of science concepts, skateboard concepts, and media preference.

Although these factors have been shown to be predictive, they were accounted for through random assignment and presentation order of the media condition. Even with these factors as covariates, it was expected they would have little to no effect.

In addition, it is hypothesized that performance in the reading condition will improve if it occurs after the viewing (video) condition, or after the doing (game) condition. This improvement should coincide with improved performance in identification of causation, and consequently robustness of mental representation. Identification of causation will be improved if preceded by participating in the narrative through the embodied game, or viewing the narrative, which should ground print narrative understanding with the memory of congruent sensorimotor experience according to the Indexical Hypothesis.

There should also be a difference in the viewing and doing condition, where visual exposure in the viewing condition to the printed descriptions in the text should expedite performance in the print condition; the combination of visual exposure and the act of rehearsal in playing the game should outperform viewing and reading, and improve performance.

In order to verify that students will have a greater tendency to read with comprehension after the viewing or embodiment condition, the printed narrative was written to prescribe a specific route through the skateboard park. Thus, students who were able to comprehend the text comprehension will likely choose to depict their route, as prescribed in the story.
Background and Role of the Researcher

As principal investigator on this study, I acted as a neutral researcher. My role was to design and implement the study as well as collect and analyze data. Additionally, I recruited experts for middle school science education and skateboarding. My preparation leading up to this study included working as a classroom teacher for ten years, as well as studying the cognitive neuroscience of reading comprehension, primarily from the perspective of the discourse processing tradition.

As an undergraduate, I received a Bachelor of Science degree in English Teaching. I used this degree and license to teach middle school language arts. Additionally, I worked as a k-8 media specialist at a public Montessori school, as well as in Engineering for high school students. As a teacher, my work using video games as new narrative texts and the use of the walkthrough as a writing assignment were celebrated in national media, and led to documented improvement in student performance on state standardized tests.

My graduate work and training has been multidisciplinary as part of my ten-year association with the Center for Cognitive Sciences. As a research associate at the CCS, I received an MA in Educational Psychology, where I studied in learning and cognition and wrote my masters thesis on reading comprehension and explicitly formatting phrase boundaries in narrative text as verse. During this time, I was the recipient of a Fulbright Fellowship, and I studied as a graduate student with Prof. Ivar Bjoergen at the Norwegian Institute of Science and Technology in the Department of Psychology. During this time I studied and taught a graduate-level course in research methods and participated in a
number of projects. Upon return, I worked as a Berman Fellow, funded by the NIH for the study of organ transplant recipients.

Over the last six years, I received a Master of Arts degree in Literacy Education, and have worked to finish my doctorate in Reading Education. I have published numerous publications related to learning, literacy, and technology integration. The current study attempts to unite my various areas of reading and study through connecting active learning with video games and multimodal media through embodiment theory and literacy, and reading comprehension from cognitive research and discourse processing.

**Restatement of Research Questions and Hypotheses**

The following research questions guided the study and are restated here:

1. Will a video game that emphasizes sensorimotor experience provide greater recall and problem solving as compared to viewing a video, or reading a printed text?
2. Will performance in the reading condition improve if it follows the game or the viewing condition?
3. How does the identification causation predict building a mental representation and problem solving?
Null Hypotheses Restated

$H_{01}$: There is statistically no significant difference in recall and problem solving in playing the video game as compared to viewing a video, or reading a printed text as measured by comparing the five dimensions of mental representation from the event indexing model in a walkthrough, as a causal network; through fifteen multiple-choice inventories from the NAEP cognitive target framework; and a STEM word problem adopted from middle school curriculum.

$H_{02}$: There is statistically no significant difference in the reading condition across treatment order improve as measured by comparing the five dimensions of mental representation from the event-indexing model in a walkthrough, as a causal network; through fifteen multiple-choice inventories from the NAEP cognitive target framework; and a STEM word problem adopted from middle school curriculum.

$H_{03}$: There is statistically no significant difference in how identification causation predicts building a mental representation and problem solving as measured by comparing the five dimensions of mental representation from the event-indexing model in a walkthrough, as a causal network.
Research Design

This experimental study was designed to assess the effect of embodied activity on comprehension and scientific problem solving. Children experienced the same narrative in three different media experiences: as an embodied game, a video, and print narrative. All three media presented a narrative about riding a skateboard through a business park. After each media presentation, the children were asked to recall their narrative experience by creating a walkthrough. The walkthrough is a combination of a map with a narrative that explains how the skateboarder navigated the business park. The walkthrough was then coded for the five dimensions of a situation model for robustness of situation model and event indexing. After the walkthrough the children solved a word problem and answered fifteen multiple-choice questions.

The skateboarding narrative was presented in a randomized sequence as an embodied video game, as a video, and as a printed narrative, Figure 1.

<table>
<thead>
<tr>
<th>Digit span/prior</th>
<th>game</th>
<th>video</th>
<th>text</th>
<th>Summary ra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digit span/prior</td>
<td>game</td>
<td>text</td>
<td>video</td>
<td>Summary ra</td>
</tr>
<tr>
<td>Digit span/prior</td>
<td>video</td>
<td>game</td>
<td>text</td>
<td>Summary ra</td>
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<td>Summary ra</td>
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<td>Summary ra</td>
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<tr>
<td>Digit span/prior</td>
<td>text</td>
<td>game</td>
<td>video</td>
<td>Summary ra</td>
</tr>
</tbody>
</table>

Figure 1 Presentation order
All three versions of the narrative presented the same character skateboarding through a business park. Each media condition presented the same content. After experiencing the narrative, the child retold the experience through mapping a walkthrough and accompanying narrative, solved a word problem, and answered fifteen multiple choice questions.

The children were randomly assigned to one of six presentation orders. The purpose of this was to counterbalance the effect of the children’s reading cut scores, working memory, media preference, and prior experience across the media conditions. Additionally, the six orders were created to look at the influence each might have on the following media condition. Of special interest was the effect that the video and the embodied game might have on the reading condition.

The walkthrough and first five multiple-choice questions were constructed to analyze the children’s ability to recall the narrative experience along the five dimensions of a situation model. A situation model is a mental representation composed of events in a narrative experience indexed and linked as causal relations, goals/motivation, space, time, and protagonist/objects. According to embodiment theorists, the ability to identify causal relations are essential for linking events. For this reason, the embodied video game should provide greater comprehension outcomes due to the physical actions undertaken to cause progression from one event in the game-narrative to the next.

It is also proposed here that comprehension in the print text-reading condition will improve if they have already experienced the video game. It is hypothesized that the embodied game condition will improve recall of causal for linking narrative events to
create a situation model. Students were randomly assigned to one of six-presentation orders of these three media conditions. These six presentation orders included:

**Description of Setting and Sample**

**Setting.**

The participating school district was located in an urban middle school in the Minneapolis Metropolitan Area. Of these students, 77 percent qualified for free and reduced lunch (101) and the remainder (31) either did not qualify or did not report their socio-economic status. Of these students, the majority claimed English as a second language.

This school has met 69.7% of the requirements for Adequate Yearly Progress under No Child Left Behind. Student demographics on race and ethnicity include 2% American Indian, 9% Asian, 21% Black, 34% Hispanic, and 35% White. Thirty percent of students are limited English proficient; 14% are listed as special education; and 61% qualify for free and reduced lunch. It is an open enrollment public school with 8% of enrollees transferring to this school, and 13% leaving.

**Sample.**

The participants in this study (58 females, 74 males) were part of a middle school summer remediation program from grades 6, 7, and 8 (46, 6th graders; 48, 7th graders; and 38, 8th graders). The primary method for selecting students for the summer program was the Minnesota Comprehensive Assessments (MCAII). However, a small number of
students were chosen for summer remedial instruction for classroom performance and attendance.

**Procedures and Data Sources**

*Protocol.* Students took a computer-mediated inventory for prior knowledge, media preference, and working memory. Then they were assigned to one of six treatment orders of: game, video, and text. After each media condition, they created the walkthrough, and completed the word problem and multiple-choice inventory.

In the walkthrough, the students were told that they would be creating a map (the walkthrough) to depict the fastest route through the park. Students were given a seven by seven grid to aid them in creating their map. The analysis plan for this walkthrough was predicated upon identification of the five dimensions of the event-indexing model: goals, causation, space, time, and object/character, from the map and the narrative, corresponding to each cell in the grid.

After the science problem, the students completed the fifteen-item multiple-choice inventory to assess student ability to “Locate and Recall” items from the media, and “Integrate and Interpret”.

**Pre-experimental mca2 test reading scores.**

The MCA2 is the Minnesota Comprehensive Assessment. The MCA2 state tests help Minnesota school districts measure student progress toward Minnesota's academic standards and meet the requirements of the Elementary and Secondary Education Act
(ESEA). The reading and mathematics tests are used to determine whether schools and districts have made adequate yearly progress (AYP) toward all students being proficient in 2014. Science tests are required by ESEA but are not included in AYP calculations.

Reading and mathematics tests are given to students in grades 3–8, 10 and 11. Science tests are given to students in grades 5 and 8 and in the year in high school when students complete a life science course. All Reading MCAs are offered in the paper administration mode only. Although the test is constructed to examine student proficiency with the state standards, the basis of the test for cognitive difficulty is based upon Blooms Taxonomy for cognitive difficulty, and question types are generated from a publishing company to match narrative and expository passages. This poses some inconsistency in measuring comprehension, as the questions are not based upon cognitive process, but rather themes and cultural values related to the passage. The items and passages are then chosen for their similarity to the state standards, and then analysis is done for categorization in Blooms Taxonomy. This process has many methodological problems for internal consistency and construct validity.

The description in the technical manual parses the taxonomy into three categories: Knowledge, Understanding (comprehension), and Application – Synthesis, Analysis, and Evaluation are omitted. This is problematic, as Blooms Taxonomy was originally intended as a framework for instructors to think about levels of difficulty in their classroom assignments and classroom assessments. Although Bloom’s taxonomy may offer the most flexibility in the creation of test items, these guidelines are not based in
any psychological metric. This can lead to issues of poor internal consistency in the test item categories, and lead to dependence on correlation rather than casual relationships.

In order to compare reading scores across grade level, separate tests are compared based upon correlation of item time. Although there is a no causal link between these categories, there is a trend in student scoring across and between the item types. This means that there is similarity between student outcomes, but not a clear indication what students need to work on specifically to improve.

The MCAII raw scores were normalized using the Minnesota Department of Education Vertical Reading Score table. The vertical score table normalizes scores by assigning a number assigning equivalence of scores across grade levels, i.e., equating a 6th grade score with an 8th grade score.

**Prior knowledge multiple-choice inventory.**

Students completed a computer-mediated inventory consisting of fifteen multiple choice questions to assess prior knowledge of science (five items) and skateboarding concepts (five items), and media preference (five items) – see Appendix A for the inventory. To view this inventory, see Appendix E, page 215, this document.

**Pre-Experimental Auditory and Visual Digit Span Measure.**

Working memory was gathered through the PsychExperiments Online Numerical Memory Experiment, an interactive, computer-mediated test was used (http://www.psych.uni.edu/psychexps/Exps/Numerical_Memory/startnm.htm). Digit Span is a measure of working memory, or the measure of how many separate ideas or symbols an individual can hold in mind at one time. As was stated in the literature
review, the average number of digits an individual can hold in mind at once is four. That can mean four objects, symbols, concepts, etc.

This particular test is used for testing how many neutral digits an individual can remember in sequence. This task is done with verbal memory, tapping into the phonological working memory, and for visual working memory. Both have been identified by Baddeley (2000) along with contextual, or epistemic memory.

This inventory is used as an intelligence measure in the Wechsler Intelligence Scale Child (WISC-R) and the Wechsler Adult Intelligence Scale (WAIS-III), and is used here to examine whether the students in the sample might have an information-processing deficit in working memory. The test presents strings of digits in a sequence in audio format and visual format to adaptively test for how many digits the participant can remember. The average digit span of an adult is four digits.

Embodiment theorists propose that working memory may be more of an indexing, or retrieval system, which is more successful based upon recency, frequency, and congruence of context for prior knowledge and retrieval. Thus, working memory may be a system for perceptual symbols and networks of memory activation for concepts.

However, because this experiment was designed with random assignment, it was expected that the pretest measures such as working memory should not account for variation in the treatment conditions. However, these pre-test measures were used as covariates in GLM Multivariate and Univariate analysis to explore the impact of working memory in explaining variance.
Post-Intervention Instruments

Post-media presentation inventory.

Questions for the post-media inventory were developed from a classroom unit on a distance, time, and speed problem. Items were developed with suggestions from two middle school science teachers and eight expert skateboarders, and constructed by the researcher to align with the National Assessment of Educational Progress (NAEP) Cognitive Targets.

The questions were constructed to specifications from the 2009 NAEP Reading Framework Assessment Specifications, with direct alignment to the “Information Text” category, with focus on Locate/Recall, and Integrate/Interpret. These two categories were emphasized in applicability to generalize across the different media formats—to examine these questions, see appendix D, p.212 this document.

The first category of questions, “Locate and Recall”, emphasized the construction of a mental representation; students were asked to locate specific information in text or graphics. These questions focused on spatial relations and recall in a mental representation, and also assessed comprehension of main idea and causal relations.

The second category of questions, “Integrate and Interpret” focused on problem solving and making inferences, and also aligned with the word problem and the creation of the walkthrough.

Two classroom teachers reviewed these questions for clarity and alignment based upon content, readability, and comprehensibility. Questions were modified to fit teacher expectations for sixth grade classroom difficulty level, and to integrate important
skateboarding concepts suggested by the expert skateboarders. When a question was not deemed appropriate, it was revised and reviewed for fit—See appendix B for Specifics on question constructs and linkage to the other data collection.

**Walkthrough.**

After each media exposure, students were asked to create a walkthrough. A video game walkthrough, according to Dubbels (2008) is a description of the possible actions, and artifacts in a game space that the player can experience. It is constructed to aid and direct game players to have an optimal experience with directed learning, rather than reliance on trial and error or expertise. A walkthrough is a paratext (Apperly & Beavis, 2011), which is a document related to text, not written by the author. The walkthrough is a document about a game that game players often build to share with other players. They are typically composed of from maps and narrative descriptions of the game levels, often offering strategy, and subtle opportunities not obvious in game play—such as secret passages, objects, or cheats. The use of a walkthrough as an assignment has been shown to be highly engaging and effective in the construction of higher order thinking as a new literacies curriculum tool (Dubbels, in preparation).

The walkthrough was scored according to the definitions of the five dimensions for a situation model as operationalized in the Event Indexing Model (e.g. Zwaan et al., 1998). In order to score the walkthrough, the game level was parsed into a seven by seven grid with topographical and conceptual details such as acceleration and deceleration points.

The “Venice Beach Speed Run” level was chosen because it emphasizes rate, or getting the fastest time. Eight expert skateboarders were recruited from a commercial skateboard park in a northwest metro suburb in the twin cities area in MN. Experts were
recruited and paid to play the game, create a walkthrough, participate in a reflect aloud protocol (Ericsson & Simon, 1989), where they would describe their route as if telling it to a skateboarder friend, and to describe terms and concepts necessary. To view the written instructions for the walkthrough, see appendix B, page 210, this document.

The skateboarders were considered expert if they were involved in competitions and had a sponsor. The experts found four possible routes through the game level, one of which was a hidden path requiring skateboard knowledge to do a special move called an Ollie. Seven of the eight experts found this route.

For analysis, the grid was organized as a seven by seven matrix, (see appendix J, page 226 this document), with each cell of the matrix scored with a rubric based upon the five dimensions of the Event Indexing Model. The scoring rubric used was developed with four graduate students seeking teacher licensure. The four scores were averaged and rounded down using the five dimensions of the Event Indexing Model. The scores were: Goals = 3, Causation=3, Space= 6, Time=2, and Character= 2. These scores were used as a proportion in calculating student scores, i.e., student score/ expert score.

