The Effects of Physicality on the Child's Imagination

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ABSTRACT

This paper investigates the effects of physical objects as support for imagination in the context of enactive storytelling. More specifically, we target nine-year-old children because of their general disengagement from creative activity, a phenomenon known as the Fourth-grade Slump that arises from a demotivational spiral brought on by social awareness. We study how enactment using physical objects may allow the child to better engage in story imagination. Our study compares the richness of the imagination under three main enactment conditions with objects that have varying degrees of fidelity to referent objects: Cultural objects (physical visual resemblance); Physical objects (similar physical affordances); Arbitrary objects (minimal physical and visual affordances). We employ a mixed-methods analysis to gauge the child's level of broader imagination from three data sources: Enactment videos, drawings and interviews with the children. We found that the object types significantly differ in their support of the imagination, with the object of highest specificity being most effective. Our findings can inform the design of embodied creativity-support systems for children.

Author Keywords
Physicality, Imagination, Creativity, Children, Storytelling, Fourth-grade Slump

ACM Classification Keywords
H.5.m. Information interfaces and presentation (HCI): Misc

General Terms
Human Factors; Design; Theory

INTRODUCTION

A child receives a felt Hogwarts student hat as a gift. She adds a TinkerToy stick from the toy box as a wand, and spends untold minutes in play, imagining herself to be a student of the mythical school. Wearing the hat and with 'wand' in hand, the child imagines herself in countless scenes at Hogwarts encountering hordes of goblins and dementors. She battles fiercely, directing her 'wand' time and again at the enemies, as she utters spell after spell.

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This scenario is familiar to all who have seen children at play. Physical toys have the power to facilitate the child's imagination. This paper investigates the relationship between physicality and the child's imagination. Research has shown that the use of physical objects (also known as tangibles or direct physical interaction) has beneficial effects on parameters such as memory, perception, spatial awareness, visualization and mental computation. The effects of physicality on imagination or creativity have received little attention. Yet, children's pretend play with physical objects has been characterized as being a highly imaginative activity [1, 2], whereby they learn how to substitute one object for another. A large space remains to be investigated to inform the design of physically-based systems to support and nurture creative activity in children.

We study whether and how physical objects can be used to engage and support the child's imagination in storytelling. Our scientific inquiry is motivated by a phenomenon in particular: the 'Fourth-grade Slump' concerns one specific segment of the child population, notably at around 8 to 10 years old, that is particularly 'at risk' in terms of creative activity engagement. Research has shown a precipitous drop in children's creativity during this period of rapid development. In the rest of this paper, we present relevant background material, a literature review on the physicality-imagination coupling, our study design and methodology proper, methods of data analysis and the study results, before ending with a discussion and conclusion.

RELEVANT BACKGROUND

Storytelling as Focus Domain

For this study of the imagination, we focus on the age-old activity of storytelling. The rationale for the focus domain is three-fold. First, storytelling is a basic activity that human beings engage in to make sense of the world. Stories or narratives structure our lives, experiences and even identity [3]. Second, storytelling, in one form or another, is a widespread instructional tool used to teach a wide range of subjects. Through a series of interviews with teachers from several elementary schools, we observed the variety of activities involving extensive use of story writing that children are already assigned to complete at school, from poetry writing to neighborhood stories and book chapter stories. Third, from a Vygotskian perspective, stories act as a proper 'cognitive tool' that satisfies all the requirements for the development of imagination. Gajdamaschko [4] enumerates the requirements as being the following: "crystallized in culture", unified in terms of "imagination, thinking and

emotions", influential of the child's behavior, and accepted by the child as part of her cultural development.

The Fourth-Grade Slump

We choose to work with children in the 3rd to 4th grades for two related reasons. First, this has been identified as the 'at-risk' period known as the Fourth-Grade Slump (hereafter, the Slump) where creative activity is at a nadir in many children. Hence, the Slump provides a 'failure condition' in creative activity that may also furnish insights on specific impediments to creativity that may recur through life. Second, the nurture of creativity in children can impact their later development. Russ, Robins & Christiano [5] showed that "the quality of fantasy and imagination" of pretend play in 2nd graders is predictive of divergent thinking at 5th and 6th grade, "independent of IQ". Addressing creativity nurture in our target age group is thus of critical importance.

Torrance [6] describes the Slump as a precipitous "decrement in all creative thinking abilities near the end of 3rd grade or beginning of the 4th grade", that has been observed through longitudinal studies in many countries from the United States to Norway, India and Western Samoa. This phenomenon, discovered more than thirty years ago, remains a worrying gap for teachers [7]. Figure 1 illustrates the Slump. From the onset of speech, the manifested creative activity of the child increases until around 9 years old when it goes into a trough period. We note that the period of the sudden Slump coincides with Piaget's 'concrete operational phase' (COP) [8, 9] where egocentric speech is eliminated, and social awareness is ignited. This furnishes a possible reason for the Slump.

