DESIGNING INTERACTIVE TOOLS TO SUPPORT NARRATIVE AUTHORING FOR ELEMENTARY-SCHOOL CHILDREN THROUGH DIGITAL ENACTMENT

A Thesis

by

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ABSTRACT

Narrative is an important part of how humans make sense of the world and express their thoughts and feelings. For children, stories are the predominant way in which they organize and express ideas and imagination. Hence, stories have a significant role in children's various play activities, especially pretend-play. At around the third to fifth grade period (8-10 years old), children are expected and encouraged to transition from embodied play to more formal linguistic modes of expression, such as writing. Supporting the child in this critical developmental stage is therefore very important in their development of writing proficiency. Research in writing support tools for children has generally focused more on facilitating the technical aspects of writing. But tapping into the potential of child's embodied imagination capacity for writing support is less explored.

This dissertation research poses the question that given the affinity children have for embodied activities and mediums, how can we use this potential in technology design to scaffold more formal types of expression. Within this scope, we present research that investigates the design of embodied technology to support narrative writing for novice writers during the third to fifth grade transition period. By developing a set of interactive tools and evaluating these tools with child participants, I explore how free-form play may be harnessed in systems to facilitate planning and writing an imaginative narrative at the elementary school level. Through this design exploration, I aim to extend the understanding of how using such embodied and interactive tools may augment the process in which children write stories and support them in writing more complex stories.

We began our exploration by focusing on the development of a tool for capturing child's enactment. Designed based on the concept of enactment-scaffolded authoring (also known as performative authoring), a story authoring system is presented whereby children's story enactment is transformed in real-time into an animated video recording. Using this testbed system we investigated how children use enactment to plan their stories - as a "prewriting" activity. We also explored how features of the recorded video can augment the child's experience and performance in the writing activity. Our studies provided evidence that using story-relevant avatars in the enacted

video can support the child's imagination, allowing them to focus on technical aspects of writing. We also uncovered that transforming the enacted story into written form is a challenge for children, so they need process support to translate the planned story into written form. We present design suggestions for children's enactment-based authoring systems based on our findings.

The next step of this research addresses the process support needed for children to transform a visual narrative into written form. We begin with a set of interviews with elementary school teachers to understand the general requirements for writing process support. An interface is developed that allows the child to watch an animated video and write the story in the video. The design is improved and finalized based on feedback from teacher interviewees. Using this system, we investigate two methods of implementing process support grounded in theories of multimedia learning and embodied cognition. Our results show that the cue design can affect how children respond to the cues, which in turn affects their writing performance. Temporally-situated cues support more structured and cohesive writing, while visually situated cues elicit more descriptive writing from children.

The body of work that is presented in this dissertation contributes (i) An understanding of the opportunities and challenges of enactment-scaffolded narrative authoring for children and (ii) Design choices for embodied narrative writing support tools for children. The findings have significance in various domains of human-computer interaction research, including interaction design for children and interactive digital storytelling. Additionally, the interdisciplinary findings have significance in media studies, education research, and psychology to create more efficient educational content and pedagogical practice for the child audience.

DEDICATION

This Dissertation is dedicated:

To my family, whose love and support was my light and guide;

And

To my husband, Sina, for holding my hand and walking by my side.

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1. INTRODUCTION

As social beings, the ability to express our thoughts, ideas and feelings to others is a prevalent aspect of our everyday lives. Self-expression ability is a skill gradually acquired through the course of our cognitive development. For children, this ability has impact on several other aspects of their growth and learning, such as agency and socialization [2]. Therefore, nurturing self-expression abilities has long been a topic of interest among researchers in various fields. Myriad questions have been asked in previous research across various domains of design, psychology and education on methods of nurturing children's self-expression abilities, for instance, through art [3, 4], technological tools [5, 6] and classroom instruction [7].

In younger ages, children tend to rely greatly on their body as an expressive medium. Embodied play activities, such as pretend play (also known as make-believe play [8] or embodied enactment [9]) are the means through which the child connects their inner and outer realities [10]. For the child at this stage, their body is the *bridge* between thought and expression. Many of these creative expressive activities are centered around creation and expression of stories [11]. As children get older, they gain the ability to express and understand image-based mediums as well, such as drawing [12].

In school, children learn to express themselves through abstract symbolic means of expression, such as writing. Unlike free-form play, writing is a challenge for children. Writing is a complex process and involves the mastery of several underlying skills. The transition from body-based to linguistic expression and literacy is a challenge for children. At middle to higher elementary school grades (8-10 years old) children are expected to gradually transition "Learning to write" into "writing to learn". This age range also marks a critical developmental period referred to by Piaget as the "Concrete Operational Phase (COP)" [13, 14]. This stage is distinguished by changes like the transition to abstract and rational thinking. Supporting the child in this critical developmental stage is therefore crucial for their journey towards literacy.

Design and development of creative and expressive authoring tools for children is a prominent area of HCI research in the Child-computer interaction domain. Research has shown that novel technological tools can offer opportunities to design engaging learning experiences for children [15]. As pointed out by Finegan and Austin [16], design choices can determine how developmentally appropriate a particular technology tool is for children. A technology tool can be beneficial for young children if designed with age-appropriate considerations. Otherwise, it may be ineffective or even detrimental to the child's learning and development [16]. In terms of the writing support tools introduced in the previous work this crucial aspect is less studied. Given the specific needs of children at the critical developmental period of 8-10 years old, there is a need to address the literacy challenge at this age through age-appropriate support tools. Research has shown that literacy problems should be addressed at early grades [17]. Left unaddressed, the lack of engagement in writing creates further delays in the child's progress towards writing proficiency as they get older.

This dissertation covers research that addressed the design of enactment-based authoring tools for children at the critical age range of third to fifth grade. Within this scope, we explore body-based enactment as prewriting support for narrative writing. The higher-level research question in this dissertation encompassing all of the studies is how embodied enactment-based technologies may be designed to support children in a narrative writing activity. Each study presented in this document investigates aspects of this general question and is guided by its own set of specifically targeted research questions that will be detailed in each chapter.

To harness children's capacity of embodied imagination for writing support, we develop a story creation system that allows the child to enact a story and record it as an animated video. We use this system to investigate the use of enactment as prewriting preparatory activity for narrative writing. We found that design choices such as avatar design can affect the child's experience during enactment, which in turn also affects their writing. We also analyzed the children's enacted and written stories in terms of their content, coherence and structure. Our analyses uncovered that transforming the acted story into written form is a challenge for children, so they may need support in this transformation process.

The next part of our research investigates design of process support for children to turn a video

Summary of studies presented in this thesis.

Study Title	Goal	Participants	Year	Chapter
Avatar design study	Investigating the effect of self-avatars and story-relevant avatars on children's writing	20 children	2019	6
Prewriting support study	Investigating body-based enactment as prewriting support	10 children	2020	7
Teacher interviews	Receiving feedback for design and study of video-stimulated writing prototype	6 teachers	2020	8
Segment cues evaluation	Evaluation of segment-based contextual cues	6 children	2021	9
Signal cues evaluation	Evaluation of signal-based contextual cues	7 children	2021	9

narrative into written form. We developed a prototype system that allows the child to watch a cartoon video and write its story. Based on Mayer's [18] cognitive theory of multimedia learning and Bordwell's [19] model for the narrative-oriented video, we propose two models for contextual cues during the writing process. Segment cues are based on key segments of the narrative. Signal cues are based on key content in the narrative. We analyzed the effects of cue type on children's written stories in a study. We found that the cue type can affect the level of description and the structure of the narrative children wrote. The studies conducted in this body of work are summarized in table 1.1. All the publications that resulted from this work are listed in Appendix A.

The rest of this document is structured as follows: Chapter 2 describes the background and context of this research. More specifically in this chapter, a review of the cognitive models of writing in children and theories of the child development are described. Chapter 3 presents a review of writing support systems that have been proposed in prior literature, identifying the gap in previous work. Chapter 4 presents an overview of our approach in this thesis and how it related to the gap in previous work that we aim to address. In chapter 5, we describe the design concept and development of our enactment-based story creation system. Chapter 6 describes the study we conducted to understand the effect of avatar design on children's story writing.

In chapter 7, we explored the use of enactment as prewriting support, and presented design suggestions for enactment-based authoring systems. Chapter 8 presents the design concept and development process of our video-scaffolded writing interface. In chapter 9, we use this interface to investigate two types of contextual cues in the process of children's writing. Chapter 10 summarizes the findings and contributions made in this dissertation research, the significance of the work and the possible venues for future work which this research puts forth. Finally, chapter 11 acknowledges the limitation and scope of this work and presents a conclusion.

2. BACKGROUND AND CONTEXT

2.1 The Challenge of Writing for Novices

Writing is an involved process, incorporating multiple underlying and interconnected operations. Previous work includes several efforts at identifying these operations and how they relate through models of the writing process. Most notable of these works is probably the Hayes-Flower cognitive process model for writing [1]. Based on this model, on a cognitive level, the writing process includes three main elements: the task environment, the long term memory and the writing process. In this model, the task environment comprises the general constraints on the task such as the topic and the audience which can determine the quality of the writing. The writing process has three main sub-processes, planning, translating and revising. During the writing process, the writer refers to their long-term memory for ideas and knowledge, language details, etc.

Similarly, Seow [20] describes the four basic stages of the writing process: Planning (prewriting), drafting, revising and editing. These stages do not necessarily occur in a linear fashion. Research has shown that many skilled writers employ a *"linear and non-recursive"* approach [21], including major spontaneous revisions [22]. Bereiter and Scardamalia's [23] further describe the differences between novice and mature writers through their *knowledge telling* vs. *knowledge transforming* model. Their model explains that novice writers generate text to convey their ideas in small

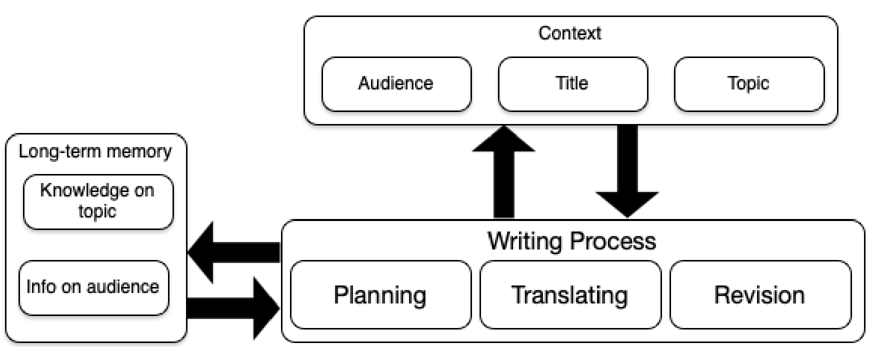


Figure 2.1: Cognitive model of writing by Hayes and Flower [1]

fragments, not necessarily keeping a holistic view of the content structure. After each idea fragment, the novice writer wonders "what next?" trying to identify the next idea fragment. The mature writer on the other hand, reviews and recombines from previously written content, thus dynamically developing and transforming the knowledge as they progress.

A common methodology to make writing more accessible to novice writers is by breaking down the writing process into its basic stages and allowing the learners to practice each stage in relative isolation. This is referred to as a *process writing* approach - i.e treating writing as an orderly process. Process writing approach is an effective strategy common in current classrooms [20].

In process writing, planning or prewriting is the first step of the writing activity [20]. Prewriting is therefore a crucial stage in writing. It's at this stage where the author's thoughts are stimulated and organized [20]. In other words, at this stage the author makes their ideas *"writing-ready"* [24] by coherently organizing the narrative structure and including details like causal links between arguments or events [25]. The ability to advance ideas into a writing-ready form requires support and practice. For children, teachers typically use visualizing methods such as storyboarding [26] and graphic organizers [27] to facilitate this process. While technological innovations can offer unique opportunities to support transforming imagination into a writing-ready form, these interventions are generally less explored compared to more classic approaches.

2.2 Theories of Child Development

Bruner [12] described the learning process as the transition across various modes of knowledge representation. He describes that humans represent knowledge in three modes: through actions (*Enactive* representations), through images or graphical summaries (*Iconic* representations), and through symbolic or logical systems such as language (*Symbolic* representations). He states that before the age of 1, children learn only in the enactive form, and don't acquire the symbolic mode until the age of 7, when they begin school. He further proposed that these three modes of representation are how knowledge is encoded in memory in all ages - not just during childhood. He theorizes that in an *optimal learning sequence*, the learner moves from the enactive representation - lower levels of abstraction - toward the symbolic representation - higher levels of abstraction. This theory suggests that providing various modes of thinking can support the progression in the learning process [28].

Bruner's theory shows that a child's body-based play is a powerful means through which they express their thoughts, feelings and imagination. Indeed, children's play is a familiar sight for us. In literature, children's free-form play has also been referred to as fantasy play [29], make-believe play [8] or story enactment [9]. With minor differences, these terms tend to be used interchangeably for a broad range of embodied activities that involve the use of one's body and manipulation of physical objects to externalize thoughts [30].

The connection between children's creative imagination and play is well-established in the literature [31, 32, 33, 34]. Prominent schools of psychology like Vygotsky [35] and Piaget [36] point out the importance of play in children's cognitive development, and recognize its role as a *Zone of Proximal Development (ZPD)* for children. Winnicott [10] describes playing as the means through which the child connects inner and outer realities. In other words, children use their body and physical means like toys in free-form play to *bridge* their thoughts to expression. A major part of children's play is centered around imaginative stories because stories are a common mode of organizing thoughts and reflection for children [11]. Chu et. al [37] have demonstrated that story enactment creates motivation in children to engage in creative activity, to the point that they experience a higher creative self-efficacy[38].

In middle to higher elementary school, namely third to fifth grade (or 8-10 years old) children are expected to have a relative mastery of the writing mechanics such as spelling, and gradually transition from "learning to write" to "writing to learn". This transition coincides with the stage that Jean Piaget [13, 14] defined as the concrete operational phase (COP). An important aspect of the child's development during the COP is the transition to abstract thinking. At this stage, the child is beginning to understand meaning at abstract levels, such as counting without using physical objects like their fingers. Although there is discussion in the field regarding Piaget's stages of development and more recent works suggest that stages of development may not always occur as fixed and rigid as Piaget theorized, the general aspects of development are still accepted. Going back to Bruner's three modes of knowledge representation, at this stage, children begin to move towards *symbolic* and linguistic expression.

This transition to higher levels of abstraction can be challenging for children. Lack of engagement and writing practice at this stage can lead to decreased performance, further leading to a reluctance in writing [39]. Designing age-appropriate intervention tools and methods to support children in this critical developmental stage is therefore important for their proper literacy development. Towards this goal, at school, writing activities are therefore typically accompanied by image-based modeling of text, for example through storyboarding or graphic organizers. These strategies follow Bruner's notion that providing various modes of thinking can support the progression in abstraction of thought in the learning process [28].

The use of drama and enactment as writing support has also been explored in the context of language arts classrooms. But the body of research has predominantly focused on strategies to include and integrate these methods in the classroom activities with teacher supervision. Much less explored however, is the design of writing support technology based on the concept of pretend play. The software and systems focusing on pretend play generally focus on using it as creativity support [37] and do not focus on technical aspects of the writing, such as topic development.

2.3 Chapter Summary

In this chapter we presented the motivation and context of this dissertation work grounded in children's stages of cognitive development and Jean Piaget's COP. We presented the idea of using enactment as writing support, and why this approach can be successful grounded in the importance of play and the role of enactive expression in learning. Previously proposed systems that embody the concept of pretend play have mostly focused on nurturing children's creativity or storytelling processes rather than writing. The body of work on using pretend play as writing support is generally centered around classroom integration and strategies teachers can include in their teaching rather than designing systems that realize this concept. The software and systems designed for pretend play support are typically focused on creativity support, oral narrative and emotional expression rather than using it as a means to facilitate writing. This thesis aims to address this gap in knowledge by investigating design of enactment-scaffolded authoring tools for children.

3. RELATED WORK

Due to the extensive benefits and importance of pretend play for children, various approaches have been proposed in HCI research to nurture these activities [40, 41], use them to support children with special needs and abilities [42], or apply them as a scaffold for learning [43]. The type of enactment in these systems range from use of tabletop toy setups [44], to puppet-based systems [45] to full-body enactment [37].

3.1 Classroom Interventions to Support Writing

Due to the importance of writing proficiency in literacy and general academic performance of students, a good body of work has addressed teaching methods of writing for elementary school students. Graham et. al [46] identified 12 types of interventions that have been investigated in previous literature as effective strategies to teach or support writing activities for students. These interventions are grouped into four overall categories - *Explicit Instruction* (e.g., Teaching students strategies to plan, draft or revise their writing, or use imagery to be more creative), *Scaffolding Student's Writing* (e.g, Pre-writing activities such as mind mapping, or peer assistance) *Alternate Modes of Composing* (e.g., using word processors) and *Other* methods (e.g., Increase writing practice, and implementation of complete writing programs). Reviewing this line of research concludes that providing instructions and strategies for better writing has an overall positive effect in student's writing prowess.

Previous work has established the importance of pretend play in children's literacy development [47]. Smith and Mathur [48] have linked children's imaginative abilities to their classroom competence and communicative skills, calling for the importance of encouraging such practices for young children. Following this body of research, previous work has extensively investigated the use of different types of drama in the classroom to support young children's reading and writing. Mc Master [49] points out that drama can be used to support all aspects of literacy development and is, therefore, a valuable tool for the elementary classroom. McNaughton [50] investigated the benefits of drama as a tool to nurture children's imaginative writing skills and motivate them to write better. Their experiment compared children's writing performance in different forms of imaginative writing - a poem, report, or a story. The control group had discussion as a prewriting activity, while the treatment group had classroom drama (paired role-play). They found that the children in the drama group performed better in all categories of writing quality, and they also wrote longer pieces. Bayraktar and Okuvran [51] have also demonstrated in their study that creative drama as a prewriting strategy can improve fifth graders writing grades and create a positive affect towards the writing activity, with the majority of the students describing their experience as enjoyable and entertaining. However, they also point out the importance of the duration of the activity in creating the intended positive impact on children's writing, i.e., a drama session that is too short in duration will not allow the children enough time to engage with the task and the story properly. These examples and other similar works demonstrate that story enactment can be a successful prewriting activity given an appropriate setup. As a result, specific strategies employed when using drama in the classroom can be very diverse depending on age and the activity goals. Regarding the strategies to include drama in writing activities, Cremin et al. [52] investigate two methods of integration: the *genre-specific method*, and the *seize-the-moment method*. They found that the latter engages the children more by allowing spontaneity and choice and can result in a more complex story writing outcome.

Previous work has extensively investigated the use of different types of dramatic play activities in the classroom to support young children's literacy development. Specific startegies to include drama in classroom can vary based on the grade level and goals of the activity. Various types of methodologies have been investigated in the previous work. For instance, Cremin et al. [52] compare two methods of integration: the *genre-specific method* - structured and focused - , vs. the *seize-the-moment method* - spontaneous and free-form. They found that the latter creates a higher level of engagement in children by allowing for spontaneity and choice. The higher level of engagement can in turn lead to a more complex story writing outcome. In another work, McNaughton [50] investigated the benefits of drama as a means of nurturing creativity and motivational tool for children's imaginative writing. In their experiment, the control group had discussion as pre-writing activity, while the treatment group had classroom drama (in the form of paired role-play). They found that the children in the drama group performed better in all categories of writing quality, and they also wrote longer pieces. These examples and other similar works demonstrate that enactment can be a successful pre-writing activity.