Analysis of student response was organized on the matrix using four possible routes through the grid identified by expert skateboarders and compared to their scores as a proportion—only similar routes were compared in the analysis. Percentages of agreement for each dimension were high (e.g., for the temporal dimension, the coders agreed 95.74% of time). Coder agreement rates were $k = .9$ for time, $k = .94$ for space, $k = .79$ for causation, $k = .91$ for goals, and $k= .86$ for characters (Landis & Koch, 1977). The cells that were constituent to each route were averaged by dimension, and then divided by the expert score for each route to create a proportion.
Word Problem.

Students were asked to complete a word problem where they estimated the fastest path through the walkthrough using the equation: time = distance/rate. Students were instructed to draw a path through their walkthrough and count each straight line as a vector, estimating the length of each line and the rate of speed based upon information from the instructions. The word problem was scored by two middle school science teachers based upon an agreed upon scoring rubric, which specified correct use of information and concepts rather than a correct answer. In order to get a perfect score of five, students needed to demonstrate: vectors +1, distance estimates +1, velocity +1, use of equation +1, and a correct calculation. Coding reflected almost complete agreement: $k = .98$ vectors, $k = .98$ distance, $k = .98$ velocity, $k = .98$ equation, $k = .98$, calculation $k = .98$.

Media Conditions

Video game.

The video game Tony Hawk Ride was selected because it represents an embodied learning experience. The game is an embodied activity because it engages multiple sensory and motor modalities by requiring the player to physically ride a plastic skateboard to control the game. The skateboard is a wireless game controller that the player stands upon, which responds to player movement through accelerometers, infrared motion sensors, and wireless connection.
Movement of the controller causes the virtual skateboard on the screen to do a trick corresponding to force of the thrust, and the depicted context and velocity. The game controller also has sensors to know when the player simulates pushing with a foot on the street, or even grabbing the skateboard with a hand.

The game was run on an X Box 360, and projected onto an eight-by-eight screen with an LCD projector. Eight experts played the game and reported three main routes, and seven of these eight experts identified a fourth, secret route emphasized in the print narrative.

**Video.**

An expert skateboarder was recorded while playing the game. The game was projected onto an 8 x 8 screen and captured with a video camera. The video was encoded into an mpeg4 file format to be projected from a computer onto an eight-by-eight, large format screen. The video was composed of six examples of the experts going through the Venice Beach Speed Run level. However, the video only depicts the three main routes, and does not include the secret route that the seven experts identified: “Route 1”.

**Print Narrative.**

The primary investigator constructed the print narrative, and reviewed by the two middle school teachers for suggestions on clarity, interest, and comprehensibility. The print narrative was written with a goal structure to get the fastest time through the skateboard park, with sub goals related to the main goal, and was written to be of interest to middle school students. In addition, emphasis was made to describe the action space and to be explicit about causation and character.
The print narrative was written specifically to suggest taking the secret route, route 1, as an indication that the main idea of the print narrative was comprehended. The narrative had a Flesch-Kincaid grade level of 6.1.

**Data Collection**

The researcher obtained written permission from an urban public schools system in the metro area of the twin cities in Minnesota for this study. The curriculum coordinator and assistant principal assisted in providing a classroom and access to students during the summer academic remediation program. The researcher explained the study to each participating summer school teacher, with explanation of the general interest of the study and the role of the video game.

As part of the summer school matriculation process, the assistant principal distributed consent and assent forms with a printed description of the study in English and Spanish. It was decided by the administrators that students would participate in the experiment during their study skills classes. The researcher visited each targeted classroom and explained the needed study of scientific problem solving, why their test scores were needed for the study, and handed out a written explanation, consent, and assent forms to be taken home and signed by parents or a legal guardian for two hundred forty-two students.

The researcher secured permissions for participation by the parent and legal guardian and assent for the students. Each form was assigned a number and randomly assigned a number from one to two hundred and forty-two. The assistant principal created
a schedule for students to visit the assigned classroom. Each student was randomly assigned to a treatment order.

**Pretest/post-test.**

Prior to the experiment, students took a computer-mediated inventory for prior knowledge, media preference, and working memory. Then they were assigned to one of six treatment orders of: game, video, and text. After each media condition, they created the walkthrough, and completed the word problem and multiple-choice inventory.

In the walkthrough, the students were told that they would be creating a map (the walkthrough) to depict the fastest route through the park. Students were given a seven by seven grid to aid them in creating their map. The analysis plan for this walkthrough was predicated upon identification of the five dimensions of the event-indexing model: goals, causation, space, time, and object/character, from the map and the narrative, corresponding to each cell in the grid.

After the science problem, the students completed the fifteen-item multiple-choice inventory to assess student ability to “Locate and Recall” items from the media, and “Integrate and Interpret”.
CHAPTER IV.

RESULTS

In this chapter, I will present my analysis from the data collection for the four analysis settings. This study is a quantitative experimental study. Because participants were randomized across one of six presentation orders, it is expected that the pre-experimental data will not predict performance in the analysis. The analysis settings include pre-experimental analysis to compare students across grades to determine normal distribution for determination on statistical models. It was found that the sample population showed normal distribution and parametric tests were chosen. The settings include:

1. The pre-experimental setting—analysis of working memory, standardized reading scores, prior knowledge of content, and media preference.
2. First media—comparison of walkthrough, NAEP targets, word problem, and covariates in the first media presentation condition. The comparison is between the first presentation condition of game, video, and text.
3. Reading across presentation order--comparison of walkthrough, NAEP targets, word problem, and covariates in the reading media condition across presentation order.
4. Influence of causation across data collection conditions

These analysis settings were created to answer the three research questions for hypothesis testing.
**Pre-Experimental Data.**

The pre-experimental data were obtained to look at issues such as reading performance on the Minnesota Standardized read comprehension assessment (MCA2), prior knowledge of science and skateboarding concepts, media preference, and working memory. The data were collected using an online inventory for prior knowledge, media preference, and the psych experiments online digit span inventory. Additionally, the MCA2 scores and student demographics were provided by the school district. Because this experiment was designed with random assignment, and these pre-experimental variables should not have much affect on the dependent variable. Exploratory data analysis was performed using Shapiro-Wilks for normality to meet the assumptions of parametric statistical tests. The data from pre-experimental inventory supported the use of parametric tests. The pre-experimental data were compared to make sure that there was no imbalance in the sample across grade level. These variables were also used as covariates in multivariate analysis to look at their importance in relation to the dependent variables.

Because the children were randomly assigned to the treatment groups, it was expected that the covariates would not explain variance on the dependent variable. Since Fisher (1926) first introduced the idea to protect against sampling error and bias. For the method to work, it is important that participants in each group should not differ in any systematic way. Thus, there should be an equal opportunity for high and low scores for each treatment and each covariate. Statistical techniques such as analysis of covariance (ANCOVA), multivariate ANCOVA, or both, are often used to adjust for covariate imbalance in the analysis stage of the clinical trial. However, the interpretation of this
postadjustment approach is often difficult because imbalance of covariates frequently leads to unanticipated interaction effects, such as unequal slopes among subgroups of covariates (Frane, 1998; Lomax, 2001). One of the critical assumptions in ANCOVA is that the slopes of regression lines are the same for each group of covariates (ie, homogeneity of regression slopes). The adjustment needed for each covariate group may vary, which is problematic because ANCOVA uses the average slope across the groups to adjust the outcome variable. Thus, the ideal way of balancing covariates among groups is to apply sound randomization in the design stage of a clinical trial (before the adjustment procedure) instead of after data collection. In such instances, random assignment is necessary and guarantees validity for statistical tests of significance that are used to compare treatments.

By employing randomization, researchers offer each participant an equal chance of being assigned to groups, which makes the groups comparable on the dependent variable by eliminating potential bias. Indeed, randomization of treatments in clinical trials is the only means of avoiding systematic characteristic bias of participants assigned to different treatments. Although randomization may be accomplished with a simple coin toss, more appropriate and better methods are often needed, especially in small clinical trials.

**Pre-Experimental Data**

*MCA2 Scores.* Analysis was conducted on students standardized reading scores to make sure that there was no significant difference across grade level. The MCA2 raw scores were normalized using the Minnesota Department of Education Vertical Reading Score
Table. The vertical score table normalizes scores by assigning an equivalent score across grade levels. This was important for comparing student performance across grade level.

<table>
<thead>
<tr>
<th>Descriptive Pre-Experimental</th>
<th>Cut score</th>
<th>Visual</th>
<th>Auditory</th>
<th>Prior Sci</th>
<th>Prior Skate</th>
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</thead>
<tbody>
<tr>
<td>N Valid</td>
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<td>132</td>
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<tr>
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<td>4.09</td>
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</tr>
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<td>2.424</td>
<td>11.43</td>
<td>.189</td>
<td>-.528</td>
</tr>
</tbody>
</table>

Table 1. Descriptive Statistics for Pre-Experimental Analysis

In Table 1, tests for normality indicated that assumptions were met for use of the general linear model. The MCA2 cut scores show a mean average, $x=1.95$, meaning that on average, the students from across grades 6, 7, and 8 were scored in the category does not meet expectations. As can be seen in Table 2 below, 72% of students did not meet expectations. Only 7 of 132 students were listed as having exceeded minimum standards, 30, or approximately 23% met or exceeded minimum expectations in the sample.
So, even though a small percentage of students 28% met minimum expectations, or exceeded them, the majority did not meet minimum expectations.

Based upon the tests for normality presented in table 1, the General Linear Model (GLM) univariate analysis was run to investigate whether there was a difference in performance on the MCA2 across grade level. The raw reading scores were transformed using the Minnesota Department of Education Vertical Reading Score Table to provide continuity across raw scores with vertical scores. These were calculated into cut scores, as defined by the Minnesota Department of Education. The cut scores were used in the General Linear Model for outcomes across grade levels 6, 7, and 8. No significant difference was found in the sample population by grade with $\alpha=.05$ (GLM (F (5, 384)= 2.1, p = .532). With the lack of significance between grade levels indicates that the
students in the sample were scored at the same ability level, and lack some of the same skills in the comprehension assessment measured across grade levels, making their developmental needs similar according to the standardized assessment.

**Working Memory.**

One process that may affect children’s propensity to monitor dimensions is working memory. Working memory refers to the ability to simultaneously manipulate multiple pieces of information in memory (Baddeley, 1986), which is limited (Miller, 1956/1994; van Geert, 1998). Assuming that children are less automatic at understanding language (e.g., Bloom, 1990, Gleason, 2001), and have less experience with narrative schemas (e.g., Hudson & Shapiro, 1991), they must allocate extra cognitive resources to such tasks. This should leave fewer resources for attending to dimensions of a situation model. For example, preschool- and elementary-aged children tend to focus on only one aspect of a problem rather than on multiple components (Piaget & Inhelder, 1969). In late elementary school, sentence and digit-span tasks of working memory explain independent variance in reading comprehension for 8-, 9-, and 11-year-olds (Cain, Oakhill, & Bryant, 2004). Such data suggest that children may not have the cognitive resources to focus on multiple aspects of a problem simultaneously, and that working memory could play a role in children’s ability to monitor multiple dimensions of a narrative.

However, other research on working memory has indicated that working memory may actually be a retrieval/delivery system for new and prior experience. Working memory is measured with response time and amount of information and individual can
remember in a sequence. There are three major working memory systems according to Baddeley (2000): phonological, visual spatial sketchpad, and episodic.

When individuals are asked to recall, they are often timed for delays in response when asked to identify or remember sequences of symbols or content. These delays identification and ability to recall sequences of symbols are thought to indicate limited working memory. This would indicate that working memory might be more of a medium, or indexing system between sensory information and prior memory. However, the way we measure working memory may be a better indication of limited prior knowledge. In a review of working memory research, Barsalou (1993) provides analysis from over two decades of working memory research and provided support for there being three factors that predict response time and correct response: recency, or how recent similar information has been experienced; frequency, or how frequent the individual has experienced and processed similar information; and congruency, or how congruent the context is for new experience, as compared to prior experiences – the more congruent, the greater recall and shorter the response time.

Working memory was measured with the psych experiments online digit span test for auditory and visual working memory. This inventory is used as an intelligence measure in the Wechsler Child (WISC-R) and the Wechsler Adult (WAIS-III), and is used here to examine whether the students in the sample might have an information-processing deficit in working memory.

The test presents strings of digits in a sequence in audio format and visual format to adaptively test for how many digits the participant can remember. The average digit span of an adult is four digits. It was found—see Table 3—that the majority of students
scored a mean average of 4, matching the reported average number of digits of the general population.

This outcome provides evidence that the majority of students have average or better working memory for both auditory and visual processing. Of interest is the difference between auditory and visual. The descriptive statistics (see table 3) indicate that the digit span scores for working memory fit within the criteria for parametric tests. However, the kurtosis indicated that a majority of the scores were concentrated as the mean average $\mu = 4.26$ for visual and $\mu = 4.09$ for auditory. This score coincides with the larger population average of a digit span of 4. The score of 4 indicates that these children had the same average working memory as the general population, and may provide support that prior sensorimotor memory of congruent experience may be more likely to explain variance in performance than working memory.

<table>
<thead>
<tr>
<th>Digit Span Measures for Visual and Auditory Working Memory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digit Span</td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td>1-3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5+</td>
</tr>
</tbody>
</table>

Table 3 Digit Span Measures for Visual and Auditory Working Memory

Based upon the tests for normality, a univariate analysis was conducted to examine the differences in the sample population of auditory and visual memory across grades. No significant difference was noted in either auditory of visual memory across
grade level. This test indicates that the students across grade levels shared similar
working memory according to the digit span test. The frequency chart presented in table
3 indicates that 18.9% of students had an auditory working memory of less than 4. This
would seem to indicate the possibility of some phonological processing difficulty. Out of
that 18.9%, 10.3% scored 2 or less. With outcomes from the analysis of working
memory from the digit span test, prior exposure to content and experience may be more
explanatory for recall and problem solving.

Prior Knowledge.

Because prior knowledge has been shown to influence problem solving (Chi and
Koeske, 1983), and the ability to construct a mental representation (Zwann, Langston, &
Graesser, 1995; Zwann & Radvansky, 1998), inventories were constructed to test
students’ prior knowledge of the science concepts present in the word problem, and
concepts from skateboarding techniques useful in visualization and strategy for problem
solving. These questions were used in pre and post-intervention surveys.

The prior knowledge of science questions were selected from the fifteen-item
inventory students completed after each presentation of the science word problem. Two
middle school science teachers constructed the pretest and inventory questions; the
concepts in the word problem aligned with the NAEP cognitive target categories as a
framework for item construction.

Although this curriculum has been identified in classrooms as early as fourth
grade, the mean scores across grades showed an alarming lack familiarity with the
science concepts. Grade 6 showed a \( \bar{x} = 1.44 \), 7th \( \bar{x} = 1.25 \), and 8th, \( \bar{x} = 1.58 \)—less than 2
of 5 were scored on average. The frequency of scores for prior knowledge of these
science concepts, are depicted below in table 4. The scores indicate that only 9/132, 6.8% of the students had a satisfactory knowledge of the content going into the experiment, which is often introduced by fourth grade.