As shown in Figure 1, the child experiences the COP before she has arrived at some *threshold of competence* in her development (this competence can be in any domain). This causes a negative self-evaluation of her contribution that suppresses creative activity. She judges her meager experience/skill/knowledge as insufficient to afford her much to say creatively. As children proceed into adolescence, some rediscover creative activity, but unfortunately many do not [10, 11]. Unlike the onset of the Slump, we do not know of any *developmental* event that would trigger reemergence of creative activity. It is likely that education and learning typically reach a critical mass as a child enters the teen years – making the Slump a cultural phenomenon of the long incubation period for competence in modern society.

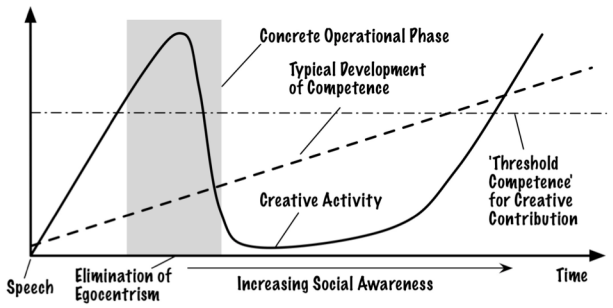

Figure 1. The Fourth Grade Slump

Torrance [12] provides a similar three-part rationale for the Slump based on factors such as social accommodation, peer approval, and the need for validation as the child comes into greater contact with society. Social awareness leads a child to be more judgmental of her own work [13] and to engage in more critical self-evaluation of competence [14]. Such self-appraisals with respect to social norms and standards lead to self-regulation of behavior [15]. Positive self-appraisals may lead to greater involvement in creative behavior, and negative self-appraisals may result in self-doubt and a decrease (and eventual withdrawal from) in creative activity. Such a feedback mechanism is likely to be characteristic of other common 'slumps' that even adults go through (e.g. beginning a career in a new environment).

Imagination and Creativity

This paper investigates storytelling through enactment with physical objects as a means of facilitating creative imagination. While literature on creativity has flourished, the study of imagination per se appears to have suffered a hiatus in recent years, with the bulk of literature on the subject appearing before the year 2000. This is unfortunate given the fundamental role of imagination, that we define as the ability to 'image' or 'see' distal or completely constructed worlds and possibilities: "every invention, whether large or small, before being implemented, embodied in reality, was held together by the imagination alone" (Vygotsky, [2]). Finke, Ward, & Smith [16] situate the capacity for mental imagery at the core of the formation of deliberate creative imagery from whence conscious innovation springs. Vygotsky places imagination at the genesis of the creative process stating: "the entire world of human culture … all this is the product of human imagination and of creation based on this imagination" [2].

Pelaprat & Cole [17] propose that imagination arises from the embodied need to 'fill the gap' in perception to produce a "stable image of the world" from fragmentary percepts in humans, and that this gap-filling capacity to produce imagery from experience ultimately leads to creativity. They further propose that imagination and creativity have a 'cyclical' relationship that is mediated by experience and knowledge. Experience shapes imagination, and imagination contributes to creative activity. This is cyclical because if the output of an activity is "perceived as new, the products of imagination become creative when they enter the cultural world of interaction." ([17], p 414) Hence, creative output shapes culture that further furnishes new experience, making experience, imagination and creativity cycle ultimately a socially-oriented activity.

This paper addresses an aspect of imagination in pretend play that is fueled by physical objects. The Harry Potter-imaginative play example at the start of our introduction is designed to illustrate the richness of this type of support for the imagination in story construction and engagement in the context of storytelling. Our focus on imagination as a nec-

essary process in creativity also serves to emphasize the need to analyze process instead of product in the general study of creativity. In this study, we sought to understand the dynamic process (rather than the static products) of creative activity.

PHYSICALITY, EMBODIMENT AND IMAGINATION

Relatively little research has looked at the empirical relationship between physicality and imagination. In HCI, many have advanced the importance of physicality, tangibility and/or embodiment for systems geared towards education, insight formation and problem solving. Psycholinguistic studies have also shown that body gesturing leads to better speech recall [18]. With respect to children however, the area of tangible interaction has focused on pen-based and touch interaction, and the effects of particular designed systems on learning in particular. Few recent works have sought to understand the effects of physicality and embodiment on creativity of children, let alone imagination that is the basis of creativity.