3.2 Systems to support Writing

Another category of writing support systems focuses on more creative and expressive types of writing such as narrative. Many of these systems are aimed at younger children and elementary school students. For narrative writing support for instance, Howland et al. [53, 54] designed and evaluated a game creation tool that supports the development of narrative writing skills for middle school children. Their interactive software, *Narrative Threads*, supported children in creating more complex storylines and characters, as well as more elaborate dialogues. Contextual cues are another approach applied in these systems. For example, Holdich and Chung's "HARRY" system [55] provides prompts for structuring and detailing an imaginative narrative for young children. Their system is designed as a conversational agent but the cues do not include a visual element. An example of a system with visual stimulus is Kuhn et al.'s "Storytime" [56] software. Storytime aims to facilitate children's writing through video scaffolding. In this software, topics are presented as short 20-second videos. The system also displays contextual cues by providing screenshots of the videos and asking for a sentence. However, this system is designed for expository writing. Our work aims to extend this body of work by investigating contextual cues in the context of video-scaffolded narrative writing.

3.2.1 Visually Scaffolded Authoring Tools

The use of pictures and motion picture as a narrative retelling or writing stimulus has been investigated in the classroom context and for emergent literacy. For example, Shapiro and Hudson [57] investigated the coherence and cohesion in young children's picture-elicited narratives. They found that if children are given a series of pictures illustrating a story-structure, they are more likely to create coherent and cohesive stories, compared to when they are presented with an uneventful sequence of pictures. Bates [58] conducted a study comparing the use of a single picture vs. a series of pictures as writing stimulus for 7 and 8 year-old children. They found that with a single picture as the stimulus, children's narratives are more structured and contain more orientation details compared to when they used a series of pictures. Pearce [59] also demonstrated that the choice of stimulus can affect children's oral narratives, with picture books resulting in more complex and informative oral narrative retellings compared to a single-scene picture.

There are relatively fewer works investigating video stimulus for children's writing. One example is Anderson et al.'s comparison of static vs. animated story stimuli [60] on children's writing. They compared the conditions based on story grammar units and found that static stimulus can be just as effective as animated stimulus for children's narrative writing support. Eaton et al. [61] investigated evaluative expressions in children's oral narratives stimulated by a video sequence without dialogue. In addition to the video, the children in this study received contextual prompt questions during video playback that drew their attention to the main action in the scene. Their study showed that the video stimulus in addition to the prompts, allowed the children to adopt a more global view of the story perspective and greatly supported their creation of evaluative statements. This body of work shows that visual stimuli can be a generally effective method for supporting children's narrative creation and writing. The type of stimulus (single picture, multiple pictures, or motion picture) can affect its efficacy - although the findings on which stimulus is most effective vary depending on specific study designs and measures. Additionally, the contextual prompts provided during the writing task can significant affect on children's writing performance.

3.2.2 Enactment-scaffolded Authoring Tools

Many if the interactive technology and tools designed to support pretend-play activities are focused on creative imaginative stories as the intended outcome rather than a more formal mode of expression such as writing. These tools tend to focus on creating an environment for nutrturing children's creativity and motivation to engage in creative tasks. For instance, Ryokai and Cassell's StoryMat [62] combine elements like small stuffed animals, voice and video recording and audio feedback to create an environment for collaborative creative storytelling. In another work, Cassell and Ryokai [63] have observed that technology-supported storytelling activities tend to be more engaging, and result in outcomes with higher creativity. In a more recent study with 100 fifth-graders, Yilmaz and Goktas [64] showed that the participants who used their designed Augmented Reality Cards for storytelling had a significantly higher story creativity scores than those in the control group using regular cards. Application of pretend play as a writing support strategy is less explored in previous work. One notable exception is Chu et al.'s DiME system [37] and their concept of *Performative Authoring* [9]. In their work, motion capture is used to record a video of the child's body-based enactment. This video recording is then used as an externalization of the child's imagination, which they can watch and revise to create more complex and coherent stories. They have shown that performative authoring can be a way to augment children's creative self-efficacy [38], especially as they reach the developmental period of *the fourth grade slump* [65]. They do not directly focus on technical aspects of narrative writing such as the topic development, and instead, develop a measure to assess imagination in stories based on the process of creating enacted stories [66].

3.2.3 Interactive AI-supported Authoring Tools

Due to the importance of writing in student's development and education, various types of writing support technologies have been proposed and investigated in the previous work. However, the body of work on writing tools designed with the elementary school student in mind is limited, and most systems are instead designed for higher level students or adults. Moreover, most of these tools are designed as *tutors* following more traditional instruction-centered models rather than constructivist approaches to teaching and learning. For instance, Roscoe et al.'s *Writing Pal* [67] is an intelligent tutoring system (ITS) that combines various adaptive teaching and feedback strategies to support users to write better. Similarly, Michaud et al. [68] investigate an intelligent tutoring system specialized to give writing feedback to deaf high school or college students. The support that younger children require during writing, however, can be very different from structured instruction. Examples of methodologies investigated in previous work include Collaborative writing techniques [69], where support is provided through peer feedback. For children with special needs, using symbols, word prediction, and displaying phonetics [70, 71, 72] can be important means of supporting writing.

Developing interactive systems to support novice writers has been the subject of several studies in HCI. These works have explored various pedagogical approaches, for instance, Roscoe et al.'s [67] "Writing Pal" system is an intelligent tutoring system designed for high school students. Writing Pal combines several strategies to support and nurture students' writing, including explicit instruction, game-based practice and automated feedback. Others have proposed writing support and tutoring systems for students with special needs, such as Michaud et al.'s [68] intelligent writing tutor system for deaf high school students. Their system automatically analyzes the text for grammatical errors and engages the student in tutorial dialogue. These examples and similar other works are mostly intended for older students and providing support in writing essays and class assignments.

Providing automated evaluations [73] are another example of methods used in systems focused on writing support. Following this methodology, several types of AI-assisted authoring systems have been proposed for creative and narrative writing. For example, stefnisson and Thue [74] introduce a Mixed-initiative model for interactive storytelling support system that uses NLP and generates suggestions through three author modules. Samuel et al.'s *Writing Buddy* system [75] is another example of a mixed-initiative model proposed for interactive storytelling. In a recent work, Roemmele and Gordon [76] introduce *Creative Help*, a system that assists with creative writing by suggesting sentences based on a RNN language model. While most of the works in this domain are not designed specifically for children, the promising results demonstrate a need for further research in this area to create tools that support literacy development, especially for children users.

Roemmele and Gordon [76] have introduced *Creative Help*, a system that assists with creative writing by suggesting sentences based on a RNN language model. In these examples, the AI-assistant can provide personalized guidance that is customized to user strengths and weaknesses.

4. OVERVIEW OF APPROACH

In this chapter, we present the theoretical foundation of our approach to writing support. Grounded in theories of embodied cognition, we describe the rationale for enactment-scaffolded authoring and why this approach may be effective in supporting children's written expression. We conclude the chapter with the research roadmap for the rest of this document.

4.1 Theoretical Foundation

Storytelling and pretend play are used as learning tools in different stages of children's development, from learning social and language skills in early childhood to written expression and reading comprehension in classroom education during later years [77]. In this body of research, we aim to explore using digital enactment to support children's writing. We investigate how the use of enactive media in the prewriting stage of the writing can facilitate children's narrative authoring process. We focus on children at the age range of third to fifth grade. At this age, children are transitioning to formal linguistic expression, so age-appropriate support tools are crucial to support this transition.

To aid the process of turning ideas and imagination into written expression, it is common in classrooms to scaffold the writing process for children by encouraging them to first plan or construct their stories in mediums that is easier and more familiar to them. These is often referred to as *pre-writing strategies*. Common pre-writing activities include storyboarding [26], drawing and drama [78]. Even for more proficient writers planning a writing in advance has shown to be helpful, for instance through making outlines [79]. The pre-writing strategy acts as a bridge across media, that allows the writer to *translate* their thoughts and ideas to the written expression by first creating a *writing-ready* form of these ideas [24]. Prewriting therefore separates the process of idea generation and planning from the technical aspect of writing such as spelling, punctuation and individual sentences, thus significantly reducing the cognitive burden of writing on the novice child writer.

We investigate using enactment in the prewriting stage. However, the child's enactment is transient and does not result in a tangible outcome to which the child can refer to during writing. To address this issue, we build our approach upon Chu et al.'s [9] conceptual model of *Performative Authoring*. In this model, the child creates a digital representation of their enactment that can be a combination of text, images and videos. This multimedia recording is a persistent externalization of the child's imagination, so it allows the child to engage in the iterative creative process of storytelling.

Theories of embodied cognition emphasize the importance of external and physical representations on human cognition. David Kirsh [80] observed that the human cognition highly depends on external structures and representations to anchor and organize ideas and make sense of them. He explains this as the reason people tend to create diagrams, gestures, or other external representations of thought, especially for complex tasks like problem solving, rather than using mere imagination. These externalizations create a reference that can be shared and can become more complex and involved as needed because they are not limited to a single person's cognitive resources [81]. In our approach, the recorded digital video of the child's enactment is a tangible externalized outcome of the imagination which can facilitate more complex modes of expression.

We summarize the rationale of our approach as below:

1. The prewriting process allows the child to separate the processes of idea generation from translation and expression, reducing the cognitive load. Embodied prewriting approaches allow for ideas to fuel the writing without the burden of thinking about writing mechanics. By allowing the child to apply their tremendous capacity for embodied imagination, pretend-play allows the child to use their cognitive capacity more effectively during writing.

2. Embodied enactment allows the child to employ their tremendous capacity for embodied imagery and creativity as scaffold - As pointed out by Kirsh's notion of externalization. At the target age range, children's mental representations are not fully symbolic yet. An embodied representation can support and catalyze idea generation with externalized representations.

3. Children's interest in embodied mediums such as pretend play and animation can motivate them to engage in the writing activity. Previous work like Chu et al.'s [9] study has demon-

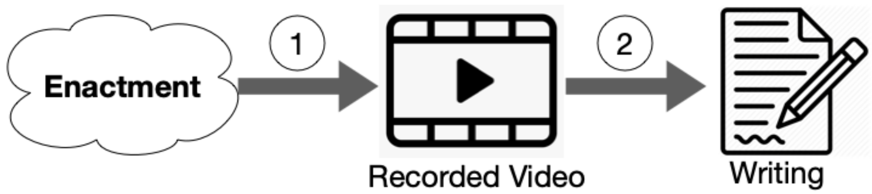


Figure 4.1: Proposed Approach

strated that embodied enactment can increase children's creative self-efficacy - particularly for introverted children. Our approach aims to make use of this potential to encourage and engage children in writing.

4.2 Research Roadmap

Our approach to designing enactment-scaffolded authoring system for children's writing support is shown in the diagram in figure 4.1. As shown, our approach has two main steps: 1- Recording the child's enactment, and 2 - Supporting the child in translating the recorded story into written from.

We began our studies by focusing on step 1 (see figure 4.1): We developed a system that allows the child to record a digital video from their story enactment. Then we used this system as a testbed to investigate aspects of design in enactment-scaffolded authoring tools that support stronger storytelling and written products. We presented design suggestions for these systems based on our observations. We also proposed two types of avatar design, and demonstrated in our user study that the choice of avatar can affect children's creative storytelling and writing.

In the next part of this dissertation research, we focused on step 2 (see figure 4.1): We investigated the structure, coherence and content in the story recorded as video and the written story. We found that these stories vary significantly in terms of structure and there is a more complex level of imagination present in the visual stories. In other words, we found that children need support in *translating* the narrative in the video into written form. In another perspective, this problem can be framed as a question of transitioning across media forms. The first medium is the embodied and enacted, the second medium is the written expression. Understanding and expressing knowledge via and across these mediums is not trivial, because each medium has different characteristics and structural properties. In the multimedia research studies, this concept has been termed as *transmedia*.

We explore the ways this support may be designed in the context of an interactive system. To this end, we propose two types of contextual cues for children's video-stimulated writing grounded in cognitive theory of multimedia learning by Richard Mayer [18]. We design and evaluate these contextual cues and provide evidence that the design of contextual cues can significantly affect children's process of writing and their written story.

5. CAPTURING THE CHILD'S PRETEND PLAY

5.1 Introduction

This chapter[1] presents the design model and development of our Story Creation System. The system was designed to capture a child-user's pretend play and record it into an animated video. The system also allows for them to view and revise the video as needed. The system is designed to embody the concept of *"Performative Authoring"* as defined by Chu [82] and Chu et al. [9]. We describe our system design and the interaction details. The story creation system is our testbed prototype for the studies described in chapters 6 and 7.

5.2 Supporting the Child's Imaginative Story Creation

Creative storytelling has a key role in children's literacy development [77]. Due to this importance, storytelling support is an important area of focus in HCI [83] and much effort has been invested to support creative storytelling activities and embodied story authoring tools in particular. Sugimoto et al.'s *Gentoro* system [84], Sylla et al.'s *TOK Stage-Narratives Creation* system [85], and Chu et al.'s *DIME* system [37] are a few examples of these efforts.

We aim to understand the effects of performative authoring on children's writing performance. We need to create a setup that allows the use of children's free-form body-based enactment as a pre-writing activity to write stories. This setup needs to afford an iterative and interactive process of story planning and creation to allow children to create imaginative stories. Moreover, since children's pretend play is transient and does not result in an immediate concrete output, the setup captures the enactment to be later on reviewed during writing. Therefore, we developed an interactive story authoring application with a simple and intuitive GUI that allows children to plan a story in multiple scenes, enact and record the scenes as videos, revise and reorganize the story scenes and playback the full story video in the end.

[1] Parts of this chapter are reprinted with permission from the following:
"Investigating the Effects of Self-Avatars and Story-Relevant Avatars on Children's Creative Storytelling." by Niloofar Zarei, Sharon Lynn Chu, Francis Quek, Nanjie 'Jimmy' Rao, and Sarah Anne Brown. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems, pp. 1-11.* Copyright 2020 by ACM.

5.3 Story Creation System

The user interface of the story creation system is a Windows-based standalone application built using the Unity3D Game Engine [86]. It allows children to plan, act, record, revise, and watch their stories as multiple video clips. The flow of the interface's story creation process is shown in figure 5.1, and is described in more detail in the following subsections.

5.3.1 Story Planning

In our interface, a story is a collection of scenes that are ordered chronologically. The planning of the story is guided by a simple given story structure often used to explain event sequences to young schoolchildren - consisting of a Beginning, Middle, and End. These three sections of a story are represented by three rows that act as containers for story scenes on a timeline screen, shown in figure 5.1a-A. Here, the child user is given a visual overview of their story for the purposes of organization and story planning. The user can add scenes in each of the three sections, drag the scenes around for re-ordering, or delete a scene using the trash icon in the bottom left corner.

5.3.2 Scene Setup

A story scene is constructed by adding four scene elements that prepare the scene with the details needed for acting and recording. These elements are:

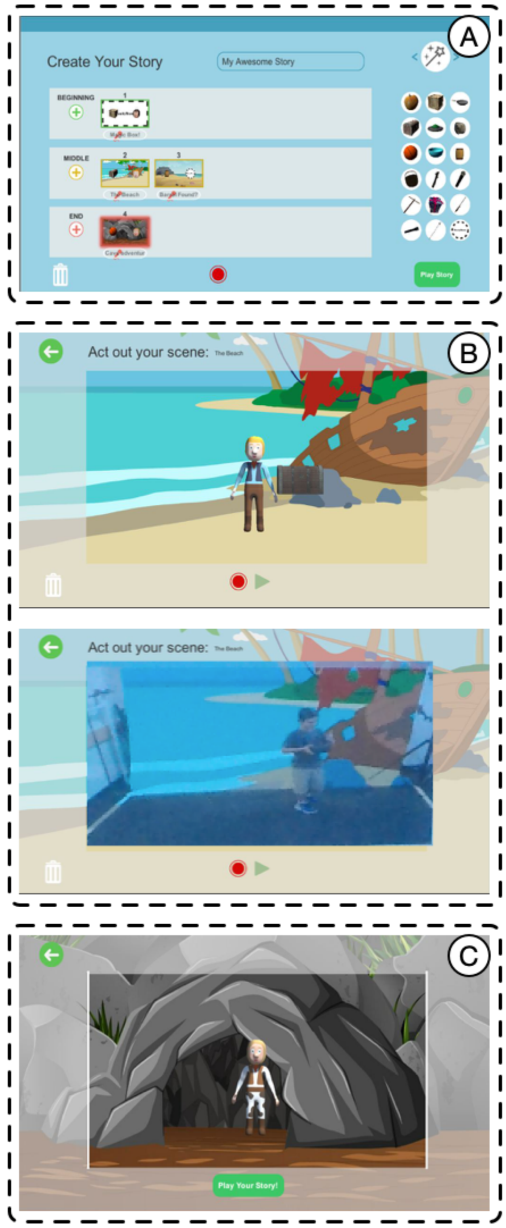
- *scene character* - who is in the scene?
- *scene prop* - what is in the scene or what is the character using?
- *scene background* - where is the scene taking place?
- *scene title* - what is the scene about?

The character, prop, and background choices are shown as icons on the right-hand side of the timeline screen (figure 5.1a-A). Some examples of the character, prop, and background choices are shown in figure 5.1b. An enlarged preview is shown when the mouse cursor is hovered over the icons, to make some of the smaller choices more visible. The elements can be added by dragging and dropping them onto the scene itself. There are also options for not choosing any character, prop, or background if the child so desires. The scene title can be typed in the field provided beneath the scene on the timeline. Once a scene has all four pieces of detail attached to it, the user may select it for recording.

5.3.3 Story Recording

To create a story scene recording, the user clicks on the red recording button on the timeline screen. The recording screen is displayed (figure 5.1a-B) with the character that the user selected (if any). A prompt then instructs the user to pick up the physical prop that corresponds to the prop they chose for the currently selected scene in the interface. Following an approach similar to Chu et al. [9] for full body-enactment storytelling for children, the physical props are objects with generic shapes (a stick, a lantern, a ball, a racket, a cylinder, and a box) that children can actually handle to help them in their story enactment. We included props in this study because props have been shown to generally support children's creative performance [87, 88]. Each physical prop corresponds to multiple virtual props shown as prop choices in the interface. A few examples of the prop choices are shown in figure 5.1b.

After picking the prop, the child is instructed to get ready to act out their story and to step into the enactment area. The enactment area is a 10 ft by 10 ft space equipped with motion tracking cameras and a green screen. Depending on the child's avatar condition, the child either sees him/herself as the avatar or a cartoon avatar on the screen. The researcher starts and stops recording of the child's story enactment by clicking the record button in the interface upon receiving a signal to do so from the child actor. The recording of a scene produces a scene video that can be reviewed by the child. If the child wants to record the scene again, the video can be deleted and re-enacted/re-recorded as many times as he/she desires. Once the child is satisfied with the specific story scene, he/she can return to the timeline screen and enact/record the other scenes in their story.



(a) A) Timeline B) Recording C) Playback.

(b) 1) Backgrounds. 2) Characters. 3)Props. Note: Character choices are only available in story-relevant avatar condition.

Figure 5.1: Story creation interface and story detail choices.

5.3.4 Story Playback

All recorded scene videos are added to the current story's video database and can be retrieved for viewing at any time from the timeline screen. After the child has finished all the scenes in the story, he/she watches all of the recorded scenes in the order they specified on the timeline using the playback function. For a story to be allowed to be played back in its entire, two conditions had to be fulfilled: (1) the story must contain at least one scene in each timeline category (beginning, middle, end), and (2) all of the scenes that have been added to the story timeline have to be enacted/recorded. We decided to limit the maximum number possible of scenes in a story to 5 scenes in each timeline category (15 scenes total) in an effort to keep the duration of the story creation process within a manageable scope. When the two above conditions are met, the green "Play Story" button is activated on the timeline screen. Clicking this button takes the user to the playback screen (figure 5.1a-C) where the entire story video can be watched. After watching, the child can return to the timeline screen to revise their story and scenes as desired.