<table>
<thead>
<tr>
<th>Prior Science</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid 0</td>
<td>39</td>
<td>29.5</td>
<td>29.5</td>
<td>29.5</td>
</tr>
<tr>
<td>1</td>
<td>36</td>
<td>27.3</td>
<td>27.3</td>
<td>56.8</td>
</tr>
<tr>
<td>2</td>
<td>35</td>
<td>26.5</td>
<td>26.5</td>
<td>83.3</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>9.8</td>
<td>9.8</td>
<td>93.2</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>4.5</td>
<td>4.5</td>
<td>97.7</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>2.3</td>
<td>2.3</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>132</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 4 Prior Knowledge of Science Concepts Frequencies Table

Additionally, scores from the prior knowledge of science inventory were used to predict performance on the Walkthrough dimensions for situation model construction. No significance was recorded across grades for prior knowledge of science. In addition to prior knowledge of science, students were asked to share their knowledge of skateboarding. The primary investigator generated the prior knowledge of skateboarding questions. These were drawn from the multiple-choice items from the experimental inventory, which were vetted by trained middle school science teachers. Exploratory data
analysis was performed as discussed previously, indicating that parametric tests could be conducted; although 7th grade scores showed a slightly skewed distribution in the peripheral area. However, Glass, Peckham, & Sanders (1972) found that parametric tests are not seriously affected by violation of assumptions. The descriptive statistics indicated that very few of the students had any knowledge of skateboarding, while a small number demonstrated knowledge of skateboarding in the sample in 7th grade, accounting for the peripheral skewness—see table 1.

Analysis of descriptive statistics described in table 5 indicated that 73.5% of the students inventoried had little or no prior knowledge of skateboarding. Although the majority of students were not aware of the elements of skateboarding from the pre-test, 13% of the students scored 80% or better on the prior-knowledge of skateboarding.
Table 5 Pre-Experimental Frequencies of Prior Knowledge of Skateboarding

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>40</td>
<td>30.3</td>
</tr>
<tr>
<td>1</td>
<td>32</td>
<td>24.2</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>18.9</td>
</tr>
<tr>
<td>3</td>
<td>17</td>
<td>12.9</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>12.1</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>1.6</td>
</tr>
<tr>
<td>Total</td>
<td>132</td>
<td>100.0</td>
</tr>
</tbody>
</table>

After conducting analysis, the outcomes indicated that there was no significant difference across grade levels for prior knowledge of skateboarding with $\alpha = .05$. (GLM (F (1,2) p= 2.56) with mean scores of $6^{th}$= 1.59, $7^{th}$=1.71, and $8^{th}$=1.28. This indicated that the sample was composed of students with very little prior knowledge of the skateboarding concepts for the most part. When the prior knowledge of skateboarding scores was used to predict performance on the Walkthrough dimensions, no significance was recorded.

Exploratory data analysis on the pre-experimental comparisons across grade level indicated that the students in the sample were of similar ability and knowledge across grade levels. With lack of significant difference in prior knowledge of science, in
working memory, standardized reading assessment scores, prior knowledge of skateboarding, the students were not assigned by grade level, but randomly across the presentation order, offsetting any concerns about representative sample.

**Experimental Data: Question 1**

This section seeks to answer *Question 1*:

- Will a video game that emphasizes sensorimotor experience provide greater recall and problem solving as compared to viewing a video, or reading a printed text?

This section utilizes the walkthrough, word problem, and fifteen multiple choice items as paratexts. A paratext supplements an original text, and is not created by the author of the original text. As a paratext, a walkthrough describes a problem space, and is often a map, and includes a set of hints and instructions created by one or more players to help others understand and succeed. The walkthrough activity involved the children creating a paratext as a walkthrough, which is a map and narrative of their experience with all three narratives, embodied game, video, and print text about skateboarding; The word problem consisted of a five-point problem that instructed the child to use their walkthrough to solve to estimate the fastest route through the problem space; The multiple choice questions were designed to assess aspects of situation model construction, as in the walkthrough, and problem solving, as in the word problem.

Before answering questions in the paratexts, the students experienced either the embodied video game, the video, or the printed narrative text and then created the walkthrough from memory to describe the environment and list the possible routes from
beginning to end in the shortest possible time. The walkthrough included a written
narrative describing the hints and actions to best travel these routes.

To help structure the creation of the walkthrough, the students were given
worksheet with instructions and a 7x7 grid for drawing the map. In each cell of the grid,
students were asked to draw what they remembered of the environment and describe the
best route in a narrative. They were told in that the narrative should include hints, tips,
and strategy for other players. They were told that their walkthrough would be used in
another context for other players, and this would make riding the skateboard through the
park easier and more fun for them.

The drawing and narrative were analyzed for each instantiation of the five
dimensions of the event-indexing model: Causality, Temporality, Spatiality, Protagonist,
and Intentionality. These dimensions were then divided by the average of the experts’
scores to create a proportion. Exploratory data analysis provided support for the use of
parametric tests. Analysis of the walkthrough using the General Linear Model indicated
that students experienced greater comprehension after the embodied video game as
compared to the video and the print narrative

**Walkthrough/ Event Indexing Dimensions.** Comparisons of the three media
conditions using the five dimensions of a situation model showed significant differences
between the embodied video game, the video, and the printed text. Wilk’s Lambda was
used for analysis with $\alpha = .05$. The $P$-value is the probability that the effect described here
has occurred by chance, where $\alpha = .05$ thus the $P$-value should be less than $\alpha = .05$ to
reject the null hypothesis, meaning $\mu_1 = \mu_2 = \mu_3 = \ldots = \mu_4$. Analysis indicated there was a
difference in the mean scores between the embodied game, video and text conditions,
therefore the null hypothesis was rejected, (GLM (F (10, 238)= 52.97) p= .000) \( \eta^2 = .69 \), and an Observed Power = 1.0. The analysis indicated that p=.000 meaning that the mean scores were not equal—meaning that the embodied video game, and the video, and printed text did not result in the same mean score. The outcome of this analysis indicates that there is a 99.9% certainty the difference between the media presentation would not occur by chance. Additionally, partial eta squared indicated an approximate effect size of \( \eta^2 = .69 \), meaning there was a medium-large effect with an observed power of 1.0, meaning this was arrived at with some certainty.

Because there was a significant difference between the mean average between the three media conditions in the multivariate analysis, a univariate analysis was performed to see which dimensions showed significance by media condition. Analysis indicates that all dimensions showed significance by media format depicted in table 6 below:

<table>
<thead>
<tr>
<th>Univariate Analysis Across First Media Condition -- Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimension</td>
</tr>
<tr>
<td>Character</td>
</tr>
<tr>
<td>Goal/Motivation</td>
</tr>
<tr>
<td>Causation</td>
</tr>
<tr>
<td>Space</td>
</tr>
<tr>
<td>Time</td>
</tr>
</tbody>
</table>

Table 6 Univariate Analyses of Dimensions First Media

The outcomes of the ANOVAs indicate that the mean-score between the dimensions according to the media condition (game, video, text) were not equal, and the null hypothesis was rejected. The partial eta squared-scores, \( \eta^2 \), indicated that there was an approximate effect size ranging from .45 to .65, which indicates a moderate to medium
effect size according to Cohen (1977), and according to Wolf (1986) the effect size was more than educationally significant, it was clinically significant.

To understand how each dimension for situation model construction was influenced by media condition, the Bonferroni correction for pairwise comparisons was applied. The resulting probability value was used as the criterion for statistical significance. In comparing each dimension according to media format in figure 2 below, results indicate that the children had better recall for the situation model dimensions in the embodied video game media condition as compared to the video and print narrative.

![Figure 2 Comparison of dimensions by media format](image)

Outcomes from the pairwise comparisons in table 7 below indicate that the mean differences in the media condition show that Game > Video > Text in all dimensions except the character dimension. This exception occurred between the game condition and
the video condition, where character did not show a significant difference p= .057. This may be because the video was made from the video game, where the perspective and the experience of the story are very similar. The only difference being that in the embodied game condition, they child controls the avatar, and in the video condition, the child watches the avatar. The difference was *doing* as compared to *viewing*.

<table>
<thead>
<tr>
<th>Pairwise comparison with Bonferroni Adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimen</td>
</tr>
<tr>
<td>sion</td>
</tr>
<tr>
<td>nce</td>
</tr>
<tr>
<td>Chara</td>
</tr>
<tr>
<td>cter</td>
</tr>
<tr>
<td>Goal</td>
</tr>
<tr>
<td>P= .000</td>
</tr>
<tr>
<td>Causal</td>
</tr>
<tr>
<td>ity</td>
</tr>
<tr>
<td>Space</td>
</tr>
<tr>
<td>P= .000</td>
</tr>
<tr>
<td>Time</td>
</tr>
<tr>
<td>P= .000</td>
</tr>
</tbody>
</table>

Table 7 Pairwise comparisons of dimensions across game, video, and text

Across all other dimensions the children in the embodied game narrative outperformed the children in the video and text; and the video condition outperformed the text, meaning Game > Video > Text. This was expected according to the indexical hypothesis, which states that children will struggle to form a mental representation when they cannot connect new information to prior knowledge. Additionally, this finding provides support for the notion of grounding instruction in embodied activities. When
conceptual learning is presented in the form of a text, and the children do not have prior experience, such as sensorimotor memory, it is not likely the children will construct an accurate or coherent situation model, understand the concept, much less use the concept in problem solving.

A case can be made for the role of sensorimotor experience. The pre-experimental inventory indicated that the majority of these children they had little or no prior knowledge of skateboarding, therefore, it may be reasonable to assume that playing an embodied game provided an embodied experience, providing sensorimotor experience for greater likelihood of recall of events, and a more robust situation model. This may either be due to an intentional, memorable action taken by the child to move the narrative along, thus punctuating and segmenting each event by highlighting what elements in the narrative caused changes in the following narrative description.

In order to understand how much more effective the game condition was in comparison to the video and text condition, the effect sizes were calculated for each situation model dimension by media condition, table 7. An effect size is exactly equivalent to a 'Z-score' of a standard Normal distribution. For example, an effect size of 0.8 means that the score of the average person in the experimental group is 0.8 standard deviations above the average person in the control group, and hence exceeds the scores of 79% of the control group. Thus an effect size gives an idea of how much effect the treatment had on where the learner scored in the ability to recall aspects of the narrative.

According to the effect sizes listed in table 7, the degree of difference in recall for the dimensions of the situation model listed in the walkthrough were enormous and present a strong case for the embodied video game experience for event indexing in the
construction of a situation model. To judge the strength of effect size Cohen (1977) stated that a large effect is .8 and above; according to Wolf (1986), an effect size above .25 is categorized as educationally significant, while an effect size above .50 indicates clinical effect, meaning something really changed. What is clearly described in table 7 is that the embodied game had an enormous effect on the ability to recall the situation model dimensions for the walkthrough when compared to the video and text condition. Additionally, the video had an enormous effect on recall as compared to the text condition. The following paragraphs will briefly define each dimension, what it represents in the construction of a situation model, and provide a description of the outcomes for each dimension listed above in table 7.

**Character Dimension.** This dimension indicates awareness of entities such as people, objects, and ideas. As was described in the literature review, characters are the agents that cause events to occur, and their actions are often goal-motivated (Perner & Wimmer, 1987; Trabasso & Nickels, 1992). Research supports the view that children as young as preschool tend to describe events in relation to, or from the perspective of the protagonist in narratives.

After coding for characters, objects, and ideas, the analysis indicates there was a significant difference in recall of the Character dimension using pairwise comparisons between game, video, and printed narrative. The results in table 7 indicate that the game was substantially more effective than the text; and that the video was substantially more effective than the text. The video and game showed no difference, although an analysis of the mean differences did indicate a small effect of the videogame being more effective than the video.
**GoalDimension.** Recall for the goal dimension indicates awareness of the protagonist’s goals and motivation to act in the narrative. When children are able to link the protagonist’s goals across events, the children construct coherence across events. The goals dimension is often linked with the space, time, and causal dimensions in regard to relational information showing ownership, kinship, and social interaction. To assess goal understanding, studies often investigate how children retell stories by assessing the organization, quantity of recalled information, and the inclusion of goal information (e.g. Brown, 1975; Trabasso & Stein, 1997). As was described in the literature review, children age ten through high school have a relatively sophisticated understanding of the importance of goals, and use goals to create titles (van den Broek et al., 2003).

Analysis provided in table 7 indicated that children were more likely to identify the goals dimension in the embodied game condition as compared to the video and print condition. The pattern for likelihood for recall indicates game > video > text. The strength of the effect sizes indicates that embodied video game condition, *doing*, provides greater recall of the goals dimension in the walkthrough.

When the goals dimension was used as a covariate to the other four dimensions, there was no indication of shared variance, meaning that recall of goals was not correlated to the other dimensions. The results from the data in table 7 indicated that students were more likely to include descriptions of the goal dimension in their narrative description in the walkthrough if they experienced the Game.

**Causation Dimension.** The causal dimension refers to how we infer causality. An event can cause or enable another event to occur if the first event is both necessary and sufficient. Such causal relations are important for narratives to be coherent (Trabasso et
al., 1989; van den Broek, 1994). As was described in the literature review, children have a solid grasp of causal relations within and between episodes and respond to questions with answers that reflect the global causal structure of a text by middle school (Goldman & Varnhagen, 1986; van den Broek, 1989). They also use abstract causal logic and make causal inferences (Casteel, 1993; Casteel & Simpson, 1991; van den Broek, 1997).

Analysis of the causal dimension indicated that students were more likely to include descriptions of the causal dimension in their narrative description in the walkthrough if they experienced the Game. Interestingly, comparisons of the mean difference between the video and text condition indicated there was no significant difference in how students recalled causation. This outcome may imply that the embodied video game provided memorable event segmentation and resultant causal relation as compared to viewing and reading the causal relations between narrative events. By virtue of embodied action, the children in the embodied video game condition may be constructing a more memorable causal relationship.

This is supported through effect size analysis using Cohen’s D. There was an enormous effect size of 2.51 between Game and Text; but between Video and Text, only 0.27. However, between Game and Video, again there was an enormous effect size of 2.74. The effect size indicated a very large effect in comparing the game to the other media. As was described previously in this section, a large, or clinical effect is .8 according to Cohen (1977).

Space Dimension. As was described in the literature review, the space dimension refers to children’s ability to monitor space. What is meant by this are the locations where things happen. Because spatial understanding seems to be tied closely to causation,
characters, and time, it is difficult to assess whether development in the ability to understand and monitor space is a byproduct of other dimensions. However, children’s ability to monitor space may be a result of their familiarity of space as a grounded concept. This sensorimotor experience may lead to better recall because it may emphasize the locations of where objects are located, and where action takes place.

As was indicated in table 7, analysis of the space dimension showed a significant difference using pairwise comparisons. The data indicated that students were more likely to include descriptions of the space dimension in the walkthrough if they experienced the embodied game. The effect size of the game as compared to the video and text was enormous. Using Cohen’s D, there was a effect size of 3.95 between Game and Text; and 1.97 between Game and Video. In addition, there was also a large effect size between video and text, indicating that viewing the narrative environment led to better recall than reading about it.

**Time Dimension.** This dimension describes the sequence with which actions and events take place. As was described in the literature review, children of elementary school age into adolescence experience difficulty with remembering stories that are not told in chronological order. By age ten, children are able to choose appropriate temporal and causal conjunctions (Cain, Patson, & Andrews, 2005). They also remember temporal events in different media (Hoffner, et al., 1988), however, performance is facilitated by causation (Hsu et al., 1987).

The analysis presented in table 7, indicate that students were more likely to include descriptions of the time dimension in the walkthrough if they experienced the embodied game condition. Analysis using Cohen’s D indicated that the embodied game
condition had an enormous effect when compared to the video and text condition. Additionally, the video condition showed an enormous effect as compared to the print condition.

**Covariates of dimensions**

Prior research has indicated that the pre-experimental variables may influence children’s ability to build a situation model. However, random assignment across the experimental conditions should have moderated any shared variance. Univariate analysis was conducted to examine the particular dimensions of mental representation. Of the five dimensions, only MCAII Vertical Reading Scores showed significant shared variance, and this was only with the space dimension (GLM (F (1, 131)= 5.26) p= .024). Again, lack of shared variance by the pre-experimental data was expected to be ineffectual based upon random assignment as described previously in this document in the section describing the MCA2 reading assessment.