Among the relevant ones that address physicality, embodiment and imagination in some way, Chu, Quek & Lin [19] studied the process of 9-year old children creating stories using an animation authoring software and found that the children naturally tend to use body enactments to create and illustrate their ideas to each other. Antle, Droumeva & Ha [20] compared 7 to 10 year-old children solving jigsaw puzzles in three conditions: a traditional cardboard puzzle, a mouse-based graphical user interface (GUI) puzzle and a tangible user interface (TUI) tabletop puzzle. They concluded that "direct handling of objects supports children to mentally solve the task through iterations of exploratory and direct placement actions" by observing interaction patterns and measuring time to completion. With the goal of informing the design of tangible environments that support 'reasoned imagination', Antle et al. [21] generated a list of design knowledge (e.g. "most conceptual systems are understood through several embodied metaphors") from three design projects. They however looked at imagination in a sense that is closer to reasoning or to a user's understanding of a designer's intended schema.

Literature that more directly relates to the investigation of the effects of physicality on imagination is mostly dated and typically deal with toddlers aged 2 to 5 years old, with theoretical underpinnings such as Piaget's [22] theory of symbolic play, Vygotsky's [2] theory of the child's imagination, El'Konin's [23] work on pretend play, or De Saussure's semiotic theory of signs. In a study on how the structure of play objects affects imaginative play in 3½ to 5 year-olds, for example, McLoyd [24] found that high structure objects significantly generated more pretend play themes. High structure objects are miniature version of objects whose "identity and functions … most preschoolers are aware of" (e.g. dolls, trucks). Low-structure objects were objects that were "less specific and unique" at least for preschoolers (e.g. boxes, pipes).

In a controlled experiment, Elder & Pederson [25] compared how children aged 2½, 3, and 3½ performed the same action with objects grouped as Similar or Dissimilar to particular objects, or with no object at all. The children's pretend performances were scored for recognizability of the action sequence using the substitute object. Their results showed that while 2½-year-old children performed significantly less well in the Dissimilar condition as compared to the Similar condition, the 3-year olds performed equally well across all conditions.

Pederson et al. [26] conducted another experiment similar to Elder & Pederson's with children of the same age group performing the same actions with substitute objects differing in form and function classified as 'ambiguous', 'unlikely to elicit a response', and 'highly likely to elicit a response'. They found again that physical similarity of the object guided actions for younger children.

Studying the behaviors of 5-year old children with interactive toys (an interactive duck toy was used), Smirnova [27] concluded that the 'openness of the image', "its capacity to accept various experiences and emotions and to perform various actions in the child's hands" can turn an object into an effective 'play tool'. A common theme in this and other (e.g. [28, 29]) studies is that objects can function as tools for psychological development with immediate effects on children's behaviors. Furthermore an object can support a child's imagination effectively when it can help the child to move "from action in response to objects present in the perceptual field to action generated and controlled by ideas" [26].

We are interested to probe whether the differing physicality of objects continues to guide imaginative behavior later in childhood, specifically for our target age of 8 to 10 years old. Imaginative play in which the child acts out roles and speaks aloud has been shown to decline at ages 6 or 7, as the child increasingly internalizes such play into "private mental activity". Nevertheless, pretend play does continue to occur in 8 to 9-year olds, becoming evident especially in group play ([1], p.39). Even in adolescent children and adults, physical objects/toys can elicit imaginative enactment (a form of pretend play). We highlight here that we look at 'broader imagination', which may or may not be facilitated by the object, instead of simply imaginary object substitution as previous studies have done. Vygotsky [2] suggests that cognitive mechanisms learnt in childhood are constantly used and built upon in adulthood. It is highly likely that in later childhood, we make use of physical affordances of objects to support imagination instead of being hindered by them.

In this study, we investigate the effects of the following on the child's imagination in the context of storytelling, with a focus on the first:

a. Objects of varying specificity, that we refer to as *object types*

b. The use of objects as compared to just the body without objects, that we refer to as *enactment conditions*

c. The type of stimulus used as story prompt, that we refer to as *visual conditions*