6. AVATAR DESIGN FOR ENACTMENT-BASED AUTHORING

6.1 Introduction

The development of the story creation system (See chapter 5) involved several choices in the system design. Our goal was to ground these choices to the best of our ability in the previous work. For example: the choice of using an enactment background has been shown by Chu et al. [89] to create motivation and engagement in children's storytelling. The choice of using generic prop has also been shown to generally support children's storytelling [87, 90].

A child's projection of mental imagery can transform her into various characters and transport her into imaginary worlds. Similarly, the vast affordances of technology can be designed in such a way to support imagination. This chapter [1] explores how avatars - one of the common affordances of virtual environments - may affect and potentially support children's story creation and writing. Prior research has shown that the choice of avatar can potentially affect how the users perceive themselves and behave in a virtual environment. Yee and Bailenson [91] term this phenomenon *The Proteus Effect*. Other works such as Guegan et al.'s study[92] investigate the effects of priming creative stereotypes and self-similarity on the user's creative performance. This line of research demonstrates the importance of avatars in designing software, especially software aimed to support creative tasks.

Prior research has heavily addressed successful aspects of avatars for personalization and customization within interactive or immersive, predefined environments for children. However, this research on avatars has been situated primarily within the context of more performance-based tasks such as video games and digital exercise. We are interested in avatar design for creative and expressive applications, where the goal of the user is to produce creative products, such as stories. We investigate two types of avatars in story creation interfaces for children: one where the avatar is

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the child him- or herself, and one where the avatar is a virtual, transformed representation of the child.

We posit that the design of the avatar used may have an effect on various qualities of the creative product generated by the child. Aspects of the avatar design can provide more or less support to scaffold the imagination of the child in mentally projecting onto the character being created in the story. For example, on the one hand, an avatar that fully represents the child may produce a high degree of identification, but may provide little support for the child to imagine a self-transformation into a given story character and create a story accordingly. On the other hand, an avatar that more accurately represents the story character may not allow the child to identify with it as easily, but may facilitate story creation. In this study, we investigate whether the use of a self-avatar or a story-relevant avatar affects children's storytelling process differently, and if so, how.

6.2 Research Questions

In the context of creative storytelling for children, to tell the story of a character, the child needs to be able to mentally project themselves onto the story character they have imagined and wish to portray. So, the story creation interface can support this mental projection by creating a visual representation of the child in their story, through an avatar that exists in the virtual story world. Thus, in our investigation, an avatar that is a direct external representation of the story character in a child's story may help to lower the need for mental projection on that specific issue. In contrast, an avatar without direct visual similarities to the story character might require a higher mental projection effort. The core question in this work is how this higher mental projection effort impacts the quality of the storytelling experience for the child user, as well as the quality of the story output created by the user.

We are interested in investigating the effects of a story-relevant avatar on the quality of children's storytelling, with the goal of informing avatar design in creative authoring applications for children. In our investigation, we make this comparison between the story-relevant avatar (an avatar resembling the story character) and the self-avatar (an avatar resembling the child user). Our study is positioned within the context of a story authoring application that allows children to create a digital story via the use of body-based enactment or pretend play. Our research questions were:

RQ1: Is there a significant difference in terms of children's sense of embodied presence and degree of identification with the avatar between the use of a self-avatar and a story-relevant avatar in an enactment-based story authoring application?

RQ2: Is there a significant difference in terms of children's quality of storytelling between the use of a self-avatar and a story-relevant avatar in an enactment-based story authoring application?

RQ3: Is there a relationship between the children's sense of embodied presence and degree of identification with the avatar and the quality of their storytelling from an enactment-based story authoring application?

6.3 Avatar Implementation

The story creation system supports two avatar types for the child users: the story-relevant avatar and the self-avatar. The researcher activates the rendering of the correct avatar type based on the condition that a child participant is assigned to by changing a variable in a system preference file. The story-relevant avatar transforms the child into a 3D cartoon character (a cowboy or cowgirl in the current study) that is specific to a predetermined story prompt during story enactment. Additionally, the child's voice is transformed into a cartoon voice during enactment. The physical objects that the child uses to support enactment are displayed as story-relevant virtual objects on the screen.

The self-avatar, on the other hand, is the direct streaming and recording of the child him/herself. Thus, the self-avatar takes on the appearance of the child and talks in the child's own voice. Furthermore, the physical objects that the child uses as props for enactment maintain their exact appearance in the virtual story. Both avatar implementations use the same cartoon-like story backgrounds.

The choice of having the prop virtually augmented in the story-relevant avatar condition and not in the self-avatar condition in our study design is because we are focusing on children's mental projection during enactment. The study design is such that children would have to mentally project both the story character and the object being used by the character in the story (e.g., a cowboy using a pickaxe) in the self-avatar condition while using the same base prop as in the story-relevant

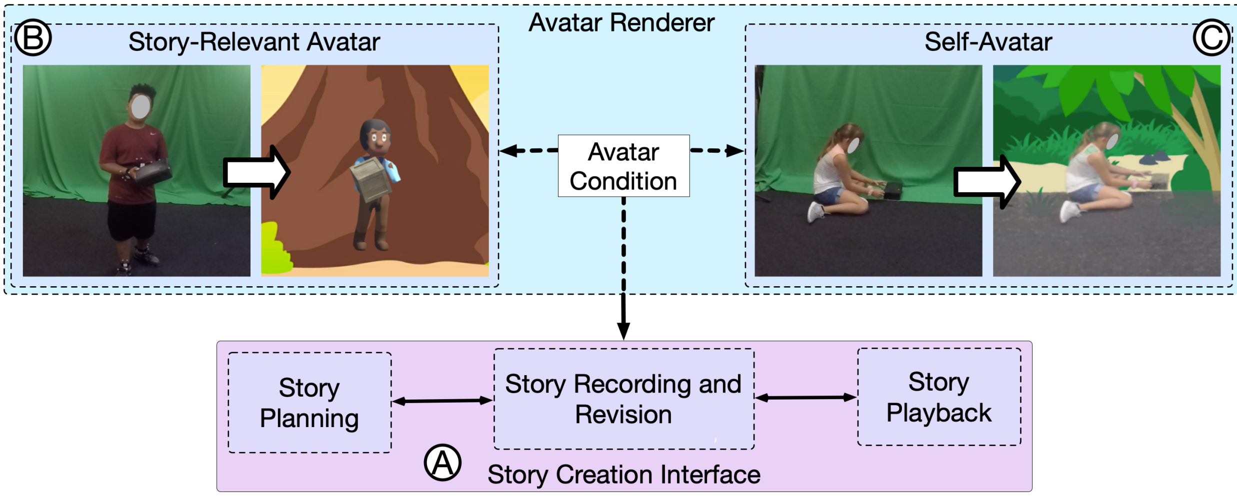

Figure 6.1: Diagram Flow of the Story Creation Interface and the Avatar Renderer. A) Story Creation Interface and its elements. B) Story-Relevant Avatar example. C) Self-Avatar example.

condition. Our study is designed such that children would have to mentally project both the story character and the object being used by the character in the story in the self-avatar condition while using the same base prop as in the story-relevant condition.

Figure 7.1E shows the two avatar implementations with respect to the overall system and an example view of the story-relevant- (B) and self- (C) avatars. Table 6.1 summarizes the different aspects of each avatar condition.

6.3.0.1 Story-Relevant Avatar Implementation

We implemented the story-relevant avatar using real-time motion capture via marker-based body tracking. Five optical markers each attached to an elastic Velcro band are placed on the child's wrists, ankles, and the torso. We also added optical markers to the physical objects used as props in order to track them. We set up 12 cameras from the *Optitrack* system to capture real-time 3D tracking data from all the markers in the enactment area. The tracking data is then transferred over a network to a computer running the story creation application. The tracking data is used to animate the corresponding virtual prop and the cartoon avatar. To obtain a fluid animation with the limited markers that the child wore, we applied Inverse Kinematic restrictions [93] to the raw

Condition	Avatar	Voice	Prop	Environment
Story-Relevant Avatar	Cartoon character, generated via live motion capture of the user	Stream of user's voice with cartoon voice effect applied	Cartoon object selected in interface, generated via live motion capture of the prop	Cartoon background selected in the interface
Self-Avatar	Unchanged video stream of the user	Unchanged audio stream of user's voice	Video stream of physical prop associated with object selected in the interface	Cartoon background selected in the interface

Table 6.1: Summary of transformations in each avatar condition.

tracking data from the body markers to estimate joint locations on the character's rig. The result is a cartoon character that moves smoothly according to the actor's body movements, although finer grain movements were not always reflected in the animation. Once a story enactment video is recorded, a pitch modification filter is applied to the resulting video file which transforms the actor's voice into a cartoon voice.

6.3.0.2 Self-Avatar Implementation

We implemented the self-avatar using a green screen setup. We placed the green screen on one side of the enactment space, facing a *Logitech* webcam connected to the computer running the story creation application. A chroma-keying effect is then applied to the video stream, replacing the green screen with the scene background previously selected in the story planning step. The child and the prop appear unchanged after this effect is applied; therefore the story avatar in this condition is the child's video image, and the prop retains its real physical look. Voice transformation is not applied in this condition and the child's own voice is heard in the recorded enactment video.

6.4 The Study

The study employed a within-subjects design with the type of avatar as the independent variable. The independent variable had two levels: story-relevant avatar and self-avatar. The dependent variables included degree of character identification, level of embodied presence, game experience, story creativity, and writing quality.

6.4.1 Participants

We recruited a total of 20 children between the ages of 8 to 12 years for this study. The participants were recruited through the campus university mailing list and a local scout group

	Baseline Measures		Dependent Measures		
Measure	Pre-Study Questionnaire	Personality Assessment	Post-Study Questionnaire	Story Essays	Story Enactment Videos
Scale(s)	Autman and Kelly (2017) Writing Apprehension; Tierney and Farmer (2002) Creative Self-Efficacy	Deal et. al (2007) Inventory of Children's Individual Differences - Short Version	Ijsselstein et al. (2013) Game Experience Questionnaire (GEQ) Post-Game Module; Van Looy et al. (2012) Avatar Identification Questionnaire	Story Complexity; Story Richness	Story Complexity

Table 6.2: Summary of the Measures Used in Our Study, and the Scales Included in Each Measure.

mailing list. Four participants did not complete the entire study protocol (for example, not filling the questionnaires), and were thus not considered in the final data analysis. The final participant count comprised of 16 children (5 female, 11 male). All participants received a small toy as compensation after completing the study.

6.4.2 Study Protocol

A child participant attended two sessions, each approximately two hours long. The participant went through the study protocol for one condition per session. The sessions were scheduled on separate days for each participant to avoid him/her becoming fatigued. The order in which the conditions were experienced was counterbalanced across the study sample. The study protocol was as follows:

At the beginning of the first session, the child and parent received an information sheet, after which they were given a parental consent form and a minor assent form respectively to read and sign. The participant was then asked to fill out a pre-questionnaire for our baseline measures and demographic information. The researcher explained to the participant how to use the story creation interface and allowed him/her to practice creating, acting, and reviewing a few created scenes for 5-30 minutes until the child felt comfortable with the interface. While the researcher explained the interface to the child, the child's parent was asked to fill out a personality category rating questionnaire [94] pertaining to their child's personality.

Once the child announced that they were ready, the researcher gave him/her a story prompt to base their story upon. To avoid learning effects in the within-subjects design of the study, two different story prompts were used for the study, both following this general format: *A cowboy/cowgirl* *found a [story prop] in a [story location]. Create a short story about what happens next."* In the first prompt, the prop was a 'magic rock,' and the location was a 'ranch', and in the second prompt, the prop was a 'mysterious box', and the location was a 'beach'. The story prompts were counterbalanced across the two conditions over the participant sample, i.e., some participants received the first prompt for the self-avatar condition and the second prompt for the story-relevant avatar condition, while others received the second prompt for the self-avatar condition, and the first for the other condition. The story props (a magic rock/a mysterious box) and story locations (the beach/the ranch) were available in the story creation interface to select for their story scenes. However, participants were free to choose props or locations other than the ones mentioned in the prompt, as many other options were present in the interface.

Participants were then given as much time as they needed to create a story using the story creation system as per the assigned condition for the current session. When participants confirmed that they have finished their story and did not want to do any more revisions, they were asked to write down their story on paper. The researcher also encouraged them to include as much detail as they can in their writing, and emphasized that they could watch the scenes or the whole story as many times as they wanted during writing.

After the completion of the main story creation task and writing, participants were given a post-condition questionnaire to fill out by thinking about their experience throughout that particular session. They were then engaged in a short semi-structured interview about their overall experience, covering questions such as "What did you like/not like about the experience?", "Did the story creation activity help you in writing your story?", and "Which one of the avatars did you prefer and why?" (this question was only asked at the end of the second session). The study was concluded with the researcher bringing a small toy as a gift/compensation for the child's participation. We also provided the story enactment videos to the parents as keepsakes, if they asked.

6.4.3 Measures

The pre- and post-study questionnaires used 5-point Likert-scales, graphically depicted (5 squares with increasing sizes underneath the options "not at all" to "very, very much").

6.4.3.1 *Baseline Measures:*

The baseline measures for each participant consisted of the following:

The pre-questionnaire consisted of nine items, including 6 items for writing apprehension taken from Autman and Kelly's Writing Apprehension questionnaire [95], and 3 items for the creative self-efficacy scale proposed by Tierney and Farmer [96]. The creative self-efficacy items were: (1) I am good at coming up with new ideas; (2) I have a lot of good ideas, and (3) I have a good imagination.

The personality assessment came from Deal et al.'s Inventory of Child Differences - Short Version (ICID-S) Questionnaire [94] - a 50-item questionnaire designed to assess the personality of children and adolescents based on the Five-Factor Model (FFM).

6.4.3.2 *Dependent Variable Measures:*

Measures for the dependent variables in our experiment were obtained from the following four data sources:

The post-study questionnaire was a set of 29 items obtained from two sources: i) IJsselsteijn et al.'s Game Experience Questionnaire (GEQ) Post-game Module [97]. GEQ contains measures for the overall game experience, such as positive/negative experience, and tiredness. Although we distinguished our story authoring application from a game application earlier in the chapter, the GEQ is still applicable because it has also been used in previous research to measure general user experiences, for example in work by Dionisio et al. [98] and Zhang et al. [99]; and ii) Van Looy et al.'s Avatar Identification Questionnaire [100], which contains questions for similarity identification and embodied presence dimensions.

Story essays were analyzed for two measures: the number of ideas in the story, and story richness.

Story enactment videos were analyzed for the number of ideas in the story.

Table 7.1 summarizes the measures used in our study and the scales for each measure.

6.5 Data Analysis

Three main types of data were collected: story enactment videos, written story essays, and questionnaires.

6.5.1 Video Analysis Method

For the coding of the enacted videos, we adapted two concepts from prior approaches to story analysis: *idea digests* and *vignettes* [9, 66]. An idea digest is the decomposition of the story into units that contain a single idea or thought, and is a concept we also utilize in our analysis of the children's written stories. As this concept is intended for written text, we determined the number of idea digests in each story from a transcription of a given story's audio dialogue. In order to also capture the ideas from the enacted performances that are introduced through action, we also count the number of vignettes present in each enacted story. A vignette operates much like an idea digest - as a unit, it encapsulates a singular conveyed idea. The key distinction is that a vignette is a single idea conveyed through action alone, instead of speech. To avoid confounding the two, during the coding of the vignettes, the video of the child's enactment was muted, such that only distinct actions could be accounted for. The end result was a score indicating story complexity, calculated by the number of idea digests in a given story's transcribed speech, combined with the count of vignettes in a story video.

Using this method with two coders, we had a final inter-coder agreement of over 90% for both the coding of idea digests across all participant stories, as well as the coding of vignettes across half of the participants. The other half of participant vignettes were assigned to only one coder. The results of this analysis were standardized by the length of the story video in seconds, and a paired t-test was used to evaluate the data.

6.5.2 Written Story Analysis Method

The analysis of written stories was done using two methods:

6.5.2.1 *a. Text Analysis*

Following the narrative analysis method from [101], one of the authors coded each participant's story into an 'idea digest', a method we utilized in the analysis of the story videos as well. Analyses of the written stories were performed to obtain a measure of story complexity and 2 different measures of story richness. **Story complexity** was operationalized as the number of idea units in the idea digest of a story. The two measures of story richness were subsequently summed to produce an overall story richness score for each written story. A **normalized overall richness score** was then obtained by dividing the score by the total word count of the story. This way, even if a story was significantly shorter than another and naturally possessed fewer details and descriptors, we could still gauge a sense of its richness.

The first measure for story richness was the sum of all occurrences of 5Ws+1H (What/Where /Who/When/Why/How) in the idea digest. Borrowing from news narratives, which are often evaluated based on the 5Ws and 1H principle [102], this analysis comprised of identifying how many idea units addressing the who, what, where, when, why and how are contained in the child's idea digest of his/her story. This analysis was done by two coders who agreed on the coding protocol prior to analysis. The outcome of this procedure (summing up the total number of idea units detailing the 5Ws+H per story) was a score embodying the richness of the child's written story.

The second measure for story richness was obtained by coding for 'richness descriptors', operationalized as adjectives, nouns used as adjectives, adverbs, and descriptive verbs. For example, this sentence: *I was walking one day and found a rainbow-colored rock.* consists of two ideas (I was walking one day + I found a rainbow-colored rock.), and it contains an adjective (rainbow-colored) and one descriptive verb (walk).

6.5.2.2 *b. Domain Expert Assessment*

All written stories from both study conditions were given to an elementary language arts school teacher with over 15 years of teaching experience, who acted as a domain expert in the grading of the stories. The essays given to the teacher were accumulated in a single folder, without any information as to the study condition they were written for. Moreover, we corrected most of the spelling and some of the grammar errors in writing (without changing any of the story structures) to prevent grading bias because of language mistakes. The teacher used the Personal Narrative Rubric [103] with 4 score increments in three categories for grading: (1) Organization (beginning, middle, end), (2) Ideas and Support (plot and details), and (3) Conventions (sentence type, word choice), and an overall score. She also provided a short reason for each essay's final grade.

6.5.3 Statistical Tests

We ran repeated measures ANOVAs with creative self-efficacy as covariate to investigate the effects of type of avatar (story-relevant avatar vs. self-avatar) on the following:

[for the participants' **enactment experience**] avatar identification scores, and embodied presence scores;

[for the participants' **enactment story videos**] number of speech-based ideas (script complexity), number of action-conveyed ideas (action complexity), and normalized overall story complexity scores;

[for the participants' **story outcomes**] number of ideas (story complexity), number of details with respect to 5Ws+1H, number of richness descriptors, normalized overall story richness scores, and the teacher's rubric grades.

Furthermore, pearson's product-moment correlations were performed to find whether there are significant relationships between: i) identification scores and embodied presence scores across the two conditions; ii) identification and the various measures of storytelling quality, and iii) embodied presence and the various measures of storytelling quality.

6.6 Results

We present the results of our various analyses below, grouped by the research question. Only significant results are reported and expanded upon.