**Word Problem**

According to the descriptive statistics, the children’s average scores for the word problem were not satisfactory from an instructional perspective. When comparing performance outcomes as depicted below in table 8 across first media conditions, the average score for the game was $\bar{x} = 3.34$. This represents a score of 3.4/5, or about 70%. Although this score represents acceptable performance from a percentage perspective, the score is likely representative of an improved situation model rather than improved problem solving.
### Descriptive Statistics for Q1 word problem

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Game</td>
<td>3.3415</td>
<td>.85469</td>
<td>42</td>
</tr>
<tr>
<td>Video</td>
<td>1.5000</td>
<td>.74377</td>
<td>42</td>
</tr>
<tr>
<td>Text</td>
<td>1.0233</td>
<td>.88609</td>
<td>48</td>
</tr>
<tr>
<td>Total</td>
<td>1.9167</td>
<td>1.27837</td>
<td>132</td>
</tr>
</tbody>
</table>

**Table 8 Descriptives for Q1 word problem**

In order to get a perfect score of 5 students needed to demonstrate: vectors +1, distance estimates +1, velocity +1, use of equation +1, and a correct calculation +1. The mean score indicates that it is likely that 2 of the possible scoring criteria were incomplete or incorrect. Comments from scorers indicated that many of the students struggled to set up the problem correctly with the equation or create a correct calculation. Additionally, many of the children failed to account for the different speed gradients experienced in the embodied game, depicted in the video, and described in the print text.

When frequencies for score were examined, see table 9 below, 71% of the children scored 2 or less, with a resulting 40% correct or classroom scoring.

### Scoring Frequency for Q1 Word Problem

<table>
<thead>
<tr>
<th>Score</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>.00</td>
<td>13</td>
<td>9.8</td>
<td>9.8</td>
<td>9.8</td>
</tr>
<tr>
<td>1.00</td>
<td>24</td>
<td>18.2</td>
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<td>28.0</td>
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<td>57</td>
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<td>43.2</td>
<td>71.2</td>
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<td>3.00</td>
<td>27</td>
<td>20.5</td>
<td>20.5</td>
<td>91.7</td>
</tr>
<tr>
<td>4.00</td>
<td>7</td>
<td>5.3</td>
<td>5.3</td>
<td>97.0</td>
</tr>
<tr>
<td>5.00</td>
<td>4</td>
<td>3.0</td>
<td>3.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>132</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

**Table 9 Scoring Frequencies for Q1 Word Problem**
Comparisons of the three media presentations on the five dimensions showed significant differences between the embodied video game, the video, and the printed text. Wilk’s Lambda was used with $\alpha=.05$. The P-value is the probability that the effect described here has occurred by chance, where $\alpha=.05$ thus the p-value should be less than $\alpha=.05$ to reject the null hypothesis, meaning $\mu_1=\mu_2=\mu_3=\ldots=\mu_4$. Analysis indicated there was a difference in the mean scores between the embodied game, video and text conditions; therefore the null hypothesis was rejected (GLM (F (2, 129)=102.93) p=.000).

**Figure 3 Question 1 Word Problem**

Comparisons of the three media presentations for performance on the word problem, as depicted above in figure 3, indicated significant differences between the embodied video game, the video, and the printed text. Using Wilk’s Lambda with $\alpha=.05$, thus the p-value should be less than $\alpha=.05$ to reject the null hypothesis. Analysis indicated there was a difference in the mean scores between the embodied game, video
and text conditions, (GLM (F (2, 129)=79.9) p=.000). Because p=.000, the null hypothesis was rejected.

<table>
<thead>
<tr>
<th></th>
<th>Game to Text</th>
<th>Game to video</th>
<th>Video to Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Difference</td>
<td>2.23</td>
<td>1.85</td>
<td>.38</td>
</tr>
<tr>
<td>Effect size</td>
<td>2.69 Giant</td>
<td>2.69 Giant</td>
<td>.59 Medium</td>
</tr>
<tr>
<td>Cohen’s D</td>
<td>P=.000</td>
<td>P=.000</td>
<td>P=.000</td>
</tr>
</tbody>
</table>

Table 10 Word Problem Pairwise Comparisons for Q1 Integrate & Interpret

Using Pairwise comparisons with Bonferroni Adjustment and Cohen’s D for effect size, presented in table 8 above, the children in the game condition showed more effective performance in solving the word problem. This is likely indicative of the creation of a more accurate and coherent walkthrough, since the walkthrough was used to solve the word problem.

Additionally, though the children were randomly assigned to media conditions, when the MCA2 score from the pre-experimental was used as a covariate, the data showed shared variance with the word problem (GLM (F (1, 131)=17.84) p=.000), indicating that performance on aspects of the comprehension assessment may be congruent with performance on the word problem.

Multiple-Choice Inventories

In the Multiple Choice sublevel, a univariate analysis was conducted to test the effectiveness of media format for constructing mental representation and problem solving on fifteen multiple choice questions. Comparisons of the three media presentations (game, video, and printed text) were conducted on fifteen multiple-choice items. These items were grouped into two separate categories from the NAEP Cognitive Targets:
Locate and Recall, and Interpret and Integrate. Each analysis was done using a GLM univariate analysis with Wilk’s Lambda with \( p = .05 \) outcomes.

Locate and Recall Cognitive Targets. There were five questions in this category. The descriptive statistics indicated that the average score of the children who played the embodied game scored \( \bar{x} = 3.8 \). This is approximate 4/5, or 80%.

### Descriptive Statistics Locate & Recall

<table>
<thead>
<tr>
<th>Media</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Game</td>
<td>3.8049</td>
<td>.90054</td>
<td>42</td>
</tr>
<tr>
<td>Video</td>
<td>3.2083</td>
<td>1.33621</td>
<td>42</td>
</tr>
<tr>
<td>Text</td>
<td>1.5116</td>
<td>1.27936</td>
<td>48</td>
</tr>
<tr>
<td>Total</td>
<td>2.8409</td>
<td>1.52751</td>
<td>132</td>
</tr>
</tbody>
</table>

Table 11 Descriptive Statistics Locate and Recall

Analysis showed (GLM (F (2, 131) = 71.23) \( p = .000 \)) \( \eta^2 = .54 \), OP= 1.0. Because \( p = .000 \), the null hypothesis was rejected indicating that there were differences between the embodied game, the video, and the text. In order to examine the impact that each media condition had on the children’s performance with the multiple-choice items, pairwise analysis was conducted using the Bonferroni Adjustment as displayed below in table 11.

### Pairwise comparison Locate and Recall

<table>
<thead>
<tr>
<th>Game to Text</th>
<th>Game to video</th>
<th>Video to Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Differ</td>
<td>Effect size</td>
<td>Mean Differ</td>
</tr>
<tr>
<td>Difference</td>
<td>Cohen’s D</td>
<td>Difference</td>
</tr>
<tr>
<td>Score</td>
<td></td>
<td>Score</td>
</tr>
<tr>
<td>2.06</td>
<td>.000</td>
<td>2.07</td>
</tr>
<tr>
<td>1.5</td>
<td>.000</td>
<td>1.31</td>
</tr>
</tbody>
</table>

Table 12 Pairwise Comparisons with Bonferroni Adjustment for Locate and Recall Items
The analysis indicates that the children in the game condition showed more effective performance in the *Locate and Recall* multiple-choice items. This is reflective of the performance the children displayed in the walkthrough. The score is congruent with the findings of the walkthrough, as the *locate and recall* multiple-choice items were constructed to assess whether students could identify the main idea, recall characters, locate objects, recall causal relations, and in general, recall content from the narrative. Thus, the *locate and recall* items are very similar to the dimensions identified in a situation model. Additionally, the outcomes are congruent with the walkthrough outcomes.

In order to examine whether the pre-experimental data might share variance with the *locate and recall* items, the pre-experimental data were used as covariates; Only the MCA2 reading comprehension cut score (GLM (F (1, 131) 92.77) p= .000) showed significance. Working memory and prior knowledge of science or skateboarding did not show significance for shared variance.

*Integrate / Interpret Cognitive Targets.* There were ten questions in this category. Ten items were chosen for this category, as compared to 5 in *locate and recall*, because the *integrate and interpret* category were constructed to assess problem solving and higher-level process.

The descriptive statistics in table 12 below indicated that the average score of the children who played the embodied game scored $\bar{x}=3.4$. Although the score from the embodied game was much better than score of the video $\bar{x}=2.7$, and the text, $\bar{x}=1.0$, the embodied game average score represents an instructional outcome of approximately 3.4/10 or 34%.
Descriptive Statistics for Integrate & Interpret

<table>
<thead>
<tr>
<th>Media</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Game</td>
<td>3.4250</td>
<td>3.49276</td>
<td>42</td>
</tr>
<tr>
<td>Video</td>
<td>2.7292</td>
<td>2.30392</td>
<td>42</td>
</tr>
<tr>
<td>Text</td>
<td>1.0000</td>
<td>1.28784</td>
<td>48</td>
</tr>
<tr>
<td>Total</td>
<td>2.3846</td>
<td>2.67456</td>
<td>132</td>
</tr>
</tbody>
</table>

Table 13 Descriptive Statistics for Integrate and Interpret

Though this is disappointing, this outcome is congruent with the outcomes from the word problem, where the children were capable of the recalling aspects of the narrative, but not in using the equation or reaching a correct answer.

Analysis using the General Linear Model showed (GLM (F (2, 130) = 10.82) p = .000). Because p = .000, the null hypothesis was rejected. The p-value indicated that there were differences between the embodied game, the video, and the text. In order to examine the impact that each media condition had on the children’s performance with the Integrate and Interpret multiple-choice items, pairwise analysis was conducted using the Bonferroni Adjustment as displayed below in table 13.

| Pairwise comparison with Bonferroni Adjustment for Integrate and Interpret Multiple-Choice Items |
|-------------------------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Game to Text Mean Difference | Effect size Cohen’s D | Game to video Mean Difference | Effect size Cohen’s D | Video to Text Mean Difference | Effect size Cohen’s D |
| Score | 1.96 | P = .000 | .96 | None | None | 1.12 | P = .012 | .95 | Giant |

Table 14 Pairwise Comparisons with Bonferroni Adjustment for Integrate and Interpret

The analysis indicates that the children in the game condition showed more effective performance in the Integrate and Interpret multiple-choice items. This is reflective of the
performance the children displayed in the word problem. The score is congruent with the findings of the word problem, as the *Integrate and Interpret* multiple-choice items were constructed to assess higher order problem solving and reasoning.

![Graph](image)

*Figure 4 Locate & Recall and Integrate and Interpret Multiple-Choice Items from Set*

Analysis of the multiple-choice items depicted in figure 4 indicate that in both the *locate and recall* items, and the *Integrate and Interpret* items that the children’s performance in the video game condition was superior to their performance in the video and text condition. The order of performance indicate that the game > video > text. The analysis indicates that the children in the game condition showed more effective performance in the *Locate and Recall* multiple-choice items. This score is congruent with the findings of the walkthrough, as the *Locate and Recall* multiple-choice items were constructed to assess whether students could identify the main idea, recall characters, locate objects, recall causal relations, and in general, recall content from the
narrative. Thus, the *locate and recall* items are very similar to the dimensions identified in a situation model.

Additionally, figure 4, the children’s performance with the *Integrate and Interpret* items are similar to the higher order problem solving identified in the word problem, where the children were not capable of taking the more accurate and coherent situation model identified in the walkthrough and first five items and using this to perform higher order problem solving.

This aligns with research in skill acquisition. Simon and Chase (1973) proposed that future experts gradually acquired patterns and knowledge about how to react in situations by storing memories of their past actions in similar situations. Learners, who lack experience and world knowledge necessary to build a situation model necessary for inference, may still need to develop and practice the strategies for scientific problem solving (Ericsson & Kintsch, 1995).

Analysis from the pre-experimental inventory on *prior science* indicated that the children were not conversant with the problem, the concepts, or the process. It may take more than an accurate and coherent situation model to engage in higher order problem solving—especially from such a brief intervention.

In order to examine whether the pre-experimental data might share variance with the *locate and recall* items, the pre-experimental data were used as covariates; only the MCA2 reading comprehension cut score showed significance (GLM (F (1, 130) 252.64) p=.000). Working memory and prior knowledge of science or skateboarding did not show significance for shared variance.
Experimental Setting, Question 2

Previous work has examined the role of embodied activities on reading performance, which has found that instruction which emphasizes sensorimotor experience and visualization has been found to improve the ability to read and comprehend printed text (Glenberg, Brown & Levin, 2007; Glenberg, Gutierrez, Levin, & Japuntich, 2004).

To examine this, the outcomes of the printed text condition were compared across presentation order to answer the question:

- Will performance in the reading condition improve if it follows the game or the viewing condition?

Analysis was conducted comparing student performance in the walkthrough condition of the five dimensions of the Event Indexing Model, the fifteen multiple-choice items, and the problem solution across the presentation order of the text condition, where

<table>
<thead>
<tr>
<th>Setting 3 Analysis for Reading Print Text Across Presentation Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presentation Order</td>
</tr>
<tr>
<td>Text₁</td>
</tr>
<tr>
<td>Video</td>
</tr>
<tr>
<td>Video</td>
</tr>
<tr>
<td>Text₁</td>
</tr>
<tr>
<td>Game</td>
</tr>
<tr>
<td>Game</td>
</tr>
</tbody>
</table>

Figure 5 Across Presentation Order Q2
The printed text condition, which relies upon reading the narrative for presenting information was compared for comprehension and problem solving outcomes across presentation order, as depicted in figure 5—meaning a comparison of when Text is presented first and when Text follows the game, the video or both game and video.

**Walkthrough/Event Indexing Dimensions.** As was depicted in figure 5, the print text condition was compared across presentation order, meaning Text1, Text2, and Text3. The reason for this analysis was to evaluate whether student performance improved if the text condition followed the embodied game, the video, or both. Analysis of the text condition indicated that recall for the five dimensions showed significant differences between Text1, Text2, and Text3. Using Wilk’s Lambda with \( \alpha = .05 \), the P-value is the probability that the effect described here has occurred by chance, where \( \alpha = .05 \) thus the p-value should be less than \( \alpha = .05 \) to reject the null hypothesis. Analysis indicated there was a difference in the mean scores between the Text1, Text2, and Text3 conditions, therefore the null hypothesis was rejected, (GLM \( F (10, 248) = 104.4 \) \( p = .000 \)) \( \eta^2 = .81 \), OP= 1.0. In this analysis, \( \eta^2 = .81 \) indicating an approximate effect size of .81, meaning that one of the three Text conditions across the presentation order experienced a large effect. Additionally, the rejection of the null hypothesis is done with an observed power of 1.0, meaning it was done with some certainty.

Because there was a significant difference between the mean average between the three media conditions in the multivariate analysis, a univariate analysis was performed to see which dimensions showed significance by media condition. Analysis indicates that all dimensions showed significance by Text presentation order as depicted in table 14 below:
The outcomes of the ANOVAs indicate that the mean-score between the dimensions according to the Text condition when compared across presentation order (Text1, Text2, and Text3) were not equal, and the null hypothesis was rejected.

To understand how each dimension for situation model construction was influenced by presentation order of the Text condition, the Bonferroni correction for pairwise comparisons was applied.

| Univariate Analysis Across Text Presentation Condition –Dimensions |
|------------------------|--------|-------|-------|
| Dimension | ν | F stat | P-value |
| Character | 2, 129 | 4.78 | .01 |
| Goal/Motivation | 2, 129 | 17.07 | .000 |
| Causation | 2, 129 | 48.29 | .000 |
| Space | 2, 129 | 370.82 | .000 |
| Time | 2, 129 | 1.06 | .35 |

Table 15 Univariate Analyses of Dimensions Text Across Presentation Order

Examination of the output presented in figure 6 indicates that there was a significant difference between Text1 and Text2, Text1 and Text3, but there was little to no difference between Text2 and Text3. For this reason a second set of analyses were
performed in order to examine whether the differences between Text\textsubscript{1} and Text\textsubscript{2} were influenced most when Text\textsubscript{2} followed the embodied video game, or the video.