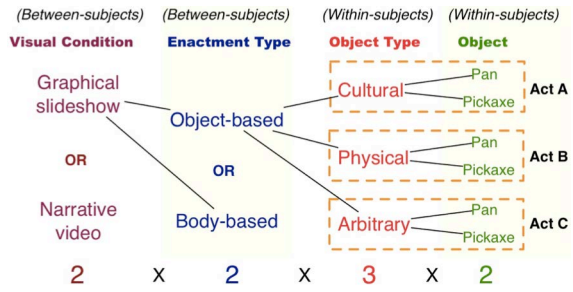

Figure 2. Study design

Figure 3. Objects used in story enactment

STUDY DESIGN

We conducted a semi-experimental 2 (Visual condition) × 2 (Enactment condition) × 3 (Object type) × 3 (Object) mixed design study (see Figure 2) to investigate the effects of physicality on children's imagination. Participants were allocated to one of two visual conditions (between-subjects factor): *graphical slides* (child watches a slideshow illustrating the stimulus story graphically) or *narrative video telling* (child watches a video of a narrator telling the stimulus story). The audio tracks are identical for both conditions. Two enactment conditions were tested as another between-subjects factor: *body-based* (the child acts without using any object) or *object-based* (the child acts with physical objects). Within the object-based condition, the type of object used was manipulated at three levels as a within-subjects factor based on different degree of fidelity to the object referent: *Cultural*, *Physical* and *Arbitrary* object. The cultural objects had visual resemblance and the same manipulative affordances as their real-life referents. The physical objects had the same manipulative affordances but decreased visual resemblance. The arbitrary objects had little visual resemblance and minimum manipulative affordances. The children were asked to enact with three objects (within-subjects factor) in the context of a story: a *frying pan, pickaxe* and *lantern*. For maximum customizability, the objects, shown in Figure 3, were handmade.

To allow for the within-subjects design of objects and object types, we constructed the stimulus story to have three acts (one act for each object type. e.g., if Act 1 is designed as being for cultural objects, all objects (frying pan, pickaxe and lantern) of cultural object type will be used in that act. Act 2 will be for physical or arbitrary objects, and the final object type will be for Act 3). The order of object types was randomized. The story tells about three dwarves setting out into the caves to collect mushrooms to help their city that will soon be attacked by an ancient enemy. Three actions of the dwarves (cooking, digging & using the lantern) were repeated in each act. Care was taken in the authoring of the story to make the story context of the actions as similar as possible across the three acts without being too repetitive.

To convey the story to the children in the slideshow condition, graphical illustrations for scenes in the story were created in cartoon style using Photoshop CS3. The story narration for children in the narrative video condition was recorded by an external performer reading the story script. Samples from the stimulus materials are shown in Figure 6. The three story acts were each around 5 to 7 minutes in length in both slideshow and narrative video formats.

At the point of the story when the dwarves performed the cooking, digging and lantern actions in each act, the story was stopped and an 'enactment prompt' slide was shown, asking the child to enact the story event that immediately preceded it with questions in the form of '[Dwarf's name] is frying/digging up/swinging the [target object]. Can you act out how he/she is using the frying pan/pickaxe/lantern?'

Measures of Imagination

Imagination has been measured in many different ways, depending on the requirements of the study in question. The issue of a general measure of imagination is complicated by the various ways in which the concept has been understood. It has previously been equated with for instance, memory, imagery, fantasy or even invention or creativity. Some of the common measures that have been used include the numerous types of inkblot tests (Rybakoff, Whipple, Rorschach, etc.), textual measures (sentence building, story creation based around certain words, descriptions of imaginary animals, compositions, theme writing), studies of dreams and fantasy [30], or different types of scales depending on the specific definition adopted.

For example, Gleason et al. [31], studying whether children with imaginary companions may have "heightened imagination abilities" used self-reports on scales of imagery use, daydreams and night dreams as measures of imagination. Studying the personality characteristics of fantasy-prone college-aged students, Lynn & Rhue [32] used the Barren-Welsh Art Scale that measures preference for line drawings, the Betts QMI Vividness of Imagery Scale that assesses vividness of image formed in response to a stimulus, and the inkblot Rorschach test. Rimm & Bottrell [33] investigated the correlation among the use of paired-associates, respiratory physiological measurements, object spatial recall from pictures, and a self-rating measure for visual imagination. They found very low correlation between all of the other measures and self-rating. Liang et al. [34], acknowledging the lack of a measure of imagination, conducted an exploratory factor analysis to validate their 10-item scale of imagination targeted at multimedia designers.

Most of the measures discussed above are either not suitable for children, or do not measure imagination in-situ. We are particularly interested in studying imagination in the process of its evocation. In our study, we devised a measure for the child that we call *broader imagination*. A similar measure was used in Chu, Quek & Lin [19]. We define 'broader imagination' as including *any form of extension and association made beyond (visual, auditory, tangible, etc.) presented materials for the task at hand*. These extensions and associations can vary on extent or amount, typicality with regard to a given situation and consistency over time. We used a multi-track approach to measure broader imagination from methods chosen to minimize the barrier of expression for our target age group: Story enactments, scene drawings, and oral recall interviews.