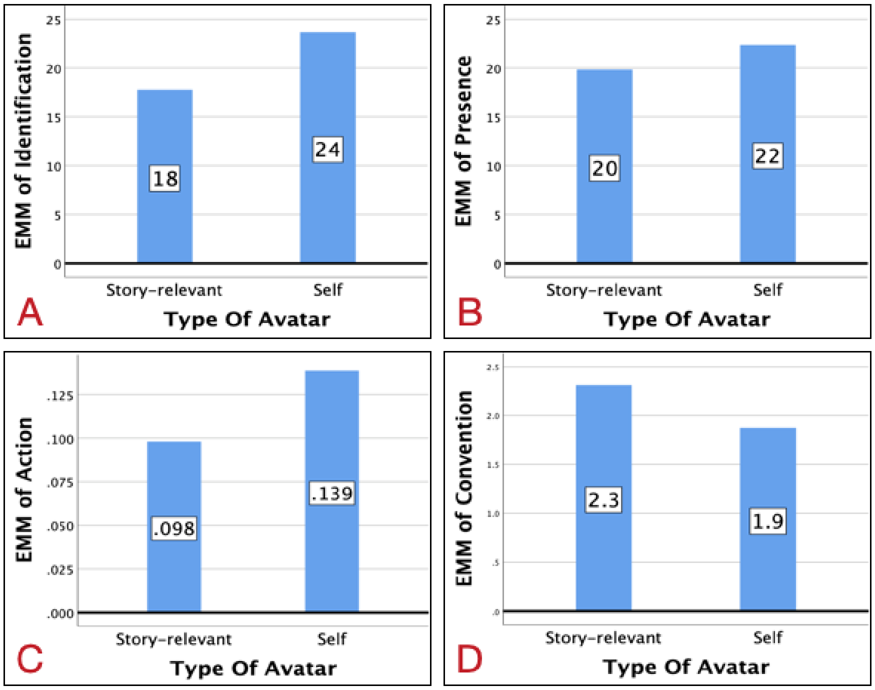

Figure 6.2: Result Plots. A) Estimated Marginal Means (EMM) of identification in the two avatar conditions. B) EMM of embodied presence in the two avatar conditions. C) EMM of vignettes in the two avatar conditions. D) EMM of language conventions grade in the two conditions.

6.6.1 RQ1: Effects on Avatar Identification and Embodied Presence

A significant difference was found between the self-avatar and story-relevant avatar conditions in terms of avatar identification score (F(1,16) = 17.058, p =.001). The self-avatar condition created a higher sense of identification (M = 23.647) compared to the story-relevant avatar condition (M = 17.765)(figure 7.2A). A significant difference was also found between the two avatar conditions on embodied presence scores (F(1,16) = 4.506, p = .050). The self-avatar also led to a higher sense of presence (M = 22.353) than the story-relevant avatar (M = 19.824)(figure 7.2B). We also found that identification and embodied presence scores across the two conditions are generally positively correlated (r = .795, p = .000).

6.6.2 RQ2: Effects on Quality of Storytelling

Storytelling quality was assessed from the analysis of story complexity of the enactment videos and story complexity, richness, and overall quality of the written stories. For the enactment videos, a significant difference between the avatar conditions was only found in the count of vignettes, or the action complexity scores $F(1,16) = 186.535$, $p = .000$. The self-avatar condition ($M = .139$) had higher action complexity scores than the story-relevant condition ($M = .098$) ((figure 7.2C)). No significant differences between the two avatar conditions were found in the text analysis of the written stories. A significant difference between the two conditions was found in the *conventions* subcategory ($F(1,15) = 5.787$, $p = .029$) of the teacher's grading, with the story-relevant avatar condition scoring higher than the self-avatar condition (figure 7.2D).

6.6.3 RQ3: Avatar Experience and Quality of Storytelling

Over the two avatar conditions, we found that avatar identification was positively correlated with normalized written story quality scores ($r = .351$, $p = .049$). A marginally significant correlation was also found across both conditions between embodied presence scores and the teacher's overall story grades ($r = 0.333$, $p = .058$).

6.7 Discussion

Our study results showed that children feel a significantly stronger sense of identification and experience stronger embodied presence with the self-avatar than with the story-relevant avatar. This is in line with what the literature suggests in that people tend to prefer avatars that have a high visual similarity to themselves [104]. We also found that action complexity (number of action-conveyed ideas) in the enactment story videos was significantly higher in the self-avatar condition. However, a possible explanation for this is that the children were able to express themselves more freely without the constraints of the motion tracking system. Thus, we do not place too much emphasis on this particular result.

Most importantly, the results indicated that language convention scores of the children's written stories, as graded by an experienced teacher, were significantly higher in the story-relevant avatar condition. Kirsh's [80] theory of mental projection can help to formulate a possible explanation here. According to Kirsh, externalized visual structures embodying specific concepts can help us to move our thinking further, since they act as scaffolds that free up cognitive resources for those concepts instead of the person having to mentally project them in the external space. In that sense, the visualized cowboy/girl cartoon character acted as a scaffold for the concept of a cowboy/girl, enabling the children to focus on other aspects of the story such as language conventions as they wrote their story reviewing their enactment videos.

Besides these results, our study also showed that sense of avatar identification is positively related to the overall written story quality scores, and embodied presence is positively related to the written stories overall scores as graded by the teacher. These correlations are across the two avatar conditions, and thus indicate more general relationships with respect to avatar design and storytelling products quality.

We summarize all our results in Figure 6.3. A more holistic consideration of all our results suggests a conundrum. The study results inform designers on the role of avatar design in embodied story authoring systems for children to influence aspects of user identification and the quality of the resulting story output (and how they may relate). On the one hand, a pathway to improving outcomes of children's use of creative authoring applications is to focus on creating avatars with which the child user identifies, and children appear to identify more with their self-avatars.

However, using a self-avatar avatar does not necessarily directly help children to produce better final written stories, since we did not find significant differences of avatar type on any measures of story richness and complexity. Using a story-relevant avatar, on the other hand, can help to improve the technical aspects of children's language (i.e., language conventions) in their final written stories because they are able to focus on this dimension of writing while specifying details (character's appearance, props used, etc.) that are already externally visualized.

Our results, therefore, show a clear design implication that further opens an interesting avenue for future HCI research on how to design avatars for story authoring systems that attempt to bridge the need for identification and quality story output. More precisely, we show that in a

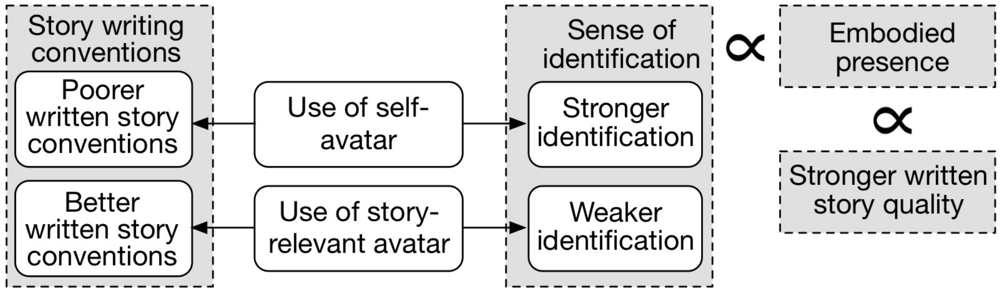

Figure 6.3: Results summary illustration

particular application, if identification is emphasized, self-avatars (i.e., enforcing mental projection of imagined story content) are preferred, but if story quality is emphasized, story-relevant avatars (i.e., providing visual externalization of story content) are preferred.

We also highlight here the possible importance of gender effects. Running a repeated measures ANOVA test with gender as a between-subject factor, we did find a significant difference between avatar type on the story complexity scores (number of ideas in the idea digest) despite the relatively small number of participants in our study ($p = .038$). There was a significantly higher number of ideas for female participants in the written story idea digests for the story-relevant avatar condition ($M = 21.932$) than the self-avatar condition ($M = 17.932$). However, we did not include this in the formal results because our sample sizes of males ($N = 11$) as opposed to females ($N = 5$) were not balanced. Thus, we interpret this specific statistical result with extreme caution, although we believe that it may be an interesting point to bring forth in the discussion here. Yet, some of our observations from our post-study interviews with the participants do reinforce this possible gender effect. When asked for their preference between the avatar types in the interview, all of the female participants answered that their preference is the story-relevant avatar, while the majority (67%) of the male participants had a preference for the self-avatar. Further investigation is needed in these areas to elicit the significance of this effect or to identify contributing factors.

6.8 Chapter Summary

In this chapter, we presented a study investigating the effects of avatar type on identification, embodied presence, and story outcomes in an enactment-based creative storytelling application. We analyzed data both in terms of creativity and writing quality. Our results revealed a complex picture. To a large extent, they support the important role of avatar identification and the theoretical framework that externalized structures may support the need to scaffold mental projection. We propose from our research not only that avatar design for children's creative authoring applications is an issue that has potential for impact and thus should be considered, but also that it is a complex issue that we lack current understanding of in HCI, relative to avatar research in predefined contexts such as games and health applications. Future work should explore other ways of making avatars in story authoring contexts more story-relevant, and their associated benefits and weaknesses on the resultant creative products.

7. ENACTMENT AS PREWRITING ACTIVITY

7.1 Introduction

Many tools and methods have been proposed to support children's writing activities by scaffolding the planning and prewriting stages. In classrooms, teachers typically use visual methods such as storyboarding [26] and graphic organizers [27] to facilitate children's writing. These methods require the teacher's regular guidance and prompting to keep students on track. Embodied means such as pretend play have also been shown as effective support for children's writing in the context of language arts classrooms [105]. However, there is limited knowledge with respect to the design of interactive technology to support the process of children's narrative writing through enactment. While Previous work such as Chu et al.'s DiME system [37] explored the effects of capturing children's playful imagination in the planning stage of the writing, support for the process of transforming writing-ready ideas into the writing was not directly addressed. Given the inherent differences of expression through pretend play and writing, children may not always succeed in this transition to generate a coherent written story. Evidence in previous work such as [106] demonstrates that children use different mediums (verbal vs. nonverbal) in different ways when engaging in multi-modal story creation, and the stories follow a fluid structure rather than a linear one. Our work, therefore, aims to compare the written and enacted versions of children's narratives to understand the underlying structures and how they relate.

In this chapter[1], we explore the design considerations and types of support that may be needed in the process of enactment-scaffolded narrative writing for elementary school children. We present a study where children used an interactive story authoring system to create, enact and record videos of imaginative stories and then wrote stories on paper while viewing these videos. We analyzed

[1]Parts of this chapter are reprinted with permission from the following:
"A Comparison of Children's Narrative Expressions in Enactment and Writing." by Niloofar Zarei, Francis Quek, Sharon Lynn Chu, and Sarah Anne Brown. In *International Conference on Interactive Digital Storytelling, pp. 125-130.* Copyright 2020 by springer.
"Towards Designing Enactment-Scaffolded Narrative Authoring Tools for Elementary-School Children." by Niloofar Zarei, Francis Quek, Sharon Lynn Chu, and Sarah Anne Brown. In *Interaction Design and Children, pp. 387-395.* Copyright 2021 by ACM.

the stories they created in their enactment videos and written story essays and compared them in terms of the structure, content, and coherence of the stories in each format. We aim to understand how children transformed the narrative between the two formats and how we may support this transformation towards a stronger written outcome. We present our findings in terms of lessons learned for designing enactment-based interactive authoring tools.

7.2 Research Questions and Approach

We frame this study based on Bruner's three modes of representation [12]: we investigate the use of story enactment, an enactive representation of narrative, as a way to support the child to progress towards written expression, which is a symbolic representation of the narrative. In other words, by using enactment as a pre-writing activity, the child then has to *translate* the story from the enactive format into a written format. In this study, we investigate this translation process and aim to understand how the children relate these two forms of representation. Our goal is to inform the design of enactment-based writing applications that can scaffold children in turning their enacted imagination into written stories. We focus our context on story authoring applications that use embodied pretend play to stimulate children's imagination. Our research questions are:

RQ1: *When using body-based enactment as a pre-writing strategy, how does the structure, coherence, and content of children's imaginative narratives compare in the pre-writing and the final written stories?*

RQ2: *What implications can be drawn for the design of enactment-based authoring systems based on the observed differences between children's enacted and written stories?*

We conducted a user study with children participants where they completed an enactment-scaffolded writing activity using the story creation system. In our study, the children first went through a pre-writing activity where they created and enacted a story using the system. Then, they were asked to write their stories on paper while viewing their enacted story videos. We performed an analysis of the stories in both formats and compared their structure, content, and coherence. Our analysis results and study observations were utilized to create a list of design suggestions for story authoring systems to support children in the translation process of story enactment towards written

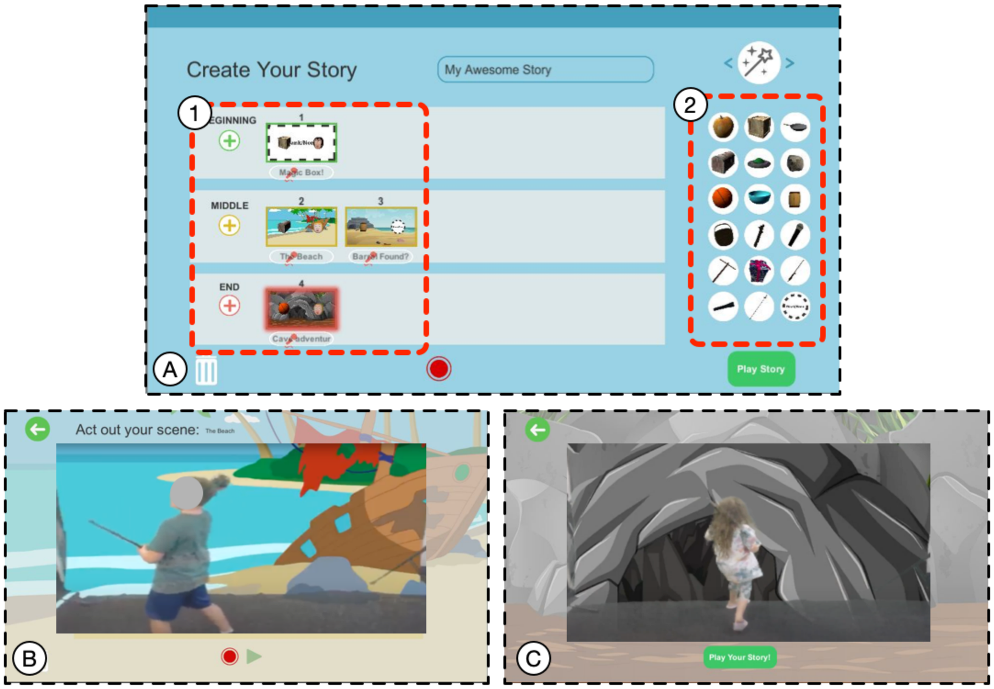

Figure 7.1: Story authoring software interface, showing the main steps of recording a story: A) Story planning: 1- Scene timeline view 2- Scene elements selection menu B) Story recording. C) Story playback.

expression.

7.3 Participants and Study Protocol

To recruit participants for our study, an email announcement was sent through the Texas A&M University student and staff mailing list as well as a local scout group mailing list. Further information and scheduling the study session were done upon a parent's response to the email call. 17 children participants (13 males, 4 females) were recruited for our study. The participants were in the age range of 8-12 years old (Mean age = 9.41). In the initial correspondence, we asked the parent to let us know if their child has been previously diagnosed with any conditions that might affect their writing ability. That was not the case for any of the participants in the present study.

Our study consisted of a single, 90-minute session. The participant and their parent were presented with the minor assent and the parent consent forms to read and sign upon arrival on site, and the study steps were briefly described to them by the researcher conducting the study. We also

Table 7.1: Summary of the variables in our study, the measure used for each variable and the scales to calculate each measure.

Story Format	Enactment and Writing			Writing Only
Variable	Story Structure	Story Coherence	Story Content	Expert Assessment
Measure	Structure Matching Score	Coherence Score	Number of Story Elements	Teacher Scores
Scale or Method	Grosz and Sidner's Purpose Hierarchy	Reese et al.'s Narrative Coherence Coding Scheme Rubric	Counting the main elements in the story (characters, objects, locations)	Personal Narrative Rubric

asked for their permission for audio and video recording throughout the study session. Then the participant filled out the pre-study questionnaire. The study began with a practice story creation task where the participant created and recorded an arbitrary story and was familiarized with the interface while using it. The practice task took about 20 minutes.

Once the participant announced that they felt comfortable with the system, we gave him/her a one-sentence story starter prompt and asked them to complete the story using our story authoring interface. We had two similar story starters in this study, and the participants were randomly assigned to use one of the story starters. The story starters followed the general format of "a cowboy/cowgirl finds a magic *object* in a *location*." In our current study, the object was either a box or a rock, and the location was either a ranch or the beach. The children were free to choose the same or different prop and background from the one stated in the story starter. They were then given about 45 minutes to create scenes for their story, act and record them, and revise if desired. Once they had completed their story, they played back all of the scenes in the arranged order, creating a continuous story video. We then asked the participant to write their story on paper, emphasizing that they can go back and watch the story they created as many times as needed, and encouraged them to include all the enacted details in the written story by saying *'I want to be able to picture the video you created when I read your writing'*. The participants were given a small toy as compensation upon completing the study. We also provided the story enactment videos as keepsake to the parents if they asked.

7.4 Data Coding Methodology

Two coders performed the qualitative coding for our data. They were not previously a part of the study conceptualization or the conduct of the study. Both coders have experience in conducting studies with elementary-school-age children and have participated in several qualitative data coding activities in the past. For each data point (participant), we had two versions of the same story: a written version and an enacted version (in the form of a video). Coders extracted the structure and content in both formats of the stories and assigned coherence scores to each version. To establish an agreement between the coders, they started by coding a random 33% subset of the data according to a set of instructions and protocol prepared by the researchers. The coders used the exact same samples for establishing the intercoder agreement, comprising of 6 different participants, 3 story enactment videos, and 3 writings. Then the coders and the researchers had a meeting where they discussed and compared the codes. The coders had about 87% percent agreement on the structure and over 92% agreement on content codes in the first round. However, we observed that the coders lacked common ground in terms of coherence coding criteria (see Section 7.4.1), especially with respect to the enactment videos. Therefore, we decided to adapt our source rubric into two separate rubrics, each intended specifically for one format. The general principles in both rubrics remained the same as the source rubric; however, they were clarified with instances and examples of the intended format to clarify the indicators of each grade level in that format. The coders then revised the coherence scores for the inter-coder data subset based on the new rubric. At this stage, we established a substantial agreement between the coders for the coherence scores with a Cohen's Kappa value of $\kappa = .695$. After establishing the intercoder agreement, we divided the rest of the study data between the coders in a way that each coder only received one format of a particular participant's story to code. This was done to ensure that a coder will not induce structure and context from one format into another. The comparison of the structure, content, and coherence was made a posteriori by the researchers.

7.4.1 Coding Protocol

We adapted our coding methods from two methodologies: For structure, we used the Purpose Hierarchy method by Grosz and Sidner [107]; and for coherence coding, we used the Narrative Coherence Coding Scheme by Reese et al. [108].

The Purpose Hierarchy is a method of coding the *structure* in a narrative based on discourse analysis. In this method, the narrative is broken into chunks that represent a single idea unit. Then, the idea units are organized as a nested list, without changing the order in which ideas were given. The hierarchy of this list represents the main ideas at the top level and their supporting ideas at the lower nested levels.

To code the story essays, we first compiled each story essay into an 'idea digest' - a collection of idea units - then organized the idea units as a nested list. For the enactment videos, the coding method had to be adapted by having the coders to first make a list of all idea units they can observe within a story scene. This resulted in the idea digest corresponding to that story video. Then they organized the idea digest as the nested list of purpose hierarchy as described above.

The Narrative Coherence Coding Scheme is a method of coding the *coherence* of a narrative structure. It is a multidimensional method in the sense that it is based on both linguistic and macro-structural aspects of the narrative. Reese et al. [108] point out that the coherence of a narrative - especially that of a personal narrative - is dependent upon both of these aspects. In this method, the story is scored based on three criteria: context, chronology, and theme, on a 4-level grading scale from 0 to 3. Then, an overall coherence score is calculated for the narrative by adding these three sub-scores.