Using Wilk’s Lambda with $\alpha = .05$, the P-value is the probability that the effect described here has occurred by chance, where $\alpha = .05$ thus the p-value should be less than $\alpha = .05$ to reject the null hypothesis. Analysis indicated there was a difference in the mean scores in Text\textsubscript{2} between following the embodied video game and the video, thus the null hypothesis was rejected, (GLM (F (5, 119) = 120.654) $p = .000$) Because $p < .05$, the null hypothesis was rejected.

To understand how each dimension for situation model construction was influenced by media condition, tests of Between-Subjects Effects were conducted. The resulting probability value was used as the criterion for statistical significance. Using Wilk’s Lambda with $\alpha = .05$, the P-value is the probability that the effect described here has occurred by chance, where $\alpha = .05$ thus the p-value should be less than $\alpha = .05$ to reject the null hypothesis. Analysis indicated there was a difference in the mean scores of the dimensions comparing Text\textsubscript{2} when it followed either the embodied video game or the video, thus the null hypothesis was rejected. table 15 below:
The outcomes of the ANOVAs indicate that the mean-score between the dimensions when Text$_2$ was followed by either the video or the game. Analysis of table 15, above, indicates that the means were not equal, and the null hypothesis was rejected. The partial eta squared-scores, $\eta^2$, indicated that there was an approximate effect size ranging from .36 to .74, which indicates a moderate to medium effect size according to Cohen (1977), and according to Wolf (1986) the effect size was more than educationally significant, it was clinically significant.

By graphically depicting the mean for each dimension of the Text$_2$, Figure 7 shows how significantly the game influenced the Text$_2$ condition when compared to the influence of the video.
In order to know how much more influence the embodied game had on the Text2 mean difference comparisons were created for walkthrough along with calculations of effect size using Cohen’s D (1977), shown below in table 16.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Video Game to Video in Text2</th>
<th>Effect size Cohen’s D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Character</td>
<td>0.45</td>
<td>3.36 Giant</td>
</tr>
<tr>
<td></td>
<td>P = .000</td>
<td></td>
</tr>
<tr>
<td>Goal</td>
<td>0.29</td>
<td>2.8 Giant</td>
</tr>
<tr>
<td></td>
<td>P = .000</td>
<td></td>
</tr>
<tr>
<td>Causality</td>
<td>0.36</td>
<td>3.4 Giant</td>
</tr>
<tr>
<td></td>
<td>P = .000</td>
<td></td>
</tr>
<tr>
<td>Space</td>
<td>0.23</td>
<td>1.6 Giant</td>
</tr>
<tr>
<td></td>
<td>P = .000</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>0.25</td>
<td>1.8 Giant</td>
</tr>
<tr>
<td></td>
<td>P = .000</td>
<td></td>
</tr>
</tbody>
</table>

Table 18 Pairwise Comparisons for Media-Specific Influence in Text2

Figure 7 Mean Scores Across Text in Q2
The outcomes of table 16 support that the children had improved comprehension outcomes in the walkthrough if they experienced the embodied video game prior to experiencing the text condition. In order to understand how much more effective the game condition was in comparison to the video for improved response to the text, consider that an effect size is exactly equivalent to a 'Z-score' of a standard Normal distribution. For example, an effect size of 0.8 means that the score of the average person in the experimental group is 0.8 standard deviations above the average person in the control group, and hence exceeds the scores of 79% of the control group. Thus an effect size gives an idea of how much effect the treatment had on where the learner scored in the ability to recall aspects of the narrative.

According to the effect sizes listed in table 16, the degree of difference in recall for the dimensions of the situation model listed in the walkthrough were enormous and present a strong case for the embodied video game experience prior to reading a print narrative for event indexing in the construction of a situation model. The effect size reported for each dimension was very large, ranging between 1.6 and 3.36. This strongly suggests that if the Text condition follows an embodied video game, children will have improved ability to construct a situation model, and greater comprehension as a result of reading the text. Much more so than if they watch a video, or just read a text with no prior experience.

To judge the strength of effect size as was reported in table 16, Cohen (1977) stated that a large effect is .8 and above; according to Wolf (1986), an effect size above .25 is categorized as educationally significant, while an effect size above .50 indicates clinical effect, meaning something really changed. With effect sizes ranging between 1.6
and 3.36, something did change when the text was preceded by the embodied game, as compared to watching a video.

**Word Problem**

According to the descriptive statistics, the children did not show acceptable performance on the word problem. When comparing performance outcomes as depicted below in table 8 across first media conditions, the best average score occurred in the third text condition, which according to table 16 below was $x = 3.36$. When compared to the embodied game condition in the first presentation, $x = 3.34$, this is not much growth. The best score represents a score about 70% on the problem. Although this score represents adequate performance from a percentage perspective, the score is likely representative of an improved situation model rather than improved problem solving as was discussed in the previous word problem results in analysis setting 2.

In order to get a perfect score of 5 on the word problem, students needed to demonstrate: vectors +1, distance estimates +1, velocity +1, use of equation +1, and a correct calculation +1. The mean score indicates that it is likely that 2 of the possible scoring criteria were incomplete or incorrect. Comments from scorers indicated that many of the students struggled to set up the problem correctly with the equation or create a correct calculation. Additionally, many of the children failed to account for the different speed gradients experienced in the embodied game, depicted in the video, and described in the print text.
Comparisons of the three media presentations on the five dimensions showed significant differences between the embodied video game, the video, and the printed text. Wilk’s Lambda was used with $\alpha = .05$. The P-value is the probability that the effect described here has occurred by chance, where $\alpha = .05$ thus the p-value should be less than $\alpha = .05$ to reject the null hypothesis.

Analysis indicated there was a difference in the mean scores across the presentation order of the print text narrative, as depicted below in figure 8. Therefore the null hypothesis was rejected (GLM (F (2, 129)=79.9) p= .000).
Because the null hypothesis was rejected, further analysis was conducted to look at whether there were differences in performance based upon when the child experienced the Text condition.

<table>
<thead>
<tr>
<th>Pairwise comparison with Bonferroni Adjustment for word problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text_1 to Text_2</td>
</tr>
<tr>
<td>Mean Difference</td>
</tr>
<tr>
<td>Score</td>
</tr>
</tbody>
</table>

Table 10 Pairwise comparison for word problem
In pairwise comparisons using the Bonferroni adjustment to compare the printed text narrative across presentation order, there was a significant difference in performance on the word problem scores for the print text media condition if it was experienced first, second, or last. Although there was significance between the three text presentations for problem solving score, it is of interest for this study to examine whether there was greater success in Text\(_2\), if Text\(_2\) followed the embodied game, or the video. For this reason analysis was conducted comparing Text\(_2\) outcomes to know whether the embodied game or the video accounted for the difference. Univariate analysis was conducted using Wilk’s Lambda with \(\alpha = .05\). The P-value is the probability that the effect described here has occurred by chance, where \(\alpha = .05\) thus the p-value should be less than \(\alpha = .05\) to reject the null hypothesis. (GLM (F (1, 41) = 20.91) p=.000) because \(p < .05\), the null hypothesis was rejected, indicating there was a difference in the mean scores.

In order to identify whether the embodied game or the video led to greater improvement in word problem performance, the descriptive statistics were examined along with the mean differences, which were examined for effect size using Cohen’s D.

<table>
<thead>
<tr>
<th>Comparison for Mean Difference and Effect Size for Word Problem</th>
<th>FollowsGame to</th>
<th>FollowsVideo</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Difference</td>
<td>Effect size</td>
</tr>
<tr>
<td>Score</td>
<td>1.22</td>
<td>1.6</td>
</tr>
</tbody>
</table>

| Table 11 Comparisons for Text\(_2\) for Prior Media Effect |

The analysis in table 17 above indicates that if the Text\(_2\) condition follows the embodied video game, there will be a significant difference in performance on the word
problem by over 20%. The calculation for effect size indicates that if the children played the embodied game prior to reading the printed text, there would be a great improvement based upon the outcomes from calculations for mean difference and effect size. To judge the strength of effect size as was reported in table 17, Cohen (1977) stated that a large effect is .8 and above; according to Wolf (1986), an effect size above .25 is categorized as educationally significant, while an effect size above .50 indicates clinical effect, meaning something really changed. With an effect size of 1.6, it is evident that something changed when the text was preceded by the embodied game, as compared to watching a video.

**Multiple Choice items**

A multivariate analysis was conducted to test for differences in the printed text reading condition through comparing the multiple choice performance of the children across presentation order, and performance differences when the text followed the embodied game as compared to following the video. A comparison was made across the presentation order of the three Text conditions: Text₁, Text₂, and Text₃, comparing the performance of the children on the fifteen multiple-choice items. These items were grouped into two separate categories from the NAEP Cognitive Targets: Locate and Recall, and Interpret and Integrate.

**Locate and Recall Cognitive Targets.** There were five questions in this category compared by media condition TEXT by presentation order: Text₁, Text₂, and Text₃. The descriptive statistics in table 18 below show that the children performed better with the Locate and Recall questions in the Text condition if the Text condition followed the
embodied game, the video, or both, i.e., Text + Game + Video < Text + Game or Video < Text.

**Across Reading Order Descriptive Statistics Locate & Recall**

<table>
<thead>
<tr>
<th>Order</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text1</td>
<td>1.51</td>
<td>1.27</td>
<td>48</td>
</tr>
<tr>
<td>Text2</td>
<td>3.58</td>
<td>1.18</td>
<td>42</td>
</tr>
<tr>
<td>Text3</td>
<td>4.55</td>
<td>.65</td>
<td>42</td>
</tr>
<tr>
<td>Total</td>
<td>3.25</td>
<td>1.6</td>
<td>132</td>
</tr>
</tbody>
</table>

Table 22 Across Reading Descriptives Statistics for Locate and Recall

When the three text conditions were compared, analysis indicated that the order in which TEXT was experienced was significant. Wilk’s Lambda was used with $\alpha=.05$. The P-value is the probability that the effect described here has occurred by chance, where $\alpha=.05$ thus the p-value should be less than $\alpha=.05$ to reject the null hypothesis (GLM (F (2, 130) = 95.07) $p=.000$ $\eta^2=.6$, OP= 1.0. Analysis indicated there was a difference in the mean scores across the presentation order of the Text condition. So when the children experienced the text influenced how successful they were in answering the questions.

**Pairwise comparison with Bonferroni Adjustment for Locate and Recall Multiple Choice Items**

<table>
<thead>
<tr>
<th>Score</th>
<th>Text1 to Text2 Mean Difference</th>
<th>Effect size Cohen’s D</th>
<th>P=</th>
<th>Text1 to Text3 Mean Difference</th>
<th>Effect size Cohen’s D</th>
<th>P=</th>
<th>Text2 to Text3 Mean Difference</th>
<th>Effect size Cohen’s D</th>
<th>P=</th>
</tr>
</thead>
<tbody>
<tr>
<td>-2.07</td>
<td>-2.07</td>
<td>1.07</td>
<td>.000</td>
<td>3.04</td>
<td>.97</td>
<td>.000</td>
<td>1.02</td>
<td>1.02</td>
<td>.000</td>
</tr>
</tbody>
</table>

Table 23 Pairwise Comparison of Reading Order Performance

The outcomes of the analysis listed in table 19 above indicate that if the print text narrative condition is placed after the other media, performance improves. There is a
difference for 3 points between the Text reading condition if it is experienced first as compared to reading the print narrative after experiencing both the game and the narrative. This is congruent with the performance the children displayed in the walkthrough. This is reasonable as the walkthrough and the locate and recall multiple-choice items were constructed to assess whether students could identify the main idea, recall characters, locate objects, recall causal relations, and in general, recall content from the narrative. Thus, the locate and recall items are very similar to the dimensions identified in a situation model.

In order to know whether the children would perform better if they experienced either the embodied game or the video before the print condition, analysis was conducted for mean differences and effect size. Analysis indicates that

<table>
<thead>
<tr>
<th>Comparison for Mean Difference and Effect Size for Locate and Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text Follows Game Compared to Text Follows Video</td>
</tr>
<tr>
<td>Mean Difference</td>
</tr>
<tr>
<td>Score</td>
</tr>
<tr>
<td>P= .143</td>
</tr>
</tbody>
</table>

The analysis indicates that the null hypothesis was not rejected, and this indicates that the children were just as successful with the video prior to the text condition as they were with the embodied game. The analyses across the presentation of the three Texts indicate that the students may have scored better because the children had a "second chance" with the questions. They could have simply ignored the texts and worked from
memory to perform the task the second time and could then be attributed to a double-test effect.

Integrate / Interpret.

There were ten questions in this category. Performance was compared by student outcomes in the text condition by presentation order: Text1, Text2, and Text3. The descriptive statistics in table 18 below indicate that the children performed better with the Integrate and Interpret questions in the second Text condition.

<table>
<thead>
<tr>
<th>Order</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text1</td>
<td>1.00</td>
<td>1.29</td>
<td>48</td>
</tr>
<tr>
<td>Text2</td>
<td>3.63</td>
<td>3.61</td>
<td>42</td>
</tr>
<tr>
<td>Text3</td>
<td>3.80</td>
<td>2.86</td>
<td>42</td>
</tr>
<tr>
<td>Total</td>
<td>2.83</td>
<td>3.02</td>
<td>132</td>
</tr>
</tbody>
</table>

When the three text conditions were compared, analysis indicated that the order in which TEXT was experienced was significant. Wilk’s Lambda was used with $\alpha = .05$. The P-value is the probability that the effect described here has occurred by chance, where $\alpha = .05$ thus the p-value should be less than $\alpha = .05$ to reject the null hypothesis (GLM (F (2, 129) = 13.85) p= .000) $\eta^2 = .18$, OP= .99. Analysis indicated there was a significant difference in the mean scores across the presentation order of the Text condition. So the order in which the children experienced the text influenced, the when influenced how successful they were in answering the Integrate and Interpret questions.
Analysis provided in Table 21, above, indicates that the performance of the children with the *Integrate and Interpret* multiple-choice items showed the greatest gain between the first text condition and the third. However, the difference shown between text condition 2 and text condition 3 was not significant, \( p = 1.0 \). The In order to understand the performance gain between Text condition 1 and Text condition 2 whether the children would perform better with the embodied game or the video prior to the text. Analysis was conducted for mean differences and effect size.

<table>
<thead>
<tr>
<th>Text1 to Text2</th>
<th>Text1 to Text3</th>
<th>Text2 to Text3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean Difference</strong></td>
<td><strong>Effect size Cohen’s D</strong></td>
<td><strong>Mean Difference</strong></td>
</tr>
<tr>
<td>Score</td>
<td>P= .000</td>
<td>-2.63</td>
</tr>
</tbody>
</table>

Table 26 Pairwise Comparisons for Integrate and Interpret

**Comparison for Mean Difference and Effect Size for Locate and Recall**

<table>
<thead>
<tr>
<th>Text Follows Game Compared to Text Follows Video</th>
<th>Mean Difference</th>
<th>Effect size Cohen’s D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2</td>
<td>P= .285</td>
<td>.35</td>
</tr>
</tbody>
</table>

Table 27 Comparisons for Prior Media Effect on Text2

The analysis indicates that the null hypothesis was not rejected, and this indicates that the children were just as successful with the video prior to the text condition as they were with the embodied game. The analyses across the presentation of the three Texts
indicate that the students may have scored better because the children had a "second chance" with the questions. They could have simply ignored the texts and worked from memory to perform the task the second time and could then be attributed to a double-test effect.