STUDY METHODOLOGY

The study was held at an elementary school with 12 children from a fourth-grade class over four days. Two additional children were recruited separately for the study, making a total of 14 participants (8 girls and 6 boys), all aged nine except for one aged 10. A packet consisting of a consent form, an information sheet and a personality questionnaire (the Big-Five Inventory-10 scale [35]) was sent to the parents via the teacher a week before the study started. The teacher was also asked to complete a questionnaire to assess (on 7-point Likert scales) the engagement, realism and imaginativeness of the typical performance of each of the child participants in day-to-day class activities.

For the study, the children were paired randomly by the teacher. Two rooms near the classroom were set up with a laptop, a large 55" display, loudspeakers, floor mats, two video cameras and a voice recorder. Additionally, in each room two boxes were drawn on the floor to act as the 'enactment areas', with a camera on tripod facing each box so that two children standing in the boxes would face away from each other (see Figure 4).

On the first day of the study, an experimenter distributed a questionnaire to all the participants asking, on 7-point Likert scales, about their enjoyment of storytelling, their confidence to tell and to act out stories, and their frequency of telling stories. They were guided to fill the questionnaire as a group. Subsequently, one pair of children at a time was sent to each 'experiment room'. A trained experimenter in each room carried out the study, while a third experimenter acted as the 'runner' to fetch the children and ensure objects and materials were in place throughout. At the beginning of the study, the two children were briefed about the study and told that they will be listening to a story and acting out (or pretend play) parts of it with different objects. They were told that it was like filming their own movie. The study then proceeded as shown in Figure 5.

For the enactments, the children were allowed to enact in any way they want and to use the objects as they desired. For the drawings, the children were asked to choose one of the scenes they just acted out and to draw it on a sheet of

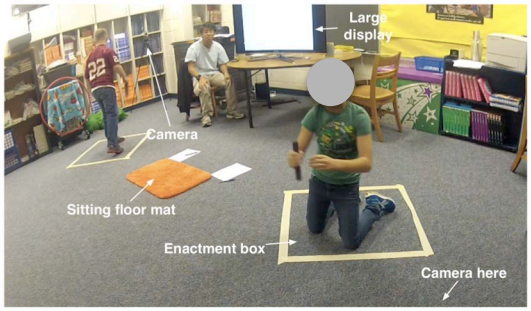

Figure 4. Room setup for study

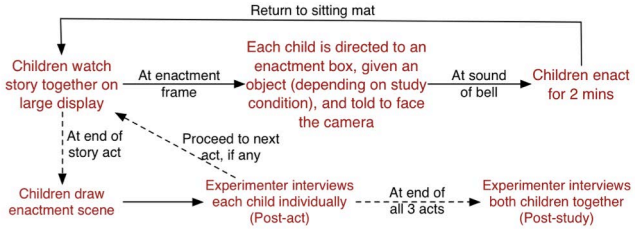

Figure 5. Study procedures

blank A4 paper. The post-act interview was semi-structured and asked the child the following questions: How did you use this object in the story? (if relevant); What were you thinking while you were acting out the [action]?; Did you think about [detail mentioned] just now or back then while acting? Follow-up questions based on their previous responses probed for indications of the depth and detail of their imagination. Enactments were video recorded and interviews were both video and audio recorded.

Although we were interested to see the effects of a non-graphical visual stimulus and a body-only enactment condition, our main focus was to study children using objects in story enactment. We therefore allocated the majority of the participants to the slideshow, object-based condition, and assigned a number of randomly selected children to the other variant conditions. Three of the children were allocated to a narrative video, object-based condition; four to a slideshow, body-based condition; and, one to a narrative video, body-based condition. For children in the object-based conditions, the order of the object type (cultural, physical, arbitrary) was randomly chosen.

DATA ANALYSIS

Personality scores from the BFI-10 were standardized and computed (according to [35]) for each child on five dimensions: Agreeableness, Extraversion, Conscientiousness,

Figure 6. Left. Sample story slide.
Right. Screenshot from narrative video.

Neuroticism and Openness. Scores from the teacher questionnaire were averaged into three dimensions: General engagement, Work realism, and Baseline imaginativeness.