To assign a narrative coherence score to the stories, we adapted the rubric provided by Reese et al. [108] into two rubrics, one for written stories and the other for the enacted stories. Both adapted rubrics followed the same principles described in the source rubric for each grade level in each sub-score. For example, a score of 3 in the 'context' sub-score requires a clear specification of the time and location of the story. This may be done in writing by a sentence like *"The cowboy was walking on his ranch one day..."*, while in the enactment, it is conveyed through the cowboy walking around and saying: *"Just a normal day on the ranch..."*. Although the participants choose the background for their story location in the story creation software, we decided not to consider that as an implicit clarification of the story location. Instead, we chose to score based on instances where the participant showed explicit awareness of their location in the act. This decision was made in a discussion meeting with the coders in an attempt to make the two narrative formats more comparable.

To gain some further insights into the content of the stories in addition to their structures, the coders also made a list of the main elements of each story in both formats. We defined the main elements of the story as the characters, objects, and locations that were mentioned and interacted with in that story.

7.5 Measures

We compiled the following three measures for each participant (see table 7.1):

Structure Matching Scores were calculated for each participant based on the level of matching between the story structures in the written and enacted formats. To calculate the structure matching scores, we analyzed the structure codes generated for both formats of each story and divided ideas into two categories: common ideas and mismatching ideas. Common ideas are those that have been conveyed in both formats, and mismatching ideas are those present only in one of the formats. The ideas in each category were then counted and normalized by the total count of ideas present in both formats, calculated from the equation below, to avoid counting the common ideas twice.

$$Ideas_{total} = Ideas_{enactment} + Ideas_{writing} - Ideas_{common}$$

Following this methodology, we calculated five different scores for quantifying the level of similarity between the two structures: the number of ideas in each format, the number of common ideas, the number of mismatched ideas in each format.

On the first round of comparison, we observed that the raw count of common ideas in the two formats might not be equal. In other words, there was not always a one-to-one relationship between the written ideas and the ideas in the enacted stories. In some cases, several pieces of enactment were intended to convey a single written idea. This is due to the inherent differences of expression between writing and acting. For example, the sentence *"She talked to many people."* is a single idea unit when written, while during enactment, the participant expressed it by the demonstration of having brief quick conversations with several (imaginary) people. This seems to indicate that ideas expressed in the act are generally divided at a more micro level, while written ideas can contain complex elements like adjectives and are expressed as single, more complex units. To overcome this issue, when counting the common ideas in these cases, we merged the pieces of the idea in the enactment and counted it as a single idea unit to be able to compare the two formats despite the differences. This was not done for the mismatching ideas because there was no reference in the other format to compare them to.

Story Coherence Scores were given by two coders based on the Narrative Coherence Coding Scheme [108] in three sub-measures: (1) Context (time and place), (2) Chronology (order of events), and (3) Theme (topic development). Each coder also provided a short reason for each of the scores they assigned. A total coherence score was also calculated by summing up these three scores.

Domain Expert Assessment for written stories was performed by an elementary school teacher with over 15 years of teaching experience. She used the Personal Narrative Rubric [103] to grade the stories. Some of the grammar and spelling mistakes were corrected in the story essays before giving them to the teacher for grading for legibility purposes. The Personal Narrative rubric consists of 4 score increments in three categories for grading: (1) Organization(beginning, middle, end), (2) Ideas and Support (plot and details), and (3) Language conventions (sentence type, word choice), and an overall score. She also provided a short reason for each essay's final grade.

7.6 Results

Repeated measures ANOVAs were calculated for all the subcategories of the structure matching scores in the two formats. These included the idea count and the mismatched ideas percentage. A logarithmic transformation with base 10 was applied on the structure matching data to achieve a normalized distribution. The results show a significant difference in terms of the number of ideas between the two formats of stories: $F(1,16) = 26.894, p < .001$; (figure 7.2-A). The enacted version of the stories contained a significantly higher number of ideas ($Mean = 33.82$) compared to the written version of the stories ($M = 17.53$) over all participants. The percentage of mismatched ideas in the enacted format ($M = 0.49$) was significantly higher than the percentage of mismatched ideas in the writing ($M = 0.12$); $F(1,16) = 23.210, p < .001$; (figure 7.2-B). The above results show that the structure in the written and enacted stories are significantly different when comparing the number of ideas expressed in each format. In terms of the mismatching ideas that were only expressed in one of the formats, a significantly higher percentage of them came from the enacted versions of the stories.

Next, we compared the content of the stories as observed by the coders in the two story formats. Our data shows that in our content subcategories, the characters and objects present in the stories matched in the enactment and writing formats for 13 out of 17 (77%) participants. In the cases of mismatch, the main character/object always matched, and the mismatch only occurred in the supporting/minor characters or additional objects that were used. On the contrary, the location of the story was only specified clearly in the writing in only 9 out of 17 (53%) participants.

Due to non-normalized distribution in the coherence scores, we used the Wilcoxon signed-ranks test to compare these scores in the two story formats. We did not observe any significant differences in coherence scores over the whole dataset. However, we observed that in participants who were 10 years old or younger (N = 14), the mean values of all the coherence sub-scores and the mean value for the overall coherence scores were higher in the enactment format (see figure 7.2-C). This pattern was reversed for participants who were 11 or 12 years old (N = 3) - meaning they had higher mean coherence scores in the written stories. Because of this discrepancy, we performed a Wilcoxon signed-ranks test on the coherence scores from the participant subset excluding those who were 11 and 12 years old. The analysis showed a significant difference effect in the theme sub-scores ($Z = -2.081, P = 0.037$) as well as a marginally significant difference for the total coherence score ($Z = -1.948, p = 0.051$). The theme scores were significantly higher in the enacted stories (Mean = 1.79), and the total coherence grades were also higher in the enacted stories (Mean = 5.71). For this

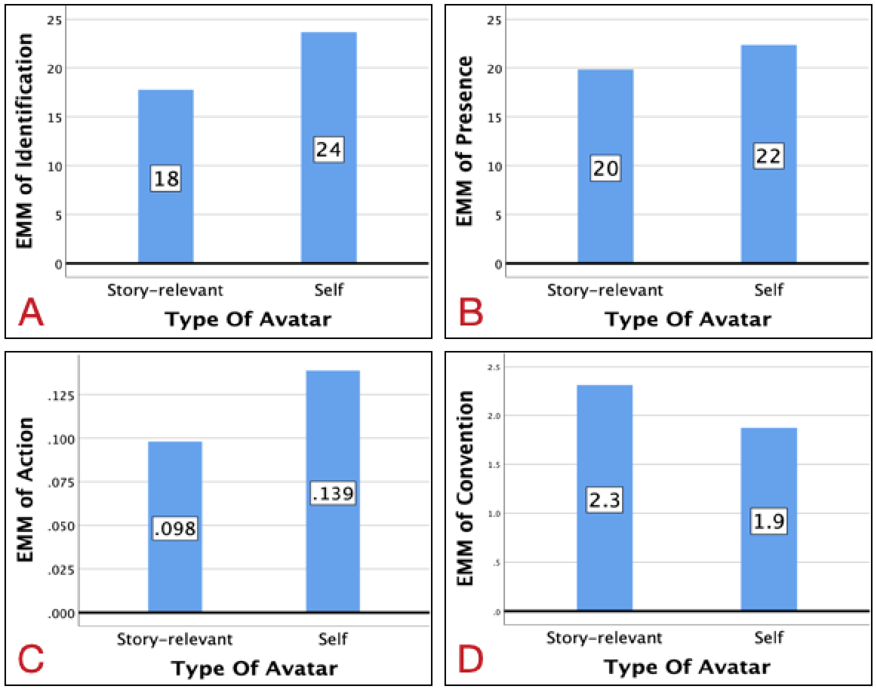

Figure 7.2: Result Plots. A) Estimated Marginal Means (EMM) of identification in the two avatar conditions. B) EMM of embodied presence in the two avatar conditions. C) EMM of vignettes in the two avatar conditions. D) EMM of language conventions grade in the two conditions.

subset of the participants, we also found a significant correlation between the total number of ideas in the enacted story and the total number of ideas in the written story $r = 0.557, n = 14, p = 0.039$. This correlation was not statistically significant over the whole participant group.

We found a significant correlation between the total coherence score and the language convention score graded by the teacher $r = 0.493, n = 17, p = 0.044$. The total coherence score also had a marginally significant correlation with the total essay grades from the teacher $r = 0.481, n = 17, p = 0.05$. These results suggest a compatibility between the teacher rubric and the chosen coherence coding methodology.

7.7 Discussion

Our results provide insights into how children use enactment-based storytelling as a preparatory activity for writing stories and how they may need to be supported in this process.

We made a comparison of children's written and enacted stories in terms of structure, content, and coherence (RQ1). The results show that the story structures vary significantly in the two formats in terms of the number of ideas. In terms of content (main story elements), they remained the same in most cases, with the exception of the background (location) which was not explicitly mentioned in almost half of the written stories. A possible explanation for this finding might be that they were assuming the enactment background to implicitly define the context of their written story as well. Finally, in terms of coherence we found that there was no statistically significant difference between the two formats. However, for participants who are 10 years old or younger, this difference is statistically significant. In other words, younger children created a more coherent narrative through enactment than through writing. Older children, on the contrary, had higher coherence scores in their writing. While we do not make a comparison between these two age groups due to small sample size, we believe that this observation opens an interesting question for future research.

When interpreting these results, we acknowledge that the higher number of ideas in the enactment might in part be caused due to the ideas being expressed in smaller fragments in the enacted version, while written format allows for expressing more complexities in a single idea unit, e.g., using adjectives. We faced this issue in our coding process and had to adapt our method to address it. However, our observations of the data show that this effect is not strong enough to cause a significant difference in the idea counts. In 12 out of 17 participants, this caused 2 ideas or less to be merged in the enacted version, which is much lower compared to the mean of the idea count in enactment (M=34). Additionally, the mismatched ideas in the enacted stories usually contained intricate and creative details, which seems to suggest that children felt comfortable expressing them through enactment but required more support to translate these ideas into writing. The mismatching ideas from the writings usually contained elaborations on details that were already present in the story and did not add new storylines.

Re-visiting Bruner's theory on knowledge representations, we conclude based on the results that for children to progress towards abstract forms of knowledge representation such as writing, they need support to *translate* from lower modes of abstraction such as embodied enactment. In other words, story enactment provides a means of planning and creating a coherent version of the story ideas, but children may not be able to fully express in writing without further support in the process of writing. Based on our findings and observations in the study, we present four lessons learned for design of enactment-scaffolded authoring tools for children (RQ2). These design implications focus on the kinds of support needed for children in the process of writing to encourage richer writing:

7.7.1 Providing Guiding Affective Prompts During Writing

A key source of mismatch between the enactment and the writing was that more details were present in the enactment for the character's emotions and actions - especially actions relating to interacting with the story prop. During the writing, without the physical presence of the character (the child's own body) and the prop, these details were not expressed in many cases. That may be due to the cognitive demand of writing, which causes a limit to the number of details the child remembers or can express. In classroom settings, teachers use structured prompts and feedback in the form of regular conferencing to guide the students on what details to add to their story and how to complete the narrative structure [109, 110]. Therefore, an important design consideration for the enactment-based authoring system would be to provide prompts for these aspects of the story. The strategy used for prompting can be static, such as [67] where they display prompt questions at specific checkpoints during the story writing activity progression. It can also be dynamic and take into account participants' state or action. An example of the latter is the *Java Sensei* [111], which is an intelligent tutoring system for Java programming, prompts are presented based on the user's affective and cognitive state.

7.7.2 Providing Visual Stimuli During Writing

When it comes to resolving the story, our participants had mixed performances. A majority of the stories (13 written stories and 12 enacted stories) lacked a resolution (and did not reach a score of 3 on the *theme* rating). Additionally, about 5 of the participants had alternate endings for their stories in the writing and in their enactment. On the one hand, this may be an indication that as the children progress from the pre-writing enactment activity into the writing, they have come up with new ideas for their narratives. However, our observations show that the endings in the enacted stories are more complex (based on the idea count). In some cases, we also observed additional storylines in the enactment that were not mentioned in writing or were only briefly mentioned. The reason could be that the visual and physical setup of the scene in the story creation interface created an opportunity for reflection on the story [112]. During writing, the playback of the recorded story did not provide a similar opportunity as it did not involve the same active engagement, which could be the reason for the poorer story resolutions in the story essays. Providing a similar engagement during the writing can be a possible solution to this problem. This may be achieved by presenting reflective prompts during playback or augmenting the enacted video with visual or acoustic effects that create additional engagement during playback.

7.7.3 Adapting Support based on Age and Writing Proficiency

Our study results indicated age can have a significant effect on the participants' performance when using the interactive system for writing. It seems that younger children are more likely to create a more coherent narrative through enactment than through writing. Older children, on the contrary, performed better in their writing compared to their enactments. This is to be expected because as children get older, they gain more writing experience and proficiency and may become less receptive to enactment. A design consideration for enactment-based story writing support systems can be adaptability to the level of the child's writing proficiency by providing more guiding prompts when needed but fewer prompts for children with higher proficiency levels. The child's proficiency level can be assigned based on a number of factors, including age and their performance in a baseline task. Given the relatively small sample size of our study and the imbalance of age in our participants over and under 10 years old, we interpret this part of the results with caution and acknowledge that there is a need for further investigation with respect to the effect of age.

7.7.4 Providing Support to Augment Children's Enactive Expression

We observed a general positive correlation between the total number of ideas expressed in the enactment and the total number of ideas in the written stories. Additional affordances of technology to support enactive expression can enable the children to express more complex ideas during enactment, which may therefore lead to a stronger written story. Examples of such support include allowing adding and scaling story objects or voice and audio modification and addition. Moreover, exploring novel features to support children during enactment can encourage highly creative or older children to engage more in the enactment activity. Chu et al. [38] have previously demonstrated that children with lower baseline creativity experienced a higher increase in the sense of creative self-efficacy as a result of using the enactment-based authoring system, while for children with higher baseline creativity levels, the system was not as beneficial. The general limitations of the enactment-based authoring system that is used for the study might result in a *ceiling effect* to the children's creative expression, where the child is not able to translate their complex imagination into enacted form. Therefore, exploration of means to increase expressive abilities of children during enactment can be a way to address this issue, which can in turn lead to enabling them to write richer and more coherent stories.

7.8 Chapter Summary

In this chapter we investigated children's use of body-based enactment as a way to support narrative writing. We aimed to understand how children's expression of the story changes when they act or write them. We found that there is a more complex level of imagination present in the enacted videos in terms of the structure, and they are generally scored higher in terms of coherence. This difference was observed to be more significant for younger children and tends to have a reverse pattern for older children. We derived four lessons learned for design of story writing support interfaces with a focus on the quality of writing.

8. VIDEO-STIMULATED COMPOSITION SYSTEM

8.1 Introduction

We concluded from the results of the prewriting study (Chapter 7) that children may need process support in turning a visual narrative into written form. In this chapter[1], we begin to explore this process support. We design an interface prototype that supports children in watching a visual narrative (animated video) and writing the story in the video. The interface design choices is evaluated based on feedback from elementary school teachers. The final interface is then used as a testbed system for contextual cues during writing.

8.2 Study Approach

To study the process support for children in visually scaffolded writing, we need to create a controlled setup for children to experience cues during writing. So for this study, enactment recorded videos can't be used, because a child's enactment is very dependent on their personality, preferences and imagination. So for this study we choose to use a pre-made video as writing stimulus.

The concept of using visual stimuli for writing support has been explored in prior work as a means to facilitate students writing [113]. Visual stimuli are common especially for classroom use because they can be easily embedded in the instruction through picture books, diagrams, drawings or videos. Studies have shown that visual representations can support children's oral retelling and writing of stories [114, 59, 115]. Previous research such as the works by Flower and Hayes [116] and Sadoski et al. [117] also demonstrate the importance of mental imagery in enhancing the overall quality of the writing and its appeal to the reader.

The premise of using visual stimuli for writing relies upon the concept of visual literacy. Visual literacy refers to the ability to perceive meaning in visual images [118]. For instance, Tan et al.'s [119] Perception, Interpretation, Expression (PIE) model of writing instruction is based on the

[1] Parts of this chapter are reprinted with permission from the following:
"Designing Interactive Contextual Cues for Children's Video-stimulated Writing." by Niloofar Zarei, Francis Quek, Sharon Lynn Chu, Angela Chan and Joshua Howell. In *ACM Interaction Design and Children (IDC) Conference*, Braga, Portugal. Copyright 2022 by ACM.

interpretation of visual media and expressing it in writing.

This translation process may not be trivial for young children: children use different modalities to express different types of content [120, 121] - e.g., when describing narrative, they tend to use drawing to show details of the story scenes but prefer writing to present the dialogue or chronology of events in a story. When children used visual means such as drawing or video as writing stimuli, previous studies have shown that richer stories produced in visual forms may not necessarily result in stronger written stories without further contextualized support during the writing process [122, 123].

The body of work on building software systems to support writing through visual stimuli is limited. Our approach to this design question is therefore to create an initial prototype and validate the design choices based on participatory design approaches. In our study, we interviewed elementary-school teachers as experts in the field. At the time of our study, all human-subject research had to be conducted remotely due to the limitations caused due to the global COVID-19 pandemic. Therefore, our prototype system was designed as a web-based interface.

8.3 Prototype Design

Our initial prototype was designed to afford a minimal video-scaffolded writing activity for children (also known as a *"Watch-Think-Write"* process [124]). Based on the research goal, we also included a minimal cuing setup where guiding prompts could be displayed at given timestamps during the video. This allowed us to demo the idea of contextual cues during the interview and inquire their opinion about the content and timing of the cues. So the initial prototype included: 1- An interface allowing the user to watch a video with replay and pause features, 2- A simple text processor where the child can draft and revise their story essay. 3- During the video playback, guiding prompts would appear as question boxes that the child needs to respond to.

An initial prototype of the authoring interface was created with the above affordances (see figure 8.1). The prototype consisted of a web-based interface developed with JavaScript that allowed for embedding and playback of a video file. The text processor on the right side of the interface enabled the user to type in and edit the writing, then download the text file using the "Done" button. The cue area (see figure 8.1-B) was designed as a pop-up view to appear at pre-determined timestamps

Figure 8.1: Interface for the video-stimulated writing system. A)Watching the video, B)Writing page, no cues visible, C)Writing page with cue visible.

and display the cue questions during video playback.

8.3.1 Expert Feedback on the Initial Prototype

We conducted semi-structured interviews with 6 elementary school instructors as experts in the field to get feedback on our initial prototype design. Five participants had over 5 years of teaching third and fourth grade language arts classes, although some were concurrently teaching other elementary grades or subjects. One participant was a language arts instructional coach at the time of this interview. The instructors were recruited through our prior contacts with [anonymized school and area name] and through snowball sampling. The interviews were conducted via Zoom video call and were video and audio recorded with consent. In these interviews, we presented a demo of the system prototype and asked for feedback on the following three aspects of the system design and use: the chosen stimulus approach, the activity process, and the cue timing and presentation.

The interviews were fully transcribed for analysis. Two coders performed qualitative coding on the interview transcriptions. The coders categorized the responses into three feedback categories: *Stimulus*, *Writing Activity*, and *Cue Design*. The coders performed the first round of coding independently, then discussed the codes to ensure agreement.

Regarding the use of video stimulus, all teachers believed that it would increase children's motivation to engage in the activity. P3 added that *"[by] engaging in any kind of visual that kids can see, it allows them to look for details in the story..."*. About the properties and content of the video, P4 and P6 suggested a video with music and sound effects - since these would grab the child's attention. P6 suggested using a video without dialogues because complex dialogues may result in children focusing too much on them to fully copy and transcribe the dialogues. P2 suggested that videos with animal characters might be an interesting choice for children. P2 also pointed out that at the target age group of our study, teaching compassion and the importance of helping others is a part of the social studies sessions in school, so videos with similar topics can be a suitable choice.