Regardless of the double test effect, the children’s scores on the Integrate and Interpret questions were not acceptable for instructional purposes. The best average score from the third text condition was only 3.8/10, meaning the children scored 38% on the problem-solving portion of the multiple-choice items.

Analysis of the multiple-choice items depicted in figure 4 indicate that in both the Locate and Recall items, and the Integrate and Interpret items that the children’s performance in the video game condition was superior to their performance in the video and text condition. The order of performance indicate that the game > video > text. The analysis indicates that the children in the game condition showed more effective performance in the Locate and Recall multiple-choice items. This is reflective of the performance the children displayed in the walkthrough. The score is congruent with the findings of the walkthrough, as the Locate and Recall multiple-choice items were constructed to assess whether students could identify the main idea, recall characters, locate objects, recall causal relations, and in general, recall content from the narrative. Thus, the Locate and Recall items are very similar to the dimensions identified in a situation model with outcomes that are congruent with the walkthrough outcomes.

Additionally, the children’s performance with the Integrate and Interpret items are similar to the higher order problem solving identified in the word problem, where the children were not capable of taking the more accurate and coherent situation model
identified in the walkthrough and first five items and using this to perform higher order problem solving. This aligns with the view that problem solving comes from creating categories and terms for processes and patterns for problem solving, such as in chess, literary interpretation (genre-level elements), and scientific problem solving. Thus, the outcomes presented here align with research in skill acquisition. Simon and Chase (1973) proposed that future experts gradually acquired patterns and knowledge about how to react in situations by storing memories of their past actions in similar situations. Children, who lack experience and world knowledge necessary to build a situation model necessary for inference, may still need to develop and practice the strategies for scientific problem solving (Ericsson & Kintsch, 1995). Additionally, analysis from the pre-experimental inventory on prior science indicated that the children were not conversant with the problem, the concepts, or the process. It may take more than an accurate and coherent situation model to engage in higher order problem solving—especially after such a brief intervention.

**Experimental Data, Question 3**

In setting four, the univariate general linear model was used to compare comprehension outcomes in a. Setting four consisted of a comparison of the initial media presentation conditions to answer the question:

- How does the identification causation predict building a mental representation and problem solving?

When the causal dimension was used as a covariate with the other four dimensions, there was statistical significance using Wilk’s Lambda with $p=.05$ outcomes
showed (GLM (F (4, 391)= 1342.08) p=.000). When univariate analysis was done by dimension, all dimensions showed significance by media format in relation to the causal dimension:

<table>
<thead>
<tr>
<th>Dimension</th>
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<td>Time</td>
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<td>.000</td>
</tr>
</tbody>
</table>

Table 28 Analysis of dimensions for covariance

This finding indicates that the ability to identify causality in the media conditions may be connected to identification of the other dimensions described in the construction of a situation model. The causal dimension refers to how we infer causality. So the identification of event can cause or enable another event to occur if the first event is both necessary and sufficient. Such causal relations are important for narratives to be coherent (Trabasso et al., 1989; van den Broek, 1994). As was described previously in the literature review, children have a solid grasp of causal relations within the structure of a text by middle school (Goldman & Varnhagen, 1986; van den Broek, 1989). They also use abstract causal logic and make causal inferences (Casteel, 1993; Casteel & Simpson, 1991; van den Broek, 1997).

The ability to identify causation is integral to completing the walkthrough assignment, so the awareness of causation was encouraged through the measures and activities. Analysis of the causal dimension indicated that students were more likely to include descriptions of the causal dimension in their narrative description in the walkthrough if they were able to identify causation.
CHAPTER V.

Discussion

The first four chapters of this dissertation presented the research problem, purpose and significance of the study; reviewed the professional and research literature on the sensorimotor system’s contribution to comprehension and problem solving; and described the experimental design, methodology and results. This chapter is devoted to a discussion of the results and what they do and do not contribute to the research and knowledge base related to effects of embodied learning, working memory and prior knowledge, comprehension, and problem solving. This chapter also includes practical discussions of educational implications based on results and how they may be used to inform decisions about making independent reading part of the school day.

There was a statistically significant difference regarding question one. It was found that the video game, which emphasized sensorimotor experience, provided greater recall and problem solving as compared to viewing a video, or reading a printed text. For this reason the null hypothesis was rejected. According to causal network analysis, students created a more robust mental representation in the walkthrough map and narrative after the embodied video game treatment. All of the five dimensions: the TimeDimension, the GoalDimension, CausalDimension, SpaceDimension, and CharacterDimension were statistically superior in the embodied videogame—outperforming the video and printed text media conditions.

There was also a statistically significant improvement when students provided a solution to the STEM word problem and answered the multiple-choice questions after playing the embodied videogame. This outcome supports the position that having a
superior mental representation can lead to superior performance in problem solving. However, the outcomes of the word problem indicate that the children struggled with the calculation time = rate/distance. The multiple-choice outcomes showed superior performance in both Locate and Recall, and Integrate and Interpret. However, scores in Integrate and Interpret were not satisfactory for academic assessment. The scores out of the ten Integrate and Interpret questions—related to scientific problem solving—were a low percentage for performance, and not acceptable to for classroom outcomes. Indications are that the children may need more time and direct instruction in how to perform the calculations and how to support a conclusion, as has been documented in the literature review.

When the pre-experimental variables: prior knowledge of science and skateboarding, working memory, and media preference were used as covariates for the five dimensions of the walkthrough, only one of five covariates, the MCA2 Vertical Reading Scores, showed significance, and this was related to SpacePerformance (GLM (F (1, 131)= 5.26) p= .024). Again, lack of influence by the pre-experimental data was expected based upon random assignment of the sample to experimental conditions.

For question two, performance in the reading condition did improve if it followed the game and the viewing condition. For this reason, the null hypothesis was rejected. There was a statistically significant difference in the reading condition across the treatment order. Comprehension and problem solving both improved when comparing the five dimensions of mental representation from the walkthrough, performance on the fifteen multiple-choice inventory, and solutions for the STEM word problem. These
outcomes are similar to the outcomes from the analysis from question 1. The reading performance outcomes did improve more if they followed the game.

Question three explored whether the role of causation in predicting the construction of a mental representation and problem solving. Analysis indicates that there was a statistically significant difference in how identification of causation predicts building a mental representation and problem solving. These outcomes support the position that comprehension and problem solving are improved through media that emphasize sensorimotor activity. The ability to identify causation was important in construction of the walkthrough, and integral to the word problem and multiple-choice questions. The embodied game emphasized causation through participating in causing the narrative events to change, and may result in greater recall of comprehension such as temporality, spatiality, intentionality, and objects.

**Discussion of Findings and Recommendations**

This experimental study provides statistical evidence that students who played an embodied video game outperformed control groups who watched a video or read a printed text with the same content. Comprehension and problem solving were superior in the video game condition for in creating a walkthrough, solving a STEM word problem, and answering fifteen multiple choice items from the NAEP cognitive targets. This is an important finding for teachers, policy makers, and comprehension and problem solving researchers, especially as it relates to classroom practice, notions of remediation, and for assessment.
The general conclusion from this study was that the students benefit from the embodied experience of the video game for comprehension and problem solving. The children in the study had struggles with academic performance in the classroom and on standardized tests. The majorities of the students were speakers of other languages, and were listed as receiving free and reduced lunch. The pre-experimental measures showed that the students’ working memory was similar to the general population. The measures also showed that the students had very little prior knowledge of the academic content or cultural content of the assessments. These pre-experimental measures indicate that the students did not from cognitive deficits in working memory and also had little prior knowledge of content. The majority reported free and reduced lunch and were from low ses backgrounds. The students showed that they have normal working memory digit span, but lacked knowledge and experience. Once this was provided through the embodied video game, they had improved performance as compared to watching or reading the same content. When they were given experience to build knowledge from with the embodied video game, they showed enormous improvement in comprehension and problem solving,

For this reason, the null hypothesis was rejected for question one, hypothesis one. There is a statistically significant difference in recall and problem solving in playing the video game as compared to watching a video, or reading a printed text. Students who played the video game outperformed students viewing a video, and reading a printed text in the walkthrough, word problem, and multiple-choice questions.

The second setting of analysis, question two, hypothesis two, showed that students performed at a higher level in the reading condition in the walkthrough, word
problem, and multiple-choice questions if they had experienced the game condition prior to the reading condition. For this reason the null hypothesis was rejected. This indicates that reading performance did improve if the students played the video game, and this indicates that providing embodied prior experience was superior to watching the same content on a video.

Question three, hypothesis three showed that there was statistical significance to support that identification of causation explained variance in three of the four dimensions of the walkthrough. For this reason the null hypothesis was rejected. This was also indicated through the superior performance in the embodied video game condition, which emphasized action to move through the narrative content.

This experiment did emphasize identification of causal relations through the chosen media narrative, data collection, and analysis. However, scientific problem solving is often predicated upon identification of causation, and utilizing causal factors for the control of variables in hypothesis testing methodology. From a cognitive perspective, the role of the body and sensorimotor system played an important role in making causation memorable. It is possible that participating and acting to change the course of the narrative, rather than viewing and reading the narrative made event segmentation more apparent, thus linking events to create a situation model punctuated through causal relations. Thus, when a student is able to identify that an action is taking place, and can connect that action to where, when, and who/what, there may be a greater likelihood that they can describe the event taking place, and create a causal link, relating one event to another.
This experiment provides explanatory evidence that the embodied video game provided a more robust mental representation as measured by the walkthrough and Recall and Locate section of multiple-choice questions. The embodied game condition also showed improved problem solving as compared to the video and print conditions, as supported by the Integrate and Interpret section multiple-choice questions and the word problem.

The embodied video game may have created segmentation that was memorable. In observing the students play the game, they began to create smaller goals in the game level based upon actions they were planning. This rehearsal was seemingly very important. When the children would attempt a route in the embodied game, they often had to try it several times to get their timing of actions correct on the objects in the space of the game. Thus, they had to create a situation model through practice. This practice represents an important process in building prior knowledge. Previous research reviewed by Barsalou (2003) showed that recency, frequency, and congruency of experience predict memory and response time. Therefore, the practice with the game increased those three factors.

The students would ride through the game level the first time with trial and error. They were shown how to do tricks with a brief tutorial on how to Ollie, the most important trick in skateboarding. After they had made a few trials, they began to refine their route and look for points in the game where they could do tricks. They would prepare their body to move when the skateboard avatar reached certain points in the game environment to do tricks. They would crouch, getting their body balanced to step on the
tail of the skateboard to make the skateboard avatar do the trick at the targeted spot in the
game environment.

As they successfully completed one segment, they prepared for the next—
seeming to memorize a sequence of actions with markers in the environment such as
ramps, picnic tables, and acceleration markers. Once the student had success knitting
these segments together in memory, they began to refine their route to compete with the
built-in game timer for the fastest completion of the level. This most likely leads to the
improved memory and situation model construction and problem solving, whereas
watching a video or reading a printed text requires that the child can create the situation
model by calling upon memories of prior experiences to re-live the what is depicted in
the media.

The embodied game condition forced the students to be methodical and find
elements in the game environment that would enable them to do tricks. As they moved
towards these points in game space-- discourse markers (Graesser, McNamara, &
Louwerse, 2003)—they would crouch and compress their bodies toward the skateboard to
jump and kick the plastic-skateboard game controller do tricks and navigate as they
moved toward their goal.

Each discourse marker, point in space, seemed to indicate a place for potential
action. It is likely that students were rehearsing, or building a mental representation for
performance, and this performance was memorable in the construction of the
walkthrough and the narrative descriptions—as indicated by the significantly larger
greater frequency of action points reported on the map and descriptions in the
accompanying narrative. These action points, or events may serve to punctuate segments, just as they have been found to do with printed text.

When students watched the video, they seemed to be more impressed with the tricks and wipeouts in the game footage, rather than segmenting sections of the game for action. Some students did report that the video provided the best aid to completing the walkthrough and word problem activities. When asked to explain why they thought the video was better, they explained that it told them what the best route was. Interestingly, the reasoning behind their choice was not supported with the statistical analysis. Students in the video and reading condition did not recall the game level to the same degree of detail as provided in embodied game condition. The walkthrough and word problem tended to be a route from the video with the shortest time matched to the grid, with inaccurate detail from the game environment, and often without description of actions taken at each vector change on their route.

In the first reading condition, most of the students tended to look at the narrative and then give up. They could often recall some idea or partial summary of what they thought the narrative was describing, that there was a secret route, but they were not able to identify where secret route was on the walkthrough. However, if the students had played the embodied video game before reading the printed text, they were more likely to have understood the print narrative, and identify it on the walkthrough.
Limitations of Study

This study did not sample from the general middle school student population. Although the sample population used in this study spoke other languages than English at home, and only 27% scored at or above a “Meets Expectations” on the MCA2 minimum standards reading comprehension assessment, the random assignment into media conditions should allow generalization of the statistical trends to the larger population. This group was also served free or reduced lunch, so they were categorized as low SES.

This study design did not include a read aloud for analysis of fluency and direct comprehension of the print reading condition. Although there was clear indication that reading improvement occurred, this may have been a result of double–testing, or seeing the same collection tools more than once. Thus, outcomes comparing the printed text condition across presentation orders may have more to do with long-term memory established in prior media conditions, than performance in the reading condition.

However, this still provides a reasonable intervention, making a case for sensorimotor experience as a pre-reading activity to ground terms and concepts in actual experience. Especially since there was improvement above the initial media in the reading condition, indicating that additional learning occurred. Additionally, the print narrative condition specified a particular route through the skate park, which was a hidden route identified by the expert skateboarders. Thus, the likelihood of choosing that route should increase if the print narrative was comprehended. Although there was not statistical difference in students choosing the secret route (route 1) from the text condition, there was a greater ability to identify the route, and the frequency of occurrence of that route in the text
condition, especially if the student had experienced the embodied game prior to reading the text.

Time for learning and exposure were limited. The concepts and problem in this study are often given much more classroom time, and students are often able to work together more to learn from each other and the teacher. The pre-experimental inventory indicated that students had no prior knowledge, or very limited prior knowledge previous to the intervention. It is reasonable to assume that more instructional modeling and scaffolding would improve student performance in demonstrating conceptual knowledge in problem solving.

**Need for Further Research**

Participants in this study were limited primarily to middle school students who were not meeting minimum expectations, and who spoke English as a second language, and were categorized as low SES. It may be beneficial to do analysis of students who scored better on the standardized assessment, as well as have greater variation in prior knowledge. It would also be beneficial to have a greater variety of students based upon language and socio-economic status. The students in this study were primarily Spanish speaking and from low SES. However, these students are often those who need the greatest amount of instruction, and often remediation. It would be useful to extend this study to create an analysis of growth and comparison using matched pairs.

Another important aspect of this study was the use of the empirically validated comprehension model to evaluate the New Literacies walkthrough assignment. As was stated in the introduction and problem statement, many activities that pass the eye-test for
being effective in classrooms have not been shown to impact traditional assessments and academic learning. The role of constructionist activities like the walkthrough represent a useful, high-interest assignment using media that is engaging and high in social capital. The ability to connect this kind of curriculum with improved performance in standardized tests is an important step. Often researchers between the positivist and socio-cultural traditions are at odds about what can be called knowledge and learning. The walkthrough is an important data collection device, as well as an important knowledge construction device. It would be very useful to conduct a similar analysis with the different assignments to see which of the assessment tools led to greater recall and performance for in mixed treatment orders—thus comparing walkthrough-multiple choice-word problem, to multiple choice-word problem-walkthrough, to word problem-multiple choice-walkthrough. Having a variety of permutations of the media and assessments in different presentation orders may begin to make a case for how content should be introduced and built upon. It is predicted that the embodied activity with the walkthrough would be most effective, but that the other assessments and media would be important for crystallizing learning into higher order concepts denoting complex academic concepts and patterns of process.