We could not find a method for analyzing imagination from gestures that was suitable for our purpose in the literature. Loke et al. [36], Andrienko et al. [37] and the Laban Movement Analysis framework for instance provide some indication as to how to analyze movement qualitatively but does not relate it to imagination in any way. Nemirovsky et al. [38] relate gestures to imagination using a method of analysis from psycholinguistics called microethnography, a "collection of techniques that focus on moment-to-moment bodily and situated activity". The enactments of our child participants however did not include co-produced speech per se. We therefore devised a method of enactment analysis to elucidate the child's in-situ imagination.

The videos of the enactments were processed as described below. The collected video stream was cut up to isolate each enactment of each child. A child had nine enactment videos in total (3 objects: [pan, pickaxe, lantern] × 3 object types: [cultural, physical, arbitrary]) across the three acts. Two coders analyzed each enactment video separately identifying micro-actions and their timings and recording these in a spreadsheet. Micro-actions represent the objective actions that the child performs in the enactment and consist of any distinguishable action such as an overhead swing of the pickaxe, a flipping action, or a swing of the lantern with the pan. Disagreements were then resolved in discussion and a consolidated 'action description' of the enactment was produced. For each enactment, the micro-actions coded in the consolidated action description were collated to produce a 'repertoire of micro-actions' for that particular enactment. Acronyms such as Flipping (F) or Put in Pan (PiP) were used to represent the micro-actions.

The two coders then did an interpretive coding pass over the video combining the micro-actions into 'story vignettes', and conferring when disagreements occurred. The vignettes for each enactment were also collated into a 'repertoire of vignettes'. Vignettes represent the semantic interpretation of the set of micro-actions in the enactment: the story that the child is trying to tell. Attention was paid to body postures, facial expressions, gaze, pace, etc. when interpreting micro-actions into vignettes. Acronyms were also used for the vignettes, such as Fanning Fire (FNV) and Misflip & Catch (MFCV). A sample of part of the consolidated coding sheet is shown in Figure 7.

We used the interviews and drawings as supporting data to elucidate the child's imagination during the enactments. All interviews relating thoughts of the child during the enactment were transcribed with timecodes using InqScribe, and inserted into the spreadsheet along with the micro-actions repertoire and the vignettes repertoire. The two coders then read and coded the transcripts separately and then together, for four dimensions: the child's stated goal in the enactment (goal); the child's operationalization of the goal (schema);

High-level Micro-Action description	Micro-Action Repertoire	Vignettes
Child's activity seems more rigorous than for Act 2 but same actions (HS and F). Eye gaze is hardly engaged throughout. Actions also seem more arbitrary, and not 'cooking-like' at certain points. Child switches pan from hand to hand. Whole thing is pretty homogeneous (7-72)	1. Horizontal Shaking Side to side (HSS); 2. Horizontal Shaking Linear (HSL); 3. Flipping (F)	**Summary: BCV** BCV Throughout with 2 kinds of HS: HSS & HSL. Begins with HSS and unlike Act 2, HS seem more dominant than Fs. (7-72)
Child is in kneeling position throughout but with a more relaxed feeling than in Act 1. At the beginning of the enactment, he glances over at the female subject across the room using the cultural object. She was 'adding condiments' to her pan (PiP). He seems to follow her action. Throughout the enactment, he adds condiments, shakes the pan (small motion side to side) (HSS) and repeats the cycle. He generally looks at the pan and the cooking activity he is doing. At about 1:30 he seems to get bored and disengages. At 1.56, he seems to do a single flip (F) after glancing at the girl again (she was doing large flips).	1. Put in Pan (PiP); 2. Horizontal Shaking Side to side (HSS) 3. Flipping (F)	**Summary: BCV, AIV** Child does BCV constantly with a lot of AIV. He does mostly SoF, adding a few subtle HSS at times and a single F toward the end. He adds ingredients throughout from both sides.

Figure 7. Sample of data analysis spreadsheet

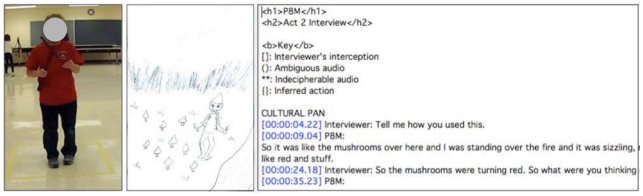

Figure 8. Sample of data sources: Left. Enactment video. Middle. Drawing. Right. Interview transcription

extra details that the child imagined (extended); and how consistent the child was during the interview in terms of intent, action and recall with regard to the enactment (consistency).

The drawings were coded by the two coders separately at first, and then in conjunction whenever disagreements arose, for three dimensions: the character, if any, in terms of his/her suggested action (character); the scene or environment and any other elements in it (scene); and how consistent the child was in his/her drawing with regard to the enactment and the interview (consistency). We highlight here that not all enactments had an associated drawing as the child was asked to draw only one of the two enactments he/she did during the previous act. The enactment videos were referenced again throughout the coding process whenever needed.