When asked about the activity process, teachers generally suggested breaking down the writing task into smaller units in a meaningful way - similar to what is done in a classroom writing activity. For instance, P1 proposed a step-by-step approach of drafting first and then editing - so that the

Table 8.1: Summary of teacher interview findings

Category	Finding/Suggestion	Details/Reason	Action
Choice of Stimulus	Including music and sound effects	Encouraging engagement	We chose a stimulus video with these features.
	Using a video without dialogues	Avoiding passive transcription of the speech	
Activity Process	Focusing on one aspect of writing at a time	Reducing cognitive load and increasing focus on narrative	In the study instructions, we emphasized the child to focus on the narrative and clarified that spelling and grammar errors were not the focus.
	Allow video and cue section replay	Enabling recall in more details	We included cue scene replay as well as video replay
	Enforcing responding to the cue questions	Prevent distraction from writing	We designed the interface to disable video playback until the cue question has been responded to.
Cue Design	Cue focused on important parts of the story	N/A	We included these findings in the design of the cues.
	Cue focused on the actions of the main character	N/A	

child can focus on one aspect of writing at a time. Others also suggested breaking down the video into smaller chunks, such as beginning, middle and end parts. P1 also pointed out that the child should be allowed to replay the video as many times as needed, but also writing should be enforced to prevent them from merely focus on watching the video.

Lastly, we asked the teachers about the cues in the system. Specifically, we asked if they were to conduct this video-scaffolded writing activity in their classroom, how they would identify possible cuing points in the video. The teachers suggested various possibilities. P1 said that they would pick *"big, important parts of the story... big cause and effect type [events]..."*. P4 suggested picking the actions of the main character as the cuing points. And P3 said that they choose major emotional events in the story. Overall, the teachers' responses seemed in consensus that key points of the narrative can be effective cuing points for children to reflect on and write about.

A summary of the interview findings along with the action taken as a result of the finding (in terms of interface modifications or study protocol modifications) is given in table 8.1.

9. WRITING PROCESS SUPPORT THROUGH CONTEXTUAL CUES

9.1 Introduction

The current chapter[1] presents a study on the design of this contextual support in the process of video-scaffolded writing for children. Through an approach based on Mayer's [125] Cognitive Theory of Multimedia Learning and interviews with field experts (Language Arts teachers), we explore how contextual cues embedded in a writing-oriented video platform may or may not support children's story writing. Building upon Mayer's theory, we proposed two possible approaches of providing contextual cues during the writing process: visually situated (signal) cues and temporally situated (segment) cues. We developed an interface that embodies the proposed cue designs for a video-scaffolded writing task. 13 children participated in our online study, where they watched a short animated video and wrote the story of the video while receiving one of the cue types. We qualitatively analyzed the process and product of their writings, aiming to understand how each cue category affected their experience and writing performance.

9.2 Research Questions and Approach

Our work investigates the design of contextual cues for an interactive system that supports video-scaffolded writing for elementary-school children. Specifically, we aim to understand how a system can provide support through contextual cues in the process of writing and facilitating the interpretation of the video and expressing it in written form. Our research questions are:

RQ1: How can we design contextual cues to facilitate children's video-scaffolded writing process in an interactive authoring system?

RQ2: Does the cue design affect children's written stories and their experience when using the system? and if so, how?

A video-scaffolded writing process requires active processing on both visual and verbal levels:

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the child needs to make sense of the narrative in the video, re-organize or synthesize it for written expression and use his/her knowledge of technical aspects of writing to produce the written form. Therefore the activity can be viewed as *Dual-channel*. Richard Mayer [125] termed a learning activity where information is presented in dual channels - both verbal and visual forms - as a *Multimedia Learning* activity. While our models of video-scaffolded writing might slightly vary with a multimedia learning activity as defined by Mayer, we posit that Mayer's three main assumptions regarding the cognitive constraints of a multimedia learning activity apply to video-scaffolded writing as well: First, humans possess separate information processing channels for visual and verbal material (*Dual-Channel Assumption*); second, processing capacity is limited in both of these channels (*Limited Capacity Assumption*); and lastly, learning requires substantial cognitive processing in both channels (*Active Processing Assumption*).

Therefore, we define video-scaffolded writing as a dual-channel learning activity. The design rationale for the contextual cues is therefore to support active processing and engagement of the child with visual and verbal channels, as well as managing the cognitive load posed on the child by dual-channel information processing.

9.3 Implementation of Contextual Cues

The findings from the teacher interviews showed that they believe the writing activity for the child needs to be guided in two ways through the contextual cues: 1- By breaking the task down into smaller, more manageable chunks, and 2- By drawing the child's attention to the *key points* of the story as a cue of what to write about. Aligning these findings with our theoretical framework for the design of the cues (Mayer's theory as discussed in section 4), we propose the following cue designs:

To manage the cognitive load during a multimedia learning task, Mayer proposes the "Segmenting" strategy [18]. Segmenting refers to dividing the multimedia content into *bite-size* segments and allowing some time between the segments for the learner to reflect on the material. Operationalized for our study, we define temporally-situated (segmenting) cues as small parts of the video throughout the video timeline. The cue question encourages the participant to describe the events in the narrative segment and write about them. Figure 9.1-A shows an example segment cue from our study.

To encourage active engagement with the multimedia material, Mayer proposes the "Signaling" strategy [18]. Signaling refers to cuing the learner on how to select and organize the information, in a way that their attention is drawn to the more significant sections of the content. Operationalized for our study, we define visually-situated (signaling) cues as screenshots displaying an event from the video. The image is augmented to visually emphasize the interaction, encouraging the participant to describe that interaction. Figure 9.1-B shows an example signal cue from our study.

9.3.1 Timing of the Cues

The process of identifying possible cuing points in a narrative video can be arbitrarily manual (e.g., performed by the teacher) or automated (e.g. performed by a machine learning algorithm). However, investigating methodologies for the identification of cue points is beyond the scope of the present work. We are not looking at *when* to display the cues, but instead, we aim to focus on the content of the cues (given similar timing) and how these different designs can affect children's writing in different ways.

Nonetheless, as shown by the previous work, the timing of the cues should be chosen in a meaningful way relative to the context of the activity. Therefore in this study, we implement the cues based on the general properties of narrative videos. Our approach is a manual adaptation of the Narrative Abstraction Framework used by Jung et al. [126]. This framework is based on Bordwell's [19] model for the narrative-oriented video. Bordwell models narrative-oriented videos as a collection of two types of scenes: a *Dramatic Incident* is a scene where the main character interacts with an object or another character; and a *Stylistic Element* comprises any scene that is not a dramatic incident, but is placed by the filmmaker to create the context for the other scenes. Based on this model and the findings from teacher interviews, dramatic incidents are *key points* of the video which can be possible cuing points.

For the present study, the research team operationalized Jung et al.'s framework through the step-by-step algorithm described below. The cue points were then chosen by the lead researcher following this algorithm and validated by the other team members in a discussion meeting:

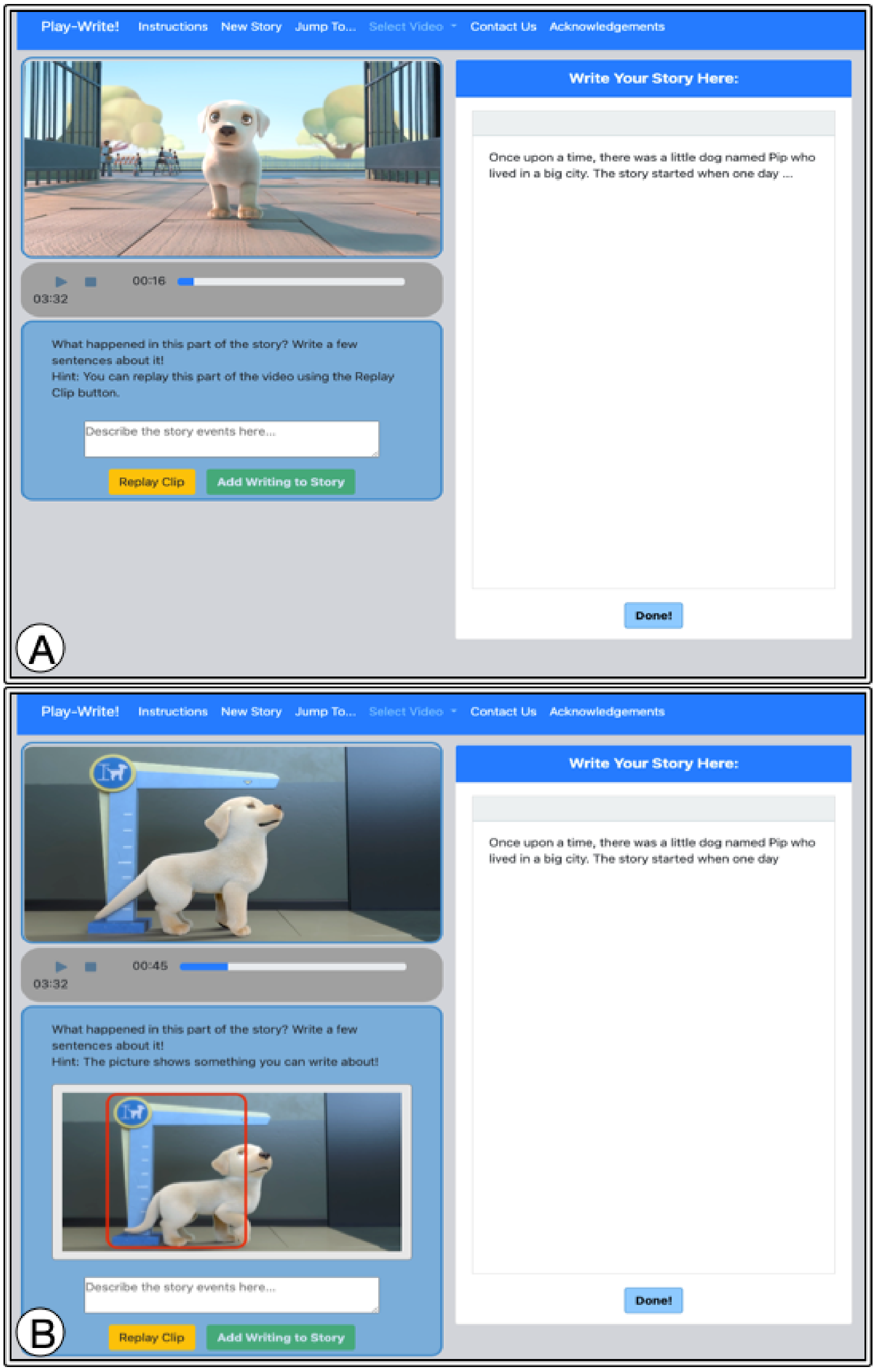

Figure 9.1: Proposed design of the cues: A) Temporally-situated B) Visually-situated.

1. Divide the chosen video into individual scenes and record the timestamp for each scene's in and out times.

2. Label each scene as either a Dramatic Incident or a Stylistic Element based on the definition given by Jung et al. [126].

3. Choose cuing points from the dramatic incidents.

For step 3, the research team reached a consensus to pick only a subset of all the dramatic incidents in the video for cuing. This decision was made to avoid too frequent cuing which may be detrimental to the child's ability to focus on writing for a sufficient duration of time. So we calculated the average duration of the dramatic incident scenes in the chosen video as the difference between the in-out times and only picked the scenes that were longer than average in duration. The idea was that the longer the scene, possibly the more significant it would be to the narrative (due to containing more information), so with this method we would choose a subset of the most significant dramatic incidents for cuing.

9.4 The User studies

To explore the effects of our proposed cue designs, we conducted two user studies: each study exploring one of the proposed cue designs in a writing activity. We clarify here that our aim in this study was not to compare the cue designs against each other, so we don't categorize our study as a between-subject study design. Instead, we explore the benefits of each cue design in isolation and during data analysis, we focus on the children's writing process and response strategies instead. Moreover, we have not included a baseline condition (no cue) due to the fact that our aim is not to prove that the cues are effective in supporting the child's writing. As described in background and literature review sections, previous work has demonstrated the importance and effectiveness of contextual cues in children's writing and indeed, it is common practice for teachers and instructors to provide such support in classrooms. In the current study, our focus is on the interaction design of the cues in the specific case of video-scaffolded writing and how it affects the child's writing process.

The studies were conducted using our web-based authoring tool. Due to the restrictions caused by the COVID-19 pandemic, the studies were conducted online via Zoom video conferencing. The same video stimulus was used for both studies. Based on the feedback from teacher interviews, we chose the video titled *"Pip | A Short Animated Film by Southeastern Guide Dogs"* available from YouTube [2]. The main character of the story is a little dog named "Pip" who wants to be a guide dog but is shorter than other dogs and that makes things difficult for him. The video has an engaging story and is about 4 minutes long. It does not include any dialogues but has background music and sound effects.

Following the methodology proposed in section 9.3.1 for the implementation of cues, we picked over 30 possible cuing points. To avoid cuing too frequently, we only chose scenes that were longer than the average length of the scenes (for this particular video average scene length was 5 seconds). This resulted in a total of 14 cuing points throughout the video. For the segment cues, the cue question was *"What happened in this part of the story? Write a few sentences about it! You can replay this part using the replay button below."*. For the signal cues, we included a screenshot of the event in the cue scene, and the cue question was *"What happened in this part of the story? Write a few sentences about it! The picture shows something you can write about."*. Based on teacher suggestions (see section **??**), the replay button was available for both cue designs. We decided to include this feature in both designs to avoid differences in terms of memory affect the detail children include in their writing.

9.4.1 Participants

We recruited a total of 13 children in the age range of 8-11 years old (7 female, mean age 9.13) to participate in our studies. All participants were neurotypical and without a diagnosis of language-related impairments. For recruitment, we sent bulk emails to the parents' mailing list for fourth and fifth graders at Bryan Independent School District (BISD) as well as the students and employees mailing list at Texas A&M University. Parents with children in the target age

[2] Video available on Southeastern Guide Dogs YouTube channel at: https://www.youtube.com/watch?v=07d2dXHYb94. Used with permission.

range were asked to contact the research team if interested in having their child participate. Seven children (P1-P7) participated in the first study (segment cues), and 6 children (P8-P13) participated in the second study (signal cues). However, one participant (P6) from the first group was unable to complete the study due to connection issues, so the final participant count for both studies was 6.

Each participant attended a single session of 60-90 minutes that was scheduled based on the child and parent's availability. The participants were required to have a working internet connection for the duration of the study session, as well as a computer with microphone and webcam to make the video call. We also asked that an adult guardian be present during the study to provide support to the child in case of technical or connectivity issues.

9.4.2 Study Protocol

A similar protocol was followed for both cue studies. Prior to the study, the lead researcher sent the parental consent and minor assent forms to the parents via email. We asked them to help their child read the minor assent form prior to the study session if possible so that they do not feel rushed to do so during the study session. We also sent them a link to the Zoom meeting for the study and instructions on how to disable the automatic spell checking feature of the browser to prevent the child from being distracted by the spell checking feedback during the writing. In the study session, the researcher conducting the study gave a brief overview of the study task and answered any questions the participant or parents had. The researcher then sent a link through the Zoom chat interface and asked the parent to open the link. We asked the parents to open the link using the Google Chrome browser in order to ensure that the interface appeared the same to all participants. They were then asked to share their computer screen over Zoom so that the researcher could guide the child during the study.

The study session began with pages displaying the parental consent and minor assent forms, which the parents and participants were asked to digitally sign by clicking a checkbox. At this stage, we confirmed the parent's permission for audio and video recording and emphasized that the identifiable data from the study will remain confidential and only be revealed to the research team members. One parent chose to opt-out of their child being video recorded. The researcher also emphasized to the child that they can change their mind about participating at any time during the study without any penalty.

Once the consent had been obtained, the researcher started the screen recording via Zoom. On the next page, the participant filled out a brief pre-study questionnaire with demographic information and Autman and Kelly's 6-item Writing Apprehension questionnaire [95]. Once the questionnaire was filled and submitted, a new page with an embedded media player was displayed. The researcher instructed the child to watch the video completely so that they can tell the story afterward. When the child had finished watching the video, the researcher asked them to tell the story in the video in their own words. This retelling was obtained for two reasons 1- As a means to measure the child's storytelling profile, 2- As a way to ensure that the child has been paying attention during the video playback. Once the child had finished retelling the story, they were asked to click a button on the screen which took them to the writing page.

At this point, the researcher explained the writing process and the appearance of the cues during video playback to the child and asked them to proceed with writing the story. A brief story starter was added in the text processor to help get them started in writing. The story starter was: *Once upon a time there was a little dog named Pip who lived in a big city. The story started when one day ...*. Participants were encouraged to start by continuing this story starter. Other features of the interface such as replaying of the cue segments and editing the writing were explained, and the participant was instructed to use the replay feature when they wish and as many times as needed. Once a cue appeared, the video was paused and the playback did not resume until the child had submitted a response for the cue. This was done to ensure that the child will not be skipping the cues without responding. The story writing task was not time-limited but all children were done within 30-60 minutes. The researcher emphasized to the participant to focus on telling the story, and not to worry about spelling or punctuation as such mistakes did not matter for the purposes of the current experimental study. The participant was instructed to freely ask spelling questions when needed.

Once they had reached the final cue, the interface displayed a pop-up message asking them to re-read what they had written and make edits if they wish to do so. Once they announced that they are happy with their story, the researcher told them to click the "Done" button which saved a text version of the story on their computer download folder. The study was concluded by an open-ended interview where the child told the researcher about their experience and what they liked and disliked about the activity and the system. Lastly, the researcher asked the parent to email them the text file of their child's written story at their earliest convenience and thanked them for participating in the study.

9.5 Data Analysis

The data gathered in the studies included the prequestionnaire, the audio and video recording from the participant (depending on consent) and the shared screen during the study session, the participant's written story essay, and the post-study open-ended interview. All the collected data was qualitatively coded: The retold stories were coded based on narrative structure as a measure of storytelling profile for that child. To understand how the children perceived and responded to the cues, we analyzed their writing on a micro and a macro level: in response to individual cues, we conducted a coding process where the coders grouped the responses based on high-level strategy themes in the response. In the full written story essays, we did an analysis where the coders coded the narrative structure and the linguistic richness in the stories. The post-study open-ended interviews were fully transcribed, then the responses were summarized for presentation.

9.5.1 Coding Methodology

The qualitative coding of the data was done by three coders. All coders had prior experience in qualitative coding and analysis of text and video data. The coding process included the coding of participants' retold stories, the writing process videos, the written story essays and the post-study interview responses.

The participant's retold stories were transcribed for coding. Three coders scored the retelling transcriptions based on Heilmann et al.'s *Narrative Scoring Scheme (NSS)* [127]. Narrative Scoring Scheme is an index of narrative macro-structure for the oral narrative retelling of school-age children. It comprises a rubric with 6 sub-scores for the following macro-components of the narrative: introduction, character development, mental states, referencing, conflict resolution, cohesion, and conclusion. Each sub-score was given a score of 1 (minimal/immature), 3 (emerging) or 5 (proficient) based on the rubric.

For inter-rater reliability analysis, the coders first coded a random 25% selection of the data (3 retold stories), providing a brief reasoning for their scores. Then they discussed and compared scores to ensure common ground. For the final coding, coder 1 scored the whole dataset of the retold stories from both studies, while coders 2 and 3 each coded half of the data. As a result, each retold story was scored by two coders independently. Cohen's κ was run to determine the inter-rater agreement level for both halves of the data. The κ values showed a substantial level of agreement for both coder pairs: $\kappa_1 = .696, p_1 < .001$ and $\kappa_2 = .667, p_2 < .001$. Disagreements in the final round of coding were resolved through a discussion between the coders to produce a final set of scores.