An important component of this study was the comparison of the game, video, and printed text across treatment order to examine the role of embodied activity, comprehension, prior knowledge, problem solving, and working memory. Although some may confuse embodiment research with learning styles (Rayner & Riding, 2000; Cassidy, 2004), or multiple intelligences (Gardner, 1983), embodiment theory is grounded in experimental research such as psychophysics, neuroscience, cognitive
science, and specifically memory. Previous studies in working memory have identified phonological processing, visual-spatial processing, and episodic memory. It would also be useful to examine the role of memory for movement and touch in sensorimotor performance – not to validate learning styles of multiple intelligences, which are curriculum frameworks, but to examine the role of recency, frequency, and context in memory learning and conceptual crystallization. The goal is not say that one student has a sensory modality that they prefer, as in learning styles or multiple intelligences, but rather how these modalities work together in creating conceptual knowledge—something that learning styles and multiple intelligences do account for. Multiple intelligences and learning styles are instructional design frameworks not theory with testable questions. Embodiment theory suggests that all of these modalities are important, and always in use. The important outcome, and goal of extending a study like this would be to examine how sensorimotor experience leads to conceptual categories and the role of instructional design in guiding that development. Thus, embodiment would provide a testable hypothesis for building memory and prior experience, and their role in building conceptual academic knowledge, useful in abstracted evaluations such as multiple choice tests and word problems.

An important part of this study was to ground new and traditional literacies in an empirically validated model for problem solving and comprehension. An extension of this study might include presenting the walkthrough, word problem, and multiple choice questions in different presentation orders in conjunction with the different sequence of media presentation. Presenting the walkthrough, word problem, and multiple choice questions may indicate differences in comprehension and problem solving. I would
predict that the walkthrough activity first would outperform the other interventions. This prediction is based upon the position that the constructionist activities provide accessible, structured learning activities for situation model construction, which can be crystallized into the conceptual terms assessed in traditional literacies.

In addition, it will be useful to examine the embodied game compared to the same game using game controllers rather than using the skateboard controller. The questions that can be asked:

- Will an embodied game result in superior comprehension and problem solving as compared to a hand-held game controller, or a mouse and keyboard?
- What is the role of physical activity in event segmentation for comprehension of game narratives?

A comparison should be made between the game experienced on the skateboard through embodied activity as compared to using a hand-held controller, and keyboard and mouse. This extension should provide insight into the question of physical experience and event segmentation through interactively affecting the game narrative

This study also included one-time quantitative measures only. A longitudinal, repeated-measures study with variations on the multiple-choice inventory and word problem would extend and deepen the findings. Working in a classroom situation that allowed for interviews and reflect aloud would provide some indication of the reasoning and discovery process. This might provide insight into how the students form new concepts. It may also offer insight into classroom models for accelerated progress for conceptual learning and problem solving.
Extensions of this study might include exploration of the amodal and embodied models of conceptual development as discussed in the literature review, with emphasis on issues of Perceptual Organization and Phonological Awareness in learning disabilities such as dyslexia, alexia, and dyspraxia. This would also provide insight into working memory and the role of prior knowledge across sensory modalities.

Dyslexia is a broad term defining a learning disability that impairs a person's fluency or comprehension accuracy in being able to read, and spell. Some students can read fluently, but cannot comprehend, and some may have difficulty decoding, but may demonstrate ability in comprehension. Visual dyslexia is characterized by number and letter reversals and the inability to write symbols in the correct sequence. Auditory dyslexia involves difficulty with sounds of letters or groups of letters. The sounds are perceived as jumbled or not heard correctly.

Alexia typically occurs following damage to the dominant hemisphere of the brain, which is usually the left. It can also occur with lesions to the occipital and parietal lobes, which are responsible for processing auditory, phonological and visual aspects of language. The region at the junction of occipital and temporal lobes (sometimes called the occipito-temporal junction) coordinates information that is gathered from visual and auditory processing and assigns meaning to the stimulus.

Dyspraxia refers to the learning disability term sensor-motor integration and is a widely pervasive motor condition characterized by impairment or immaturity of the organization of movement, with associated problems of language, perception and
thought. Typically, the child in question may be seen to be clumsy and poorly coordinated.

Perceptual Organization and Phonological Awareness are cognitive functions that have been examined in previous research for their roles in nonverbal learning disabilities and phonological dyslexia. Results were interpreted as supporting the hypothesis that integrative processes usually characterized as nonverbal were nonetheless used by readers with and without disabilities to understand text. Similar findings have been replicated in embodiment research. Working memory and prior experience may provide some insight along with learning preferences when children have learning disabilities based upon specific sensory modalities.

**Educational Implications and Recommendations**

Although the statistical analysis supports optimism for classroom reading instruction and scientific problem solving, the outcomes did not raise performance to grade-level classroom performance. The mean average for the word problem in the game condition was 3.34/5. And of the 132 students, out of 121 scored a three or lower, meaning 91.7% of students still struggled with the word problem scoring 3 or less, or 60%.

This was a great improvement, and may be attributed to having a better sense of each segment of the game level. They were able to recall and visualize their route, and this was always coupled with awareness of the actions they took on the skateboard, and the skateboard kinematics—motion and the forces required. Each segment was related to
plan actions on the skateboard in relation to points in space in the game—discourse markers for potential action.

This finding, along with the statistical analysis did show that students created more robust mental representations, had a greater ability to describe each section of their solution, and were able to support their reasoning with descriptions from the game. Students also demonstrated that they had a better understanding of the concepts used in the word problem and improve their comprehension of the printed text if they had played the game.

The same can be said for the multiple-choice questions. From an instructional perspective, students in the best performing condition—the game—had a combined mean average of seven out of fifteen. This means that statistical analysis showed that the students clearly improved in their performance, but they were still scoring below grade level.

This was more evident in the ten Integrate and Interpret questions. The Integrate and Interpret section of multiple-choice questions emphasized problem solving and conceptual knowledge. In the best performing media condition—the video game—students scored a mean average 3.42 out of 10 possible correct answers; well below frustration level. However, this was a statistically significant gain as compared to the video: 2.73/10, and the text: 1.0/10

This study does provide support for multimodal digital narratives pervasive in the social constructivist approaches to reading instruction,(Cope & Kalantzis, 2000); (New London Group, 1996), (Coiro 2009) Coiro, Knobel, Lankshear, & Leu, 2008) (Kist, 2005) (Knobel & Lankshear, 2007) (Hobbs, 2007) (Kress, 2003), (Alvermann, Moon,
Hagood, 1999) (Beach & O’Brien, 2008), such as the study of games and movies, and look at how they may influence and improve traditional academic reading through transduction, or connecting traditional print-based narratives with action and experience in an empirical study of comprehension and media presentation.

When video games are used in the correct context, they do show improved mental representation in detail and application. With a greater ability to draw details and context from memory, there is a greater likelihood of identification of affordance, developing conceptual knowledge, and the ability to transfer this knowledge to traditional forms of assessment and evaluation—as shown here in the use of the walkthrough as an instructional exercise that may have informed performance in the word problem and multiple choice questions. Reinforcing memory by drawing from experience and memory to redescribe their experiences into a representative strategy for solving a related problem.
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### Tables

#### Table 12, Setting 1– Pre-Experimental Survey

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<th>Auditory</th>
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#### Table 13. MCA2 Reading Cut Scores

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### Table 14 Visual Working Memory Frequency

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### Table 15. Auditory Working Memory

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Table 17 Prior Skateboarding Knowledge Frequency

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Table 19, Setting 2: First Media Presentation Walkthrough Dimensions

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Table 20. Setting 2, Word Problem

Descriptive Statistics
Dependent Variable: ProbSolGrade

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Table 21 Q2, H2 Word Problem Frequency

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Table 22 Setting 2, First Media NAEP Locate & Recall

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Dependent Variable: LocateRecall

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Table 23. Setting 2, First Media NAEP Integrate & Interpret.

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Table 24. Setting 3 Walkthrough Dimensions Text Across-Order Comparison

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Table 26. Setting 3, Word Problem

Descriptive Statistics

Dependent Variable: ProbSolGrade

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Table 27. Route Chi Square

Route * order (first, second, or third) Crosstabulation

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Table 28. Q3, H3, NAEP Locate Recall Questions

**Descriptive Statistics**

Dependent Variable: LocateRecall

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Table 29. Q3 NAEP Integrate & Interpret Questions

**Descriptive Statistics**

Dependent Variable: IntegrateInterpret

<table>
<thead>
<tr>
<th>Order (first, second, or third)</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>first</td>
<td>1.0000</td>
<td>1.28784</td>
<td>48</td>
</tr>
<tr>
<td>second</td>
<td>3.6341</td>
<td>3.61079</td>
<td>42</td>
</tr>
<tr>
<td>third</td>
<td>3.8043</td>
<td>2.86449</td>
<td>42</td>
</tr>
<tr>
<td>Total</td>
<td>2.8372</td>
<td>3.02281</td>
<td>132</td>
</tr>
</tbody>
</table>
Table 30 Q3 H3 Walkthrough Event Indexing Dimensions

**Descriptive Statistics**

<table>
<thead>
<tr>
<th>Media</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Charperformance</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>game</td>
<td>.9184</td>
<td>.14407</td>
<td>42</td>
</tr>
<tr>
<td>Text</td>
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<td>.21781</td>
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<tr>
<td>video</td>
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<td>.14675</td>
<td>42</td>
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<td>Total</td>
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<td>.24626</td>
<td>132</td>
</tr>
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</tr>
<tr>
<td>game</td>
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<tr>
<td>Text</td>
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<td>.21235</td>
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</tr>
<tr>
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<td>.16745</td>
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<td><strong>spaceperformance</strong></td>
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<td>Text</td>
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<td>video</td>
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<td>video</td>
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</tbody>
</table>
APPENDICE A: Narrative text

“Hey, nice Skateboard!”

My name is Paul Rodriguez, and I just rode my skateboard through this park in less than a minute—let me tell you how I did it.

There are three main ways you can go from “A” to “B”. But if you want to take the best route, you need to listen to me. I found a route that is much faster than taking the sidewalk to the right and left, or going through the middle. Here, look at this map I made.

You are standing at the “A” by the arrow in the middle. Do you see the sun shaped marks on my map? They show you were you can accelerate, by going downhill. When you go downhill you go faster, so hit the suns. The stars tell you where you slow down because the surface is rough (this causes resistance—your wheels don’t roll smoothly, they resist). Don’t hit the stars.

You should try and ride to the suns when you can, but let me tell you the best route. It starts at “A”. You should ride down the ramp and ollie onto the handrail. You will go faster if you ollie—you can go over obstacles by doing an ollie.

You know how to ollie? Just make a sudden kick with your foot onto the tail of the
skateboard. This will make you fly up in the air so that you avoid the areas that slow you down.

There are three main ways through the park, but my way is kind of secret. I like to ollie onto the handrail, and then where the path splits, you ride to the left. When you turn to the left you will cross the first sun. After hitting it, I ollie over to the left onto the concrete fence. This takes me up onto the roof. You ride on them and jump from one roof to another by doing an ollie at each jump. There will be four jumps. Each time you see the jump coming, hit the tail of your skateboard and jump over the gap to another roof.

The cool thing about doing jumps with ollies is that you go faster when you are in the air. That is because your wheels do not feel the same resistance to the ground. So the more jumps and suns, the faster your ride. Once you have made all your jumps, four of them, remember! You will jump onto the sidewalk in front of the second sun. You will notice that there is an open sidewalk here with planters, benches, and railings. Stay to your left. But you should ollie on to the grey benches and concrete railings. This way you can avoid the star, hit the sun and turn towards the middle to make the jump through the circle.

So when you come towards the middle, make sure to hit that last sun, go up the ramp, and jump over the star. When you do, I will stop the timer and see how fast you went. You are going to rock this skate park.
Make a map of the skateboard park, draw your route, and write a description of each move you make

1. First draw the skate park on your map.
2. Then draw your path (route) on your skateboard.
   a. Make connect-the-dots.
   b. Pick two spots on your route, draw a line between them, and then choose the next dot and draw a line to it.
3. After you have made the lines and dots marking your route, including where you turned, and jumped over things, you should write a description explaining the route you took through the skateboard park. Make sure to:
   a. Describe your goals – why you are going where you are going and how you are riding,
   b. Describe what the character is doing—explain why you took the route you did. Your purpose.
   c. Describe and explain what actions you took. Explain what actions you took, and what caused them (Ollies and Jumps).
   d. Draw and describe the things in the space you remember from the skate park (colors and things like picnic tables, jumps, and people).
   e. Describe how long it took you for each line.

When you are done drawing your map and writing your description, go to page two.

Draw features of the skateboard park. Make connect-the-dots of your route.
APPENDICE C: Word Problem

You have now drawn a series of lines mapping your route through the skate park, and you have written a description of each section of your route (what happened between the dots).

Each one of those lines you made is called a vector. Each of the dots connecting them is called a coordinate. Your job is to estimate the distance of each vector and divide by your rate of speed (velocity)

In order to make this simple, you should number each line below, and write the distance traveled, the velocity.

This will help you estimate how long it takes you to travel each vector.

- You should know that each rectangle is 30 feet long and 10 feet wide.
- Your velocity is 6 feet per second.
  - If you hit a sun, your velocity will accelerate to 10 feet per second for 30 feet.
  - Hitting a star will slow you to 5 feet per second.
  - Jumping in the air adds 2 feet per second for 5 feet.
- After you have drawn your path with vectors and coordinates, add up the time it takes to travel each vector. Add that together for your estimated time through the whole skateboard park.
  - You can use the equation: \( \text{Time} = \text{distance} / \text{velocity} \).
  - \text{Show your work on a clean sheet of paper}

Example:

Line 1: 10 feet going 6 feet per second \(10/6 = 1.6\) seconds
Line 2: 10 feet at 10 fps \(10/10=1\) second

Key terms:

- \text{Velocity} – how fast you go;
- \text{Vector}—line between two points, and the magnitude is the direction;
- \text{Acceleration} – the result of force on an object to make it go fast or slow;
- \text{FPS} – feet per second, how many feet per second the object travels;
- \text{Time Interval}—the amount of time and distance the object travels in one vector;
- \text{Coordinates} – direction of the vector, points A and B for each vector leading to the larger path.
APPENDICE D: NAEP Cognitive Targets

NAEP Cognitive Targets

1. The main idea of the story in the media.
   - to tell you about the best way through the skateboarding park
   - that skateboarding is very cool, and you are going to be good at it.
   - that science and skateboarding have a lot in common.
   - to tell you about the best way through the business park

2. The skateboarder Paul Rodriguez (the author) talks to you at the beginning of the story to:
   - tell you to ollie over the obstacles to go faster.
   - tell you to get the shortest time riding through the park
   - tell you to be safe and have fun.
   - tell you that skateboarding is cool and so are you.

3. Moving into the green spaces on the map:
   - makes you wipe out
   - makes you ollie — jump in the air
   - makes you go faster
   - makes you go slower

4. When you begin riding the skateboard, your character is next to:
   - a handrail.
   - an escalator.
   - a playground.
   - a pop machine.

5. You will find pedestrians in the business park if you:
   - go underground
   - go to the center
   - go the left or right.
   - go the second level on the left.

6. The purpose of this activity is to:
   - See what you know about skateboarding
   - Learn new vocabulary, science talk, and math
   - Try different kinds of media.
   - Estimate the fastest path through the park using vectors and feet per second.