Finally, each of the two coders gave an 'overall broader imagination score' (referred to as imagination score hereafter) for each enactment based on a gestalt view built from all of the child's enactment's micro-actions and vignettes, interview analysis and drawing observations (see Figure 8). Unmatched scores (only 10%) between the two coders were discussed and resolved into a score that both agreed was adequately representative. A sample of part of this analysis is shown in Figure 9. The imagination scores, personality

Enactment Thoughts from Interview	Interview Coding	Drawing Coding	Imagination Score
[00:03:25.16] Interviewer: How about the third one? [00:03:27.14] P12F: The third one like trying to get rocks away with an axe. [00:03:34.17] Interviewer: How were you doing that? [00:03:36.27] P12F: You were like hammering down and then you would move it away. [00:03:43.28] Interviewer: You mean the rocks? What kind of rocks were you hitting? [00:03:45.18] P12F: Just old..debris pretty much. [00:03:53.20] Interviewer: What color were they? Did you think about.. [00:03:56.18] P12F: Black. [00:04:00.12] Interviewer: What were you thinking about? [00:04:07.22] P12F: The rocks and trying to get them away [00:04:13.12] Interviewer: And who were you acting as, when you were doing.. [00:04:16.12] P12F:	**Goal:** Get rocks away with axe **Schema:** Hammer down, Move rocks away **Extended:** Object of hit, Color of rocks, Acting as Berin **Consistency with Enactment:** Intent, Action, Recall - Yes (basically the same actions)	**General:** Two dwarves, one male holding a pickaxe and one female holding a lantern **Scene:** Scribblings represenging rocks around and two lines to signify a pathway **Consistency with Interview/enactment:** Not quite - Drawing does not show much action but shows more of surroundings imagined	6

Figure 9. Interview and drawing analysis

scores from the parents and the baseline performance scores from the teacher were entered into SPSS for statistical data analysis. A repeated measures two-way ANOVA was run with object type (3 levels) and object (2 levels) as within-subjects variables and visual condition as between-subjects factor. The openness scores from the personality questionnaire, the imaginativeness scores from the teacher questionnaire, and gender were used as covariates. Further, two between-subjects one-way ANOVAs were run with imagination scores as dependent variable and enactment condition as factor for the first, and visual condition as factor for the second, both with the same covariates.

Clustered barcharts were generated in a spreadsheet to illustrate the number of micro-actions and number of vignettes per object condition. This allowed us to analyze the enactments in greater detail. Other clustered barcharts were generated in SPSS for the imagination scores per child for each object separately. This allowed us to identify patterns in the ordering of the object types across participants.

STUDY FINDINGS

Participants: Descriptive statistics of the participants showed that our sample was very diverse with a wide range of personality characteristics, strenthening our external validity: the openness dimension from the parent's questionnaire had a SD of 1.68, the teacher's imaginativeness score had a SD of .94, the child's enjoyment of storytelling had a SD of 2.62. Imagination scores had an average SD of 1.60 across all object types.

Enactments: Enactments were coded in terms of micro-actions (MAs), representing the diversity of the child's story operationalization, and vignettes, representing the complexity of the child's story construction. There were a total of 52 unique MAs and 20 unique vignettes across all participants and across all object types of the frying pan object, 47 MAs and 50 vignettes for the pickaxe object, and 48 MAs and 28 vignettes for the lantern. We classified the MAs into three types of actions: *Object actions*, encompassing any action that simulate the use of the frying pan (e.g. flipping, shaking, tossing), the pickaxe (e.g. chopping, stabbing) or the lantern (e.g. swinging, sweeping, flicking); *Body actions*, signifying actions that involve the use of one or more parts of the body (e.g. peeling, sprinkling, smelling of pan, kicking, wiping forehead, clearing with hand for pickaxe, simulating running); *Facial actions*, including expressions or other actions that involve parts of the face (e.g. chewing, making surprised look, making sound effects). Figure 10 shows the percentage distribution of the different types of actions within each of the body- and object-based conditions. Figure 10 shows the proportion of the vignettes by complexity, where simple vignettes contain ony one MA per vignette and complex vignettes contain two or more MAs. This indicates the consistency and extension of the story pieces being enacted. Trendlines (dotted blue and red lines) have been overlaid on top of the charts to make the patterns clear.