To code the video recording from the study sessions (the writing process), the coders started with a random 33% selection of the video data (4 participants, 2 selected from each study). The video recordings covered parts of the study session where the participants wrote the story while the cues appeared during playback. Each coder reviewed the session videos in this subset of the data and took notes regarding the child's interactions, use of the system, and their responses to the cues. Specifically, the coders looked for the ways in which children's responses to the cue question related to the cue scene, the context of the video, and the overall structure of the narrative in the video. Then, the coding team met to compare and discuss the observations and came up with a consolidated list of codes for the rest of the videos. We concluded upon a discussion that the children's responses to cues varied relative to the narrative structure, level of detail that was expressed, and the degree of interpretation.

In the second round, the coders did a decomposition analysis on the cue responses by dividing each response into individual meaningful sentence units, then assigning *response strategy* categories to each sentence. First, coders noted if the child is describing the cue scene only, or also including details from before or after the cue scene. Next, they made notes of instances where the child was describing the visible elements (*"There was two dogs and one was black and the other one was gold ..."*) or when the child was summarizing the story events without describing all the events in detail ("He did everything wrong..."). And lastly, the coders noted instances where the child tried to interpret events of the video in ways that were not directly shown in the video (eg. "The trainer believes in Pip and thinks that he can do it [the training task]..."). Some of these codes could have overlapped as well, for example if the child is writing an interpretation about the scenes prior to the cue, both codes will be assigned to that unit. The coders conferred in depth for all instances of codes in the first 33% of the data. The rest of the data was coded by all coders independently, and disagreements were resolved based on a majority vote. In the few cases which a majority vote was not available, the lead researcher (coder 1) resolved the disagreement.

The final written stories were coded based on an adaptation of Shapiro and Hudson's [57] methodology of measuring coherence and cohesion in young children's picture-elicited narratives. For coherence, their method includes *Basic* coherence elements (begin and end of the story, orientation, character description, dialogue and actions) as well as *Episodic* coherence elements (goals, Internal responses, obstacles and repairs). For story cohesion, their method looked at the frequency of various types of inter-clausal additives and the pronoun use strategy used in the story. We also included an additional dimension for textual richness, including the frequency of adjectives, adverbs and descriptive verbs in the story. The coders first coded a random 25% selection of the data (3 written story essays), and a pairwise agreement of over 80% was calculated based on the code overlaps. Then, the coders coded the rest of the data independently, each covering 25% of the data.

The baseline measures included the writing apprehension and storytelling quality. The writing apprehension score was obtained by summing up the 7-point Likert scale responses from the pre-study questionnaire for each participant. The storytelling ability score was calculated by summing up the NSS scores from the story retelling transcript for each participant.

9.6 Results

In this section, we present our findings categorized for each cue study:

9.6.1 Study 1: The Temporally-situated (Segmenting) Cues

Our analysis of cue response strategies showed that the most frequently observed strategy of responding to the segmenting cues is mentioning the cue scene events. The second most common strategy is that the child describes all events starting from right after the previous cue up to the current cue event. Effectively children tend to treat segmenting cues as checkpoints where they try to recollect the events in the story from the previous checkpoint (cue) up to the current one. We also observed high frequency of "summarizing" codes: sometimes children gave a high level summary of a series of events rather than describing individual events in more detail. For example, P3 summarized Pip's failures in the Canine University by writing *"... All week Pip kept trying and failing..."*. While this does not necessarily affect the story coherence and cohesion in a negative way, it does reduce the level of detail and description included in the story.

We observed varying preferences in terms of using the system features such as replaying the cue scene. Some children used the replay feature to "double check" if they had covered all the story details they wanted to mention. Also, one participant (P1) did not use the cues at all and instead chose to write the whole story from memory. The results of the cohesion analysis showed that all participants in this study used clear and unambiguous referencing strategies. Thematic-subject (referencing the main character with pronoun and using nominal forms for other characters) or full-anaphoric (using nominals to switch references and pronouns to maintain references) pronoun strategies were used by the participants. Use of unambiguous pronouns is another indicator that participants in this study were able to maintain an understanding of the overall narrative structure while writing.

When asked about their experience, all children stated that they had enjoyed the writing activity. P2 described the activity as *"fun and easy"* and said that she preferred this method to what they always do at school. P4 said that she enjoys sentimental movies which is why she enjoyed the writing activity. P4 and P5 said that they liked writing based on video because of all the ideas it gives them to write about. P6 said that the video gave him a foundation for the story to write. When asked if and how the cues had been helpful in their writing, P2 and P4 said that the cues had helped them in remembering the details. P3 said that the cues had helped her write more than she usually would: *"Well... I don't usually write this long!"*. P6 said that the cues had helped *"... really to just put my ideas in little pieces..."*

9.6.2 Study 2: The Visually-situated (Signalling) Cues

Our analysis showed that the most common strategy in responding to the cues in this study was to mention the cue scene events. The second most common strategy was description of the cue scene, and the third strategy was interpretation. In many cases, this involved description of a character's feelings or thoughts (e.g. *"he was proud of Pip because he saved a life..."*). However, this description may not necessarily improve the written story. For instance, when presented with an image of the Canine University sign in a cue (as Pip was entering), P7 responded by writing *"Canine University is a place where dogs learn many things."*. The participant tried to explain the cue image, but this description is not moving the narrative plot forward. We also found that in the majority of cases, children either fail to or choose not to include events that are not shown in the cue image. Therefore, signal cues seemed to have resulted in a localized focus on parts of the narrative.

In general, the participants seemed to be having a hard time maintaining a cohesive narrative structure. When they used the replay feature, they seemed to want to be reminded of where in the video the cue image belonged - trying to get ideas on how to describe the image in response to the cue - and did not focus on events leading to the cue scene. We also found that participants in this study either did not use any pronouns, or had a confused (ambiguous) or indeterminable (changing) pronoun use strategy. This finding also shows that the participants were probably more focused on localized details of the story rather than the overall structure.

In the post-study interview, participants responded with mixed feelings about the experience. P7 said that he would have preferred having less frequent cue questions. P9 said that he found the chosen video boring, although he enjoyed the writing activity. On the contrary, P8 said that she liked the video because it was about dogs but was not sure about the writing. When asked about the ways in which the cues helped in their writing, P9 said *"I didn't remember the whole thing so this just kinda... refreshed my [memory]..."*. P10 said she probably would have written more without the cues. She explained that she had focused on the cue scenes and less on other parts of the video. P12 said that the way the cue image is circled can show you what to write about

9.6.3 Correlation Analysis

Correlation analysis was performed over the aggregated data from both studies for possible effects of baseline factors. Pearson's product-moment correlation analysis showed a moderate positive correlation between age and word count which was statistically significant ($r = .578, p = .049$). Moreover, there was a statistically significant, strong positive correlation between the total writing apprehension scores (reverse scored) and the written story word count ($r = .845, p < .001$). No statistically significant correlation was observed between the storytelling profile scores and the written story properties.

9.7 Discussion

We conducted two studies to explore the effects of two contextual cue designs on children's video-scaffolded writings. Our results show that the design of the cues can affect the way children respond to them to construct their stories. In the case of temporally situated cues, children seemed to be focusing on all the story events from one cue to the next. In visually situated cues, the responses followed a different pattern, where children focused on the cue scene and tried to describe or interpret what was shown in the video, especially thoughts and feelings of the characters. But this could sometimes result in redundant descriptions of less important details as well. An interesting finding was the difference in children's pronoun use strategies in the two studies. The majority of children who received temporally situated cues had consistent and unambiguous pronoun strategies, while those who received visually situated cues had mixed or confused strategies, or avoided using pronouns altogether. We must note the possible effects of individual differences such as age and interest in writing on the participants' experience and writing quality. Nonetheless, the majority of the participants in both studies seemed to have had a positive experience in the study. Five parents reached out to the lead researcher after the session and informed that their child has expressed interest and enthusiasm (after the video call had ended) about their study session experience.

Given the positive and negative effects of each cue type on children's writing, we propose that based on our results, a hybrid cuing approach might provide a more comprehensive support for children's writing. Where detail matters, signal cues can elicit more description from the child, while occasional segment cues can help them keep track of the structure of their writing as well. An important observation in these studies was that children's performance in video-stimulated writing can be significantly affected by their ability to interpret media - i.e. participant's media literacy. Despite the fact that our chosen video for the study was intended for a young audience, there was still variations in the level the participants could interpret and understand causal links in the video. For example, two of the participants did not realize at first that the lady in the story was blind, and that had caused them confusion.

We also note the limitations of our studies: our studies were conducted on a small sample size, therefore we exercise caution in interpreting the results - however, we do believe that our findings can motivate interdisciplinary questions for future research in the fields of HCI, education and multimedia. Another important limitation of the present study was that it was conducted remotely due to the global pandemic. Given the circumstances, connectivity issues, differences in the participants' environments, and the device they use for the study can all introduce variations in the user experience. Although we have tried to the best of our ability to control these confounds, we acknowledge this issue in general regarding remote studies, especially with children.

9.8 Chapter Summary

In this chapter, we proposed and explored the effects of two cue designs for children's video-stimulated writing. Our results show that the cue design can affect how children respond to the cues, which in turn affects their writing performance. Temporally-situated cues support a more strcutured and cohesive writing, while visually situated cues elicit more descriptive writing from children. Our work opens up several possibilities for future work, from exploring other cue designs and system use scenarios to evaluating the cues in larger sample sizes or in classroom environment.

10. CONTRIBUTIONS AND SIGNIFICANCE

10.1 Contributions

This dissertation covers multidisciplinary research that contributed to the fields of Interaction Design for children, interactive digital storytelling, educational psychology and creativity and cognition. Most of our findings have been published and presented in premiere conferences of the fields of Human-Computer Interaction, Interaction Design for Children and Interactive Digital Storytelling.

Our research findings include contributions to the design of children's enactment-based authoring tools on two general directions:

First, our research focuses on several aspects of the child's experience and performance during enactment-based authoring activities and provides evidence on how design choices in the authoring tools can augment and affect this performance

Second, our research contributes design suggestions for a number of design choices in children's authoring tools to support a stronger writing product.

We describe our contributions in further detail below:

- Children's enactment-based authoring
  - Designed and developed the story creation interface for children's enactment-based authoring
  - Showed that enactment and narrative videos can be an effective means of prewriting support for children's narrative writing.
  - Provided evidence that "translating" a narrative from enacted to written form is a challenge for children during enactment-based authoring.
  - Proposed a methodology to compare story complexity in video vs. written forms.
- Avatar Design in Children's Authoring Tools

  - proposed the design of self-avatars and story-relevant avatars.
  - Showed that Avatar design can augment children's experience and performance in story authoring
  - Provided evidence that Story-relevant avatars can support children to write more complex stories compared to self-avatars.
  - Provided evidence that Self-avatars can create higher self-identification and embodied presence for the child during story enactment compared to the story-relevant avatar.
- Contextual Cues for Video-stimulated Writing
  - Designed and developed the online video-stimulated writing interface
  - Proposed two types of contextual cue design for children's video-stimulated narrative authoring grounded in multimedia literature
  - Provided evidence that various cues can create different effects on children's writings

10.2 Research Significance

The body of research presented in this dissertation has had several broader impacts. The research studies conducted in our work provided a venue for the children participants to experience new ways of expressing themselves and write. They experienced the joy and excitement of using new tools and interfaces, but more importantly, many of the children also expressed that they had enjoyed writing more than they ever had. Moreover, many children even expressed an interest in learning how to develop tools and technology themselves and pursue a career in research. Among the parents who answered our calls for participation in the studies, there were moms who told us they were hoping the experience of participating in the studies could teach their little children about research. We are honored to have had an impact beyond the direct scope of this dissertation towards the children's interest in science and technology.

Writing proficiency is an important part of children's literacy development. Research has shown that children's literacy development can have a key role in their social involvement and future career path. The presented research is an effort to extend the knowledge on educational technology. We hope that the findings may in the future be applied in classroom practices to promote children's learning.

Most of the work presented in this dissertation has been presented in premiere conferences of the field. In doing so, we hope to have brought attention to the need for further research on design of children's authoring tools, as well as the great potential novel technology can have on facilitating children's written expression and engaging them in writing.

10.3 Further Study

The presented work has the potential for several future extensions. We list a few possibilities below:

- **Curriculum Integration and Long-term Effects**: Variations of enactment-based authoring proposed and studied in this dissertation work have the potential to be integrated into school and after-school curricula in a variety of ways. Possible studies include specific technology design or teaching protocols to use these methods in specific parts of the language arts classes.

  The engagement and motivation created in the children due to enactment-based authoring can in turn motivate them towards writing as well. This suggests that another possible direction would be the longitudinal effects that such interactive tools can have on children's writing performance and writing self-efficacy.

- **Design Choices and Personalization**: In designing the software and study protocols, we had to make several choices for specific features or processes. We tried to ground this choices in previous work and knowledge to the best of our ability. Nonetheless, it would be interesting to evaluate the effects of other such choices on system performance and effectiveness. One example is the choice of contextual cues design.

  Another aspect that was raised in our design suggestions is the personalizations of various system features depending on the child's preferences or writing proficiency level. In addition to possibly providing more effective support tailored to each child's needs, customization of features can make the experience of using the system more enjoyable for the child.

- **English Language Learners (ELLs) and Neuro-divergent Children**: The challenges of self-expression are experienced by most children, but these challenges are more serious for English Language Learners (ELLs). Gandara et al.'s [128] survey of ELL students' teachers uncovered that teachers believe there is a lack of tools designed for teaching bilingual students. Thus, there is a need for further research in this domain. Our approach may present new ways to support bilingual students in learning self-expression and writing.

  Another possible direction for research can be the adaptation of the enactment-based or video-stimulated authoring methods for neuro-divergent children. For example, the literature on video-stimulated writing shows that this method may be effective in teaching self-expression for children on the Autism. spectrum.

11. LIMITATIONS AND CONCLUSION

11.1 Limitations

While we tried to the best of our ability for robustness and rigor in the presented work, we also acknowledge the limitations of the studies presented in this dissertation. Empirical findings are inherently limited to the settings and samples of the particular studies, so we acknowledge that the results are not intended to be generalized beyond the presented scope. We hope however, that the results show the promise of the proposed methods and designs and open up opportunities for further research, such as with different cultures and user profiles.

An important limitation in our studies is the limited sample size. While this is customary and acceptable for the field of child-computer interaction, further studies with larger sample sizes are necessary to further investigate the roles of different between-subject factors in the results, such as the children's writing apprehension. Moreover, the context in which the studies were conducted could have introduced confounding factors into the study setup despite our best efforts to control the confounding factors. An example is the remote setup of the contextual cuing studies which was due to the global COVID-19 pandemic, as well as the limitations caused by the motion tracking system in the avatar study.

11.2 Conclusion

This dissertation presented a body of work on how we may use embodied enactment in technology design to support children's narrative writing. We began by capturing the child's enactment as animated videos in real-time, as a tangible outcome of the child's free-form play. Then we explored the effects of avatar design in children's enactment-based authoring. We found that varying levels of similarity between the avatar, the user and the story character can potentially affect children's story authoring. We investigated how children used enactment as a prewriting activity and provided evidence for the need for contextual cues during writing. Finally, we investigated the how two types of design of contextual cues in a video-stimulated writing setup can affect children's writing process.

We found that visually-situated cues during writing encourage more descriptive and interpretive writing, while temporally-situated cues support the child in writing more coherently. Our work has potential for further investigation in several directions. We provided a few possibilities in the final chapter of this document.

REFERENCES

[1] L. Flower and J. R. Hayes, "A cognitive process theory of writing," *College composition and communication*, vol. 32, no. 4, pp. 365–387, 1981.

[2] C. Baraldi, "Promoting self-expression in classroom interactions," *Childhood*, vol. 15, no. 2, pp. 239–257, 2008.

[3] S. Striker, *Young at art: teaching toddlers self-expression, problem-solving skills, and an appreciation for art*. Holt Paperbacks, 2011.

[4] B. Hawkins, "Children's drawing, self expression, identity and the imagination," *International Journal of Art & Design Education*, vol. 21, no. 3, pp. 209–219, 2002.

[5] C. Wilson, L. Sitbon, B. Ploderer, J. Opie, and M. Brereton, "Self-expression by design: Co-designing the expressiball with minimally-verbal children on the autism spectrum," in *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, pp. 1–13, 2020.

[6] C. Wilson, M. Brereton, B. Ploderer, and L. Sitbon, "Myword: Enhancing engagement, interaction and self-expression with minimally-verbal children on the autism spectrum through a personal audio-visual dictionary," in *Proceedings of the 17th ACM Conference on Interaction Design and Children*, pp. 106–118, 2018.

[7] R. H. P. Cheung, "Teaching for creativity: Examining the beliefs of early childhood teachers and their influence on teaching practices," *Australasian journal of early childhood*, vol. 37, no. 3, pp. 43–52, 2012.

[8] M. Dias and P. L. Harris, "The effect of make-believe play on deductive reasoning," *British journal of developmental psychology*, vol. 6, no. 3, pp. 207–221, 1988.

[9] S. L. Chu, F. Quek, and J. Tanenbaum, "Performative authoring: nurturing storytelling in children through imaginative enactment," in *International Conference on Interactive Digital*

Storytelling, pp. 144–155, Springer, 2013.

[10] D. W. Winnicott, *Playing and reality*. Psychology Press, 1991.

[11] F. Garzotto, P. Paolini, and A. Sabiescu, "Interactive storytelling for children," in *Proceedings of the 9th International Conference on Interaction Design and Children*, pp. 356–359, 2010.

[12] J. S. Bruner *et al.*, *Toward a theory of instruction*, vol. 59. Harvard University Press, 1966.

[13] J. Piaget, *The child and reality: Problems of genetic psychology.(Trans. Arnold Rosin).* Grossman, 1973.

[14] J. Piaget, B. Inhelder, and H. Sinclair-De Zwart, *Memory and intelligence*. Basic Books, 1973.

[15] K. G. Burris and C. Wright, "Review of research: Children and technology: Issues, challenges, and opportunities," *Childhood education*, vol. 78, no. 1, pp. 37–41, 2001.

[16] C. Finegan and N. J. Austin, "Developmentally appropriate technology for young children," *Information Technology in Childhood Education Annual*, vol. 2002, no. 1, pp. 87–102, 2002.

[17] K. R. Harris, S. Graham, and L. H. Mason, "Improving the writing, knowledge, and motivation of struggling young writers: Effects of self-regulated strategy development with and without peer support," *American educational research journal*, vol. 43, no. 2, pp. 295–340, 2006.

[18] R. E. Mayer and R. Moreno, "Nine ways to reduce cognitive load in multimedia learning," *Educational psychologist*, vol. 38, no. 1, pp. 43–52, 2003.

[19] D. Bordwell, K. Thompson, and J. Smith, *Film art: An introduction*, vol. 7. McGraw-Hill New York, 1993.

[20] A. Seow, "The writing process and process writing," *Methodology in language teaching: An anthology of current practice*, pp. 315–320, 2002.

[21] S. D. Krashen, T. D. Terrell, M. E. Ehrman, and M. Herzog, "A theoretical basis for teaching the receptive skills," *Foreign Language Annals*, vol. 17, no. 4, p. 261, 1984.

[22] R. T. Kellogg, "Training writing skills: A cognitive developmental perspective.," *Journal of writing research*, vol. 1, no. 1, 2008.

[23] M. Scardamalia and C. Bereiter, "Knowledge telling and knowledge transforming in written composition," *Advances in applied psycholinguistics*, vol. 2, pp. 142–175, 1987.

[24] A. Nicolopoulou, "The elementary forms of narrative coherence in young children's storytelling," *Narrative Inquiry*, vol. 18, no. 2, pp. 299–325, 2008.