7. Since the distance of each rectangle is thirty feet, hitting a green sun will make you travel 30 feet in 3 seconds. The value of hitting a green sun is in feet per seconds is:
   - 6 fps
8. In this activity, doing tricks in the air increases your velocity and will reduce your time from beginning to end. This will make you ride faster. This is because:
- Being in the air is like being a bird, and birds are fast and streamline.
- The force you create from jamming your foot down on the skate board makes it go faster from the force.
- The time in the air means there is less resistance from the wheels on the ground, so you go faster.

9. Decide which of the following statements is a fact—not an opinion:
- the kind of music you like is what makes you a skateboarder.
- the author Paul Rodriguez says that skateboarding is the best sport.
- the brand of skateboard you purchase will determine how fast you can go.
- the way to estimate the time traveled, is to divide distance by velocity.

10. Which of these statements is the most important:
- doing tricks in the air makes you go faster.
- wearing a helmet and pads are a good idea.
- avoiding the deceleration points (red stars) will shorten your time.
- going to the acceleration points (green stars) makes you go faster.

11. You were asked to make estimation on the fastest route through this business park. By making an estimation, you should be able to:
- Choose a path that looks like it will give the fastest time under the right circumstances
- Get the right answer by drawing the best path and knowing how long it will take.
- Calculate the fastest time without any mistakes

12. When the words “ollie” and “nollie” were described, you were told that you can do these tricks by jamming your foot with force on the front of the board for a nollie and the back for an ollie. What is it about creating force that might make your skateboard go in the air?
- The reason the board flies up when you kick is partly because you’ve used the tail as a lever to lift most of the skateboard off the ground, giving it upward momentum, and partly because of the elasticity of the wood in the deck which causes the board to
- It’s similar to when you flip a spoon across the room by slapping your hand down on the lip of the spoon. The difference is that, whereas the spoon tumbles, with the skateboard you use your feet to control the takeoff and flight of the skate board so that
- You have kicked down and the result is a rebound in gravity.

13. What statement provides the best description of great terrain for skateboards?
- Hard concrete area, because you should be able to ride fast.
- Streets surrounded by soft grassy areas where if you fall you will not get hurt.
- A public place with lots of people where you can show off your skills.
14. By skateboarding one can learn physics and math because:

- Skateboarders naturally know math and physics and those is how come they can defy gravity and do awesome tricks on ramps and half-pipes—and when you skateboard, you get better in math and science.
- It is important so that you can learn to defy the laws of gravity and do tricks that science cannot explain.
- Physics and math help to explain the execution of a trick in skateboarding, or the way to do the tricks better and understand why things work the way they do in skateboarding.

15. It is assumed in this activity that doing tricks in the air increase your velocity and will reduce your time from beginning to end, making your ride faster. Is this because:

- The force you create from jamming your foot down on the skate board makes it go faster from the force.
- The time in the air means there is less resistance from the wheels on the ground, so you go faster.
- Being in the air is like being a bird, and birds are fast and streamline.
APPENDICE E: Pre-Experimental Inventory

Pre-Test for Embodiment Study

Note: You are currently in preview mode and your responses are being saved. You should be sure to delete your entries before collecting real responses and analyzing your data.

1. Please enter your code from the numerical memory game:

Please take this survey about learning from different kinds of media.

2. What grade are you in?*
   - Fifth
   - Sixth
   - Seventh
   - Eighth
   - Ninth

3. How many years old are you?*

4. Rate in order, ONE being your favorite, activities you participate in.*

   | 1 | 2 | 3 | 4 | 5 |
---|---|---|---|---|---|
listening to a lecture | o | o | o | o | o |
playing outside | o | o | o | o | o |
watching television or a movie | o | o | o | o | o |
video games | o | o | o | o | o |
reading a book, magazine, or web page | o | o | o | o | o |
   | 1 | 2 | 3 | 4 | 5 |

5. Rate in order, ONE being your favorite, an activities you would like as a learning experience in class.*

   | 1 | 2 | 3 | 4 | 5 |
---|---|---|---|---|---|
watching television or a movie | o | o | o | o | o |
listening to a lecture | o | o | o | o | o |
reading a book | o | o | o | o | o |
video games | o | o | o | o | o |
playing outside | o | o | o | o | o |
   | 1 | 2 | 3 | 4 | 5 |

6. Have you ever played a video game?
13. What is acceleration?*
- To cause to move faster; to quicken the motion of; to add to the speed of.
- The rate of change of position.
- A straight line segment whose length is magnitude and whose orientation in space is direction.
- A variable quantity that can be resolved into components.

14. What is a vector?*
- Someone who is victorious in a race or competition.
- Speed: distance travelled per unit time.
- A line between two points whose length is magnitude and coordinates orient the lines direction.
- The rate of change of position.

15. What are coordinates?*
- A rate of increase of velocity.
- A set of numbers on a map used to find the distance from a specific place, also known as the origin. In a Cartesian coordinate system, there's an "x,y".
- A whole number.
- A straight line segment whose length is magnitude and whose orientation in space is direction.

16. What does v=d/t represent?*
- Velocity = distance/ time.
- Velocity = distance/ total speed.
- Volume = diameter/ time.
APPENDICE F: Route Syntax

*Creating the aggregate scores for all 5 dimensions using "MATCHED EXPERT COLUMNS SPSS FILE".

```
COMPUTE goal=mean(g1,g2,g3,g4,g5,g6,g7,g8).
EXECUTE.

COMPUTE causation=mean(c1,c2,c3,c4,c5,c6,c7,c8).
EXECUTE.

COMPUTE space=mean(s1,s2,s3,s4,s5,s6,s7,s8).
EXECUTE.

COMPUTE time=mean(t1,t2,t3,t4,t5,t6,t7,t8).
EXECUTE.
```

*******START HERE TODAY 03/23/11.

*Open THawk expert AGG scores, Fill in values for cell 42 (the mean scores for experts) so that the following syntax will work. If it works, it should produce four columns titled route 1 through 4.

```
compute route1=SUM(cell4,cell11,cell12,cell13,cell14,cell15,cell28,cell29,cell39,cell40,cell41,cell42).
EXECUTE.

compute route2=SUM(cell4,cell11,cell12,cell13,cell14,cell16,cell27,cell30,cell39,cell40,cell41,cell46).
EXECUTE.

compute route3=SUM(cell4,cell11,cell18,cell25,cell32,cell39,cell46).
EXECUTE.

compute route4=SUM(cell4,cell9,cell10,cell11,cell20,cell23,cell34,cell37,cell38,cell39,cell46).
EXECUTE.
```

*These columns will be the denominators for your student route data.

*using the "all media dimensions.sav" file run the following syntax to get scores for each student on each dimension based on the route they took.

```
IF (Route=1)
goalperformance=SUM(c4Goal,c11Goal,c12Goal,c13Goal,c14Goal,c15Goal,c28Goal,c29Goal,c39Goal,c40Goal,c41Goal,c42Goal,c46Goal)/(39.25).
EXECUTE.
```
IF (Route=1)
causperformance=SUM(c4Caus,c11Caus,c12Caus,c13Caus,c14Caus,c15Caus,c28Caus,c29Caus,c39Caus,c40Caus,c41Caus,c42Caus)/(42.25).
EXECUTE.

IF (Route=1)
spaceperformance=SUM(c4Space,c11Space,c12Space,c13Space,c14Space,c15Space,c28Space,c29Space,c39Space,c40Space,c41Space,c42Space)/(48.00).
EXECUTE.

IF (Route=1)
timeperformance=SUM(c4Time,c11Time,c12Time,c13Time,c14Time,c15Time,c28Time,c29Time,c39Time,c40Time,c41Time,c42Time)/(46.98).
EXECUTE.

IF (Route=1)
Charperformance=SUM(c4Char,c11Char,c12Char,c13Char,c14Char,c15Char,c28Char,c29Char,c39Char,c40Char,c41Char,c42Char)/(17.34).
EXECUTE.

*Route 2.

IF (Route=2) Charperformance=SUM(
c4Char,
c11Char,
c12Char,
c13Char,
c16Char,
c27Char,
c30Char,
c39Char,
c40Char,
c41Char,
c46Char)/(13.97).
EXECUTE.

IF (Route=2) goalperformance=SUM(
c4Goal,
c11Goal,
c12Goal,
c13Goal,
c16Goal,
c27Goal,
c30Goal,
c39Goal, 
c40Goal, 
c41Goal, 
c46Goal)/(30.53).
EXECUTE.

IF (Route=2) causperformance=SUM(
c4Caus, 
c11Caus, 
c12Caus, 
c13Caus, 
c16Caus, 
c27Caus, 
c30Caus, 
c39Caus, 
c40Caus, 
c41Caus, 
c46Caus)/(36.75).
EXECUTE.

IF (Route=2) spaceperformance=SUM(
c4Space, 
c11Space, 
c12Space, 
c13Space, 
c16Space, 
c27Space, 
c30Space, 
c39Space, 
c40Space, 
c41Space, 
c46Space)/(39.75).
EXECUTE.

IF (Route=2) timeperformance=SUM(
c4Time, 
c11Time, 
c12Time, 
c13Time, 
c16Time, 
c27Time, 
c30Time, 
c39Time, 
c40Time,
c41Time, 
c46Time)/(32.25).
EXECUTE.

*Route 3.
IF (Route=3) Charperformance=SUM(
c4Char, 
c11Char, 
c18Char, 
c25Char, 
c32Char, 
c39Char, 
c46Char)/(8.06).
EXECUTE.

IF (Route=3) goalperformance=SUM(
c4Goal, 
c11Goal, 
c18Goal, 
c25Goal, 
c32Goal, 
c39Goal, 
c46Goal)/(13.25).
EXECUTE.

IF (Route=3) causperformance=SUM(c4Caus, 
c11Caus, 
c18Caus, 
c25Caus, 
c32Caus, 
c39Caus, 
c46Caus)/(17.01).
EXECUTE.

IF (Route=3) spaceperformance=SUM(
c4Space, 
c11Space, 
c18Space, 
c25Space, 
c32Space, 
c39Space, 
c46Space)/(25.23).
EXECUTE.
IF (Route=3) timeperformance=SUM(
c4Time,  
c11Time,  
c18Time,  
c25Time,  
c32Time,  
c39Time,  
c46Time)/(13.30).
EXECUTE.

*Route 4.

IF (Route=4) Charperformance=SUM(
c4Char,  
c9Char,  
c10Char,  
c11Char,  
c20Char,  
c23Char,  
c34Char,  
c37Char,  
c38Char,  
c39Char,  
c46Char)/(11.41).
EXECUTE.

IF (Route=4) goalperformance=SUM(
c4Goal,  
c9Goal,  
c10Goal,  
c11Goal,  
c20Goal,  
c23Goal,  
c34Goal,  
c37Goal,  
c38Goal,  
c39Goal,  
c46Goal)/(23.51).
EXECUTE.

IF (Route=4) causperformance=SUM(
IF (Route=4) spaceperformance=SUM(c4Space, c9Space, c10Space, c11Space, c20Space, c23Space, c34Space, c37Space, c38Space, c39Space, c46Space)/(31.41).
EXECUTE.

IF (Route=4) timeperformance=SUM(c4Time, c9Time, c10Time, c11Time, c20Time, c23Time, c34Time, c37Time, c38Time, c39Time, c46Time)/(16.82).
EXECUTE.
APPENDICE G: Consent Form

CONSENT FORM

Project Title: Tony Hawk RIDE, Video, and Printed Text – Literacy comparison in presentation order and context Using the indexical hypothesis to measure learning and comprehension across multimodal presentations with digital models that simulate real activities with informative assessment, motion capture, and haptic feedback.

Subproject: Comprehension as a sub-medial trait for numeracy and scientific habits of mind.
Principal Investigator: Brock Dubbels, (612) 747-0346

Your child has been invited to participate in a study of the role of media in learning.

The research will better our understanding of perceptual factors in learning to read.

Your child was chosen as a possible participant because they are a child in middle school.

If you decide to allow your child to participate, we will follow these steps:

- An informational meeting will be held before we begin which you or a person of your choice may attend to ask questions and learn more about the study.
- Describe the experiment and procedures to your child
- Check to see if they understand what they are being asked to do, and to confirm their willingness to participate.

You or a person of your choice is most welcome to accompany your child if you wish.

- We will measure their memory with a memory game, which involves asking your child to read numbers presented on a computer screen.
- We will ask your child to participate in a survey their preference of media types, media usage, and how they feel about reading.
- Following the experiment, we will return your child to their classroom.

Risk: The experiment involves no risk to your child.

The experiment will take place in two one-hour sessions. Your child will be brought to the computer lab twice for one hour. If completion of the experiment requires one or more additional sessions, we will ask your child if they are interested in returning. But your child has no obligation to return.

If your child wishes to take breaks during a session, or to terminate a session early because they are tired, this is fine.

Confidentiality: Any information that is obtained in this study concerning your child will be confidential. Publication or other public distribution of the experimental results will not mention your child by name.
Voluntary Nature of Study: Your decision whether or not to have your child participate will not prejudice your future relations with this laboratory, the department of curriculum and instruction, or the University of Minnesota. If you decide to allow your child to participate, they are free to discontinue participation at any time without prejudice.

Contact and Questions: At any time, please feel free to ask questions about you, or your child’s role in the experiment, or any other aspect of the experiment.

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher(s), contact Patient Relations Department, B-310 Mayo Memorial Building, 420 Delaware Street SE, Minneapolis, Minnesota 55455; telephone 612.273.5050.

Statement of Consent:

You are making a decision whether or not to allow your child to participate.

Your signature below indicates that you have read the information provided above and have decided to allow your child to participate.

If you are under 18 years of age, a parent or guardian must also sign this form. You may withdraw at any time after signing without prejudice.

You will be given a copy of this form to keep for your records.

By signing this, your child’s information will be shared with the participating school.

I am 18 Years of age or older:

Yes___No__, (If "No," a parent/guardian must also sign.)

__________________________________________
Child’s Name (Please Print)

__________________________________________
Parent/ Guardian’s SIGNATURE Parent/ Guardian’s Name (Please Print)

__________________________________________
INVESTIGATOR’S SIGNATURE Date
APPENDICE H: Assent Form

ASSENT FORM

Project Title: Tony Hawk RIDE, Video, and Printed Text – Literacy comparison in presentation order and context Using the indexical hypothesis to measure learning and comprehension across multimodal presentations with digital models that simulate real activities with informative assessment, motion capture, and haptic feedback.

Subproject: Media and learning

Principal Investigator: Brock Dubbels, Department of Curriculum & Instruction, S 310 Elliott Hall, 75 East River Road, Minneapolis, MN 55455, Phone: (612) 747-0346.

You are invited to participate in research on learning and media.

You were chosen because you are in middle school.

If you would like to participate, you will come to the computer lab twice:
- Once to fill out a survey
- Once to try the different media.
- We will ask you some questions about your favorite media
- Measure your memory with a game by reading words and from a computer screen.

Sometimes, people wish to take breaks, or to finish early because they are tired. This is fine. We want you to feel good. You can stop any time you would like and do not have to come again.
- The experiment involves no risk to you.
- Your results will not be told to anyone outside the research team at the university and your teachers.

At any time, please feel free to ask questions about the experiment.

Statement of Assent:

I have read this information. I have asked questions and have received answers. I agree to participate in the study.

Child’s name: __________________________ Date: __________

Signature of Investigator: __________________________ Date: __________

You will be given a copy of this information to keep for your records.
APPENDICE I: Expert Recruitment Letter

Like video games and skateboarding?

Want to make 15 bucks for playing Tony Hawk RIDE?

We are looking for skaters with knowledge and demonstrable skill, and people who know nothing about skateboards to participate in a study from the University of Minnesota exploring the potential of using this game in the classroom.

The study takes 90 minutes of video game play, and then a brief question answer session about the game.

To participate, contact:
Brock Dubbels
Dubbe003@umn.edu
612.747.0346
# Independent Variable / Rubric

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