[25] D. J. Meyer, "The effects of graphic organizers on the creative writing of third grade students.," 1995.

[26] S. L. Harrington, "An author's storyboard technique as a prewriting strategy," *The Reading Teacher*, vol. 48, no. 3, pp. 283–286, 1994.

[27] M. Brown, "Effects of graphic organizers on student achievement in the writing process.," *Online Submission*, 2011.

[28] E. Di Paolo, M. Rohde, and H. De Jaegher, "Horizons for the enactive mind: Values, social interaction, and play," in *Enaction: Towards a new paradigm for cognitive science*, 2010.

[29] A. L. Seja and S. W. Russ, "Children's fantasy play and emotional understanding," *Journal of clinical child psychology*, vol. 28, no. 2, pp. 269–277, 1999.

[30] C. Howes and C. C. Matheson, "Sequences in the development of competent play with peers: Social and social pretend play.," *Developmental Psychology*, vol. 28, no. 5, p. 961, 1992.

[31] A. S. Lillard, "Pretend play skills and the child's theory of mind," *Child development*, vol. 64, no. 2, pp. 348–371, 1993.

[32] S. Sansanwal, "Pretend play enhances creativity and imagination," *Research gate*, pp. 70–83, 2014.

[33] K. C. Tsai, "Play, imagination, and creativity: A brief literature review.," *Journal of Education and learning*, vol. 1, no. 2, pp. 15–20, 2012.

[34] D. Bergen, “The role of pretend play in children’s cognitive development.,” *Early Childhood Research & Practice*, vol. 4, no. 1, p. n1, 2002.

[35] L. S. Vygotsky, *Mind in society: The development of higher psychological processes*. Harvard university press, 1980.

[36] J. Piaget, *The language and thought of the child*, vol. 10. Psychology Press, 2002.

[37] S. L. Chu, F. Quek, and K. Sridharamurthy, “Ready... action! a performative authoring system for children to create animated stories,” in *Proceedings of the 11th Conference on Advances in Computer Entertainment Technology*, pp. 1–4, 2014.

[38] S. L. Chu, F. Quek, and K. Sridharamurthy, “Augmenting children’s creative self-efficacy and performance through enactment-based animated storytelling,” in *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction*, pp. 209–216, 2015.

[39] I. Thompson, “Stimulating reluctant writers: a vygotskian approach to teaching writing in secondary schools,” *English in Education*, vol. 46, no. 1, pp. 85–100, 2012.

[40] J. Hong, D. Ko, and W. Lee, “Investigating the effect of digitally augmented toys on young children’s social pretend play,” *Digital Creativity*, vol. 30, no. 3, pp. 161–176, 2019.

[41] K. Ryokai, H. Raffle, and R. Kowalski, “Storyfaces: pretend-play with ebooks to support social-emotional storytelling,” in *Proceedings of the 11th International Conference on Interaction Design and Children*, pp. 125–133, 2012.

[42] C.-H. Chung and C.-H. Chen, “Augmented reality based social stories training system for promoting the social skills of children with autism,” in *Advances in ergonomics modeling, usability & special populations*, pp. 495–505, Springer, 2017.

[43] B. Gros, “Digital games in education: The design of games-based learning environments,” *Journal of research on technology in education*, vol. 40, no. 1, pp. 23–38, 2007.

[44] E. I. Mansor, "'my world (s)' a tabletop environment to support fantasy play for kindergarten children," in *Proceedings of the 6th international conference on Interaction design and children*, pp. 193–196, 2007.

[45] Z. Bai, A. F. Blackwell, and G. Coulouris, "Exploring expressive augmented reality: The fingar puppet system for social pretend play," in *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, pp. 1035–1044, 2015.

[46] S. Graham, D. McKeown, S. Kiuhara, and K. R. Harris, "A meta-analysis of writing instruction for students in the elementary grades.," *Journal of educational psychology*, vol. 104, no. 4, p. 879, 2012.

[47] A. D. Pellegrini and L. Galda, "Children's pretend play and literacy," *Beginning reading and writing*, vol. 50, pp. 58–65, 2000.

[48] M. Smith and R. Mathur, "Children's imagination and fantasy: Implications for development, education, and classroom activities," *Research in the Schools*, vol. 16, no. 1, p. 52, 2009.

[49] J. C. McMaster, "" doing" literature: Using drama to build literacy," *The reading teacher*, vol. 51, no. 7, pp. 574–584, 1998.

[50] M. J. McNaughton, "Drama and children's writing: A study of the influence of drama on the imaginative writing of primary school children," *Research in Drama Education*, vol. 2, no. 1, pp. 55–86, 1997.

[51] A. Bayraktar and A. Okvuran, "Improving student's writing through creative drama," *Procedia-Social and Behavioral Sciences*, vol. 51, pp. 662–665, 2012.

[52] T. Cremin, K. Goouch, L. Blakemore, E. Goff, and R. Macdonald, "Connecting drama and writing: Seizing the moment to write," *Research in Drama Education*, vol. 11, no. 3, pp. 273–291, 2006.

[53] K. Howland, J. Good, and B. du Boulay, "A game creation tool which supports the development of writing skills: interface design considerations," in *5th International Conference on*

Narrative and Interactive Learning Environments Edinburgh, Scotland 6th–8th August 2008, 2008.

[54] K. Howland, J. Good, and B. Du Boulay, "Narrative support for young game designers' writing," in *Proceedings of the 14th International Conference on Interaction Design and Children*, pp. 178–187, 2015.

[55] C. Holdich and P. W. Chung, "A 'computer tutor'to assist children develop their narrative writing skills: Conferencing with harry," *International Journal of Human-Computer Studies*, vol. 59, no. 5, pp. 631–669, 2003.

[56] A. Kuhn, C. Quintana, and E. Soloway, "Storytime: a new way for children to write," in *Proceedings of the 8th International Conference on Interaction Design and Children*, pp. 218–221, 2009.

[57] L. R. Shapiro and J. A. Hudson, "Tell me a make-believe story: Coherence and cohesion in young children's picture-elicited narratives.," *Developmental psychology*, vol. 27, no. 6, p. 960, 1991.

[58] L. Bates, "The effects on the structure of young children's written narrative of using a sequence of pictures or a single picture as a stimulus.," *Reading*, vol. 25, no. 3, pp. 2–10, 1991.

[59] W. M. Pearce, "Does the choice of stimulus affect the complexity of children's oral narratives?," *Advances in Speech Language Pathology*, vol. 5, no. 2, pp. 95–103, 2003.

[60] M. DeBeyer, S. Anderson, T. Servant, K. Willerton, A. Marcinkow, and S. Scheffers, "The effect of static versus animated story stimuli on children's ability to tell stories," 2012.

[61] J. H. Eaton, G. M. Collis, and V. A. Lewis, "Evaluative explanations in children's narratives of a video sequence without dialogue," *Journal of Child Language*, vol. 26, no. 3, pp. 699–720, 1999.

[62] K. Ryokai and J. Cassell, "Computer support for children's collaborative fantasy play and storytelling," 1999.

[63] J. Cassell and K. Ryokai, "Making space for voice: Technologies to support children's fantasy and storytelling," *Personal and ubiquitous computing*, vol. 5, no. 3, pp. 169–190, 2001.

[64] R. M. Yilmaz and Y. Goktas, "Using augmented reality technology in storytelling activities: examining elementary students' narrative skill and creativity," *Virtual Reality*, vol. 21, no. 2, pp. 75–89, 2017.

[65] E. P. Torrance, "A longitudinal examination of the fourth grade slump in creativity," *Gifted Child Quarterly*, vol. 12, no. 4, pp. 195–199, 1968.

[66] S. Chu and F. Quek, "Maia: A methodology for assessing imagination in action," in *CHI 2013 Workshop on Evaluation Methods for Creativity Support Environments*, 2013.

[67] R. D. Roscoe, L. K. Allen, J. L. Weston, S. A. Crossley, and D. S. McNamara, "The writing pal intelligent tutoring system: Usability testing and development," *Computers and Composition*, vol. 34, pp. 39–59, 2014.

[68] L. N. Michaud, K. F. McCoy, and C. A. Pennington, "An intelligent tutoring system for deaf learners of written english," in *Proceedings of the fourth international ACM conference on Assistive technologies*, pp. 92–100, 2000.

[69] A. Lingnau, H. U. Hoppe, and G. Mannhaupt, "Computer supported collaborative writing in an early learning classroom," *Journal of Computer Assisted Learning*, vol. 19, no. 2, pp. 186–194, 2003.

[70] A. S. Evmenova, H. J. Graff, M. K. Jerome, and M. M. Behrmann, "Word prediction programs with phonetic spelling support: Performance comparisons and impact on journal writing for students with writing difficulties," *Learning Disabilities Research & Practice*, vol. 25, no. 4, pp. 170–182, 2010.

[71] J. Cullen, S. B. Richards, and C. L. Frank, "Using software to enhance the writing skills of students with special needs," *Journal of Special Education Technology*, vol. 23, no. 2, pp. 33–44, 2008.

[72] J. M. Prest, P. Mirenda, and D. Mercier, "Using symbol-supported writing software with students with down syndrome: An exploratory study," *Journal of Special Education Technology*, vol. 25, no. 2, pp. 1–12, 2010.

[73] M. Warschauer and P. Ware, "Automated writing evaluation: Defining the classroom research agenda," *Language teaching research*, vol. 10, no. 2, pp. 157–180, 2006.

[74] I. S. Stefnisson and D. Thue, "Mimisbrunnur: Ai-assisted authoring for interactive storytelling," in *Fourteenth Artificial Intelligence and Interactive Digital Entertainment Conference*, 2018.

[75] B. Samuel, M. Mateas, and N. Wardrip-Fruin, "The design of writing buddy: a mixed-initiative approach towards computational story collaboration," in *International Conference on Interactive Digital Storytelling*, pp. 388–396, Springer, 2016.

[76] M. Roemmele and A. S. Gordon, "Automated assistance for creative writing with an rnn language model," in *Proceedings of the 23rd International Conference on Intelligent User Interfaces Companion*, p. 21, ACM, 2018.

[77] J. Peck, "Using storytelling to promote language and literacy development," *The Reading Teacher*, vol. 43, no. 2, p. 138, 1989.

[78] B. H. Moore and H. Caldwell, "Drama and drawing for narrative writing in primary grades," *The Journal of Educational Research*, vol. 87, no. 2, pp. 100–110, 1993.

[79] R. T. Kellogg, "Effectiveness of prewriting strategies as a function of task demands," *The American Journal of Psychology*, pp. 327–342, 1990.

[80] D. Kirsh, "Projection, problem space and anchoring," in *Proceedings of the Annual Meeting of the Cognitive Science Society*, vol. 31, 2009.

[81] D. Kirsh, "Thinking with external representations," *Ai & Society*, vol. 25, no. 4, pp. 441–454, 2010.

[82] S. L. Chu Yew Yee, *Performative Authoring: Nurturing Children's Creativity and Creative Self-Efficacy through Digitally-Augmented Enactment-Based Storytelling*. PhD thesis, 2015.

[83] F. Garzotto, "Interactive storytelling for children: a survey," *International Journal of Arts and Technology*, vol. 7, no. 1, pp. 5–16, 2014.

[84] M. Sugimoto, T. Ito, T. N. Nguyen, and S. Inagaki, "Gentoro: a system for supporting children's storytelling using handheld projectors and a robot," in *Proceedings of the 8th International Conference on Interaction Design and Children*, pp. 214–217, ACM, 2009.

[85] C. Sylla, C. Coutinho, and P. Branco, "A digital manipulative for embodied "stage-narrative" creation," *Entertainment Computing*, vol. 5, no. 4, pp. 495–507, 2014.

[86] U. Technologies, "Unity3d." `https://unity.com`, 2019.

[87] M. A. Pulaski, "Toys and imaginative play," *The child's world of make-believe*, pp. 74–103, 1973.

[88] V. C. McLoyd, "The effects of the structure of play objects on the pretend play of low-income preschool children," *Child Development*, pp. 626–635, 1983.

[89] S. L. Chu and F. Quek, "The effects of visual contextual structures on children's imagination in story authoring interfaces," in *Proceedings of the 2014 conference on Interaction design and children*, pp. 329–332, 2014.

[90] S. L. Chu and F. Quek, "Things to imagine with: Designing for the child's creativity," in *Proceedings of the 12th International Conference on Interaction Design and Children*, pp. 261–264, 2013.

[91] N. Yee and J. Bailenson, "The proteus effect: The effect of transformed self-representation on behavior," *Human communication research*, vol. 33, no. 3, pp. 271–290, 2007.

[92] J. Guegan, S. Buisine, F. Mantelet, N. Maranzana, and F. Segonds, "Avatar-mediated creativity: When embodying inventors makes engineers more creative," *Computers in Human Behavior*, vol. 61, pp. 165–175, 2016.

[93] U. A. Store, "Rootmotion: Finalik." https://assetstore.unity.com/packages/tools/animation/final-ik-14290, 2019.

[94] J. E. Deal, C. F. Halverson Jr, R. P. Martin, J. Victor, and S. Baker, "The inventory of children's individual differences: Development and validation of a short version," *Journal of Personality Assessment*, vol. 89, no. 2, pp. 162–166, 2007.

[95] H. Autman and S. Kelly, "Reexamining the writing apprehension measure," *Business and Professional Communication Quarterly*, vol. 80, no. 4, pp. 516–529, 2017.

[96] P. Tierney and S. M. Farmer, "Creative self-efficacy: Its potential antecedents and relationship to creative performance," *Academy of Management journal*, vol. 45, no. 6, pp. 1137–1148, 2002.

[97] W. IJsselsteijn, Y. De Kort, and K. Poels, "The game experience questionnaire," *Eindhoven: Technische Universiteit Eindhoven*, 2013.

[98] M. Dionisio, P. Bala, V. Nisi, and N. Nunes, "Fragments of laura: incorporating mobile virtual reality in location aware mobile storytelling experiences," in *Proceedings of the 16th International Conference on Mobile and Ubiquitous Multimedia*, pp. 165–176, ACM, 2017.

[99] L. Zhang, D. A. Bowman, and C. N. Jones, "Exploring effects of interactivity on learning with interactive storytelling in immersive virtual reality," in *2019 11th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games)*, pp. 1–8, IEEE, 2019.

[100] J. Van Looy, C. Courtois, M. De Vocht, and L. De Marez, "Player identification in online games: Validation of a scale for measuring identification in mmogs," *Media Psychology*, vol. 15, no. 2, pp. 197–221, 2012.

[101] L. M. Register and T. B. Henley, "The phenomenology of intimacy," *Journal of Social and Personal Relationships*, vol. 9, no. 4, pp. 467–481, 1992.

[102] V. Gupta, "Elements of news story-5ws and 1h," *Handbook of Reporting and Communication Skills*, vol. 25, 2003.

[103] S. of Texas Assessments of Academic Readiness, "Personal narrative writing rubric - grade 4." `https://tea.texas.gov/sites/default/files/Rubric-WritingGr04.pdf`, September 2019.

[104] P. R. Messinger, X. Ge, E. Stroulia, K. Lyons, K. Smirnov, and M. Bone, "On the relationship between my avatar and myself," *Journal For Virtual Worlds Research*, vol. 1, no. 2, 2008.

[105] B. Edmiston, P. Enciso, and M. L. King, "Empowering readers and writers through drama: Narrative theater," *Language Arts*, vol. 64, no. 2, pp. 219–228, 1987.

[106] S. Wright, "Graphic-narrative play: Young children's authoring through drawing and telling.," *International Journal of Education & the Arts*, vol. 8, no. 8, pp. 1–28, 2007.

[107] B. J. Grosz and C. L. Sidner, "Attention, intentions, and the structure of discourse," *Computational linguistics*, vol. 12, no. 3, pp. 175–204, 1986.

[108] E. Reese, C. A. Haden, L. Baker-Ward, P. Bauer, R. Fivush, and P. A. Ornstein, "Coherence of personal narratives across the lifespan: A multidimensional model and coding method," *Journal of Cognition and Development*, vol. 12, no. 4, pp. 424–462, 2011.

[109] D. H. Graves, *Writing: Teachers and children at work.* ERIC, 1983.

[110] T. Thomason, *Writer to Writer: How To Conference Young Authors. The Bill Harp Professional Teachers Library Series.* ERIC, 1998.

[111] M. L. Barrón-Estrada, R. Zatarain-Cabada, F. G. Hernández, R. O. Bustillos, and C. A. Reyes-García, "An affective and cognitive tutoring system for learning programming," in *Mexican International Conference on Artificial Intelligence*, pp. 171–182, Springer, 2015.

[112] F. Decortis and A. Rizzo, "New active tools for supporting narrative structures," *Personal and Ubiquitous Computing*, vol. 6, no. 5-6, pp. 416–429, 2002.

[113] J. Strasser and H. Seplocha, "Using picture books to support young children's literacy," *Childhood Education*, vol. 83, no. 4, pp. 219–224, 2007.

[114] P. Schneider and R. V. Dubé, "Story presentation effects on children's retell content," 2005.

[115] T. K. Chan, S. W. Wong, A. M.-Y. Wong, and V. W.-H. Leung, “The influence of presentation format of story on narrative production in chinese children learning english-as-a-second-language: A comparison between graphic novel, illustration book and text,” *Journal of psycholinguistic research*, vol. 48, no. 1, pp. 221–242, 2019.

[116] L. Flower and J. R. Hayes, “Images, plans, and prose: The representation of meaning in writing,” *Written communication*, vol. 1, no. 1, pp. 120–160, 1984.

[117] M. Sadoski, W. A. Kealy, E. T. Goetz, and A. Paivio, “Concreteness and imagery effects in the written composition of definitions.,” *Journal of Educational Psychology*, vol. 89, no. 3, p. 518, 1997.

[118] P. Yenawine, “Thoughts on visual literacy,” 1997.

[119] M. Tan, J. Randi, B. Barbot, C. Levenson, L. Friedlaender, and E. Grigorenko, “Seeing, connecting, writing: Developing creativity and narrative writing in children,” *Writing: A mosaic of new perspectives*, pp. 275–291, 2012.

[120] G. Kress, *Before writing: Rethinking the paths to literacy*. Routledge, 2005.

[121] S. Beam and C. Williams, “Technology-mediated writing instruction in the early literacy program: Perils, procedures, and possibilities,” *Computers in the Schools*, vol. 32, no. 3-4, pp. 260–277, 2015.

[122] M. Madden, P. W. Chung, and C. W. Dawson, “Cartoons beyond clipart: A computer tool for storyboarding and storywriting,” *Computers & Education*, vol. 52, no. 1, pp. 188–200, 2009.

[123] N. Zarei, F. Quek, S. L. Chu, and S. A. Brown, “Towards designing enactment-scaffolded narrative authoring tools for elementary-school children,” in *Interaction Design and Children*, pp. 387–395, 2021.

[124] M. Serrato, “Watch-think-write’and other proven strategies for using video in the classroom,” 2016.

[125] R. E. Mayer, "Cognitive theory of multimedia learning," *The Cambridge handbook of multimedia learning*, vol. 41, pp. 31–48, 2005.

[126] B. Jung, J. Song, and Y. Lee, "A narrative-based abstraction framework for story-oriented video," *ACM Transactions on Multimedia Computing, Communications, and Applications (TOMM)*, vol. 3, no. 2, pp. 11–es, 2007.

[127] J. Heilmann, J. F. Miller, A. Nockerts, and C. Dunaway, "Properties of the narrative scoring scheme using narrative retells in young school-age children," 2010.

[128] P. Gándara, J. Maxwell-Jolly, and A. Driscoll, "Listening to teachers of english language learners: A survey of california teachers' challenges, experiences, and professional development needs," 2005.