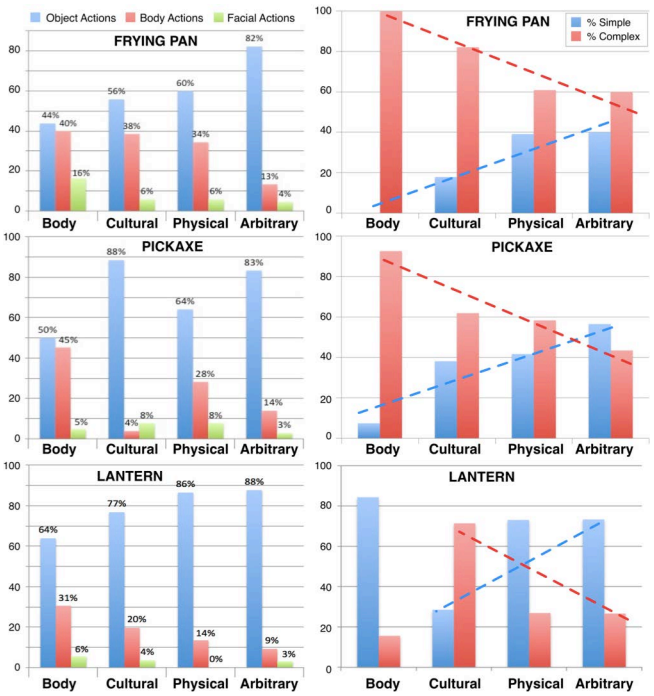

Figure 10. Distributions of Micro-actions (Left) & Vignettes (Right)

Object Types: We compared the use of objects of three differing set of characteristics in story enactment on the child's imagination. The two-way repeated measures analysis of variance test on scores of imagination yielded a significant interaction effect of *Object* × *Object type,* $F_{(4, 20)} = 3.23$, $p < .05$, partial $\eta^2 = .392$.

Analysis of the clustered barcharts revealed an interesting pattern in terms of object type. Four main groups can be distinguished from the object type order: one set of children, labeled I in Figure 12, had higher imagination scores for the arbitrary objects, and consistently followed by a higher score for the physical objects and then the cultural objects. A slight variation of this first group, labeled II, had similarly high scores for the arbitrary objects, but followed by the cultural then the physical objects. Conversely, a third group labeled III performed best with the cultural objects, followed by the arbitrary and then the physical objects. Group IV is a variation of group III whereby the orders of arbitrary and physical objects flipped. Only one child had the highest scores with the physical objects. Thus, two main groups of tendencies (Figure 11) can be distinguished: one where the arbitrary objects take prominence, the other where the cultural objects support imagination best.

Group	Pattern
I	A-P-C
II	A-C-P
III	C-A-P
IV	C-P-A

Figure 11. Object type patterns

Enactment Conditions: We compared the condition of story enacting with objects with that of enacting without (with

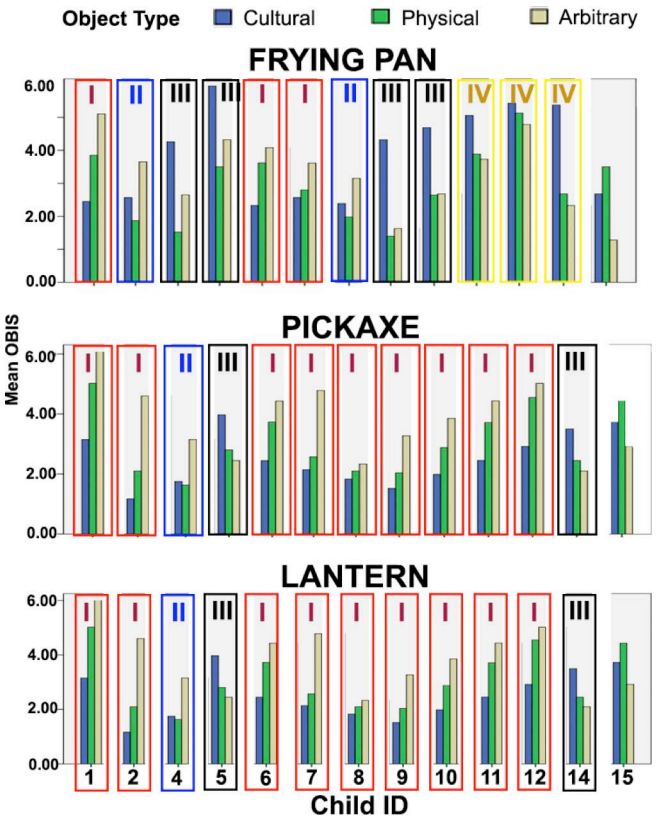

Figure 12. Barcharts of Imagination scores per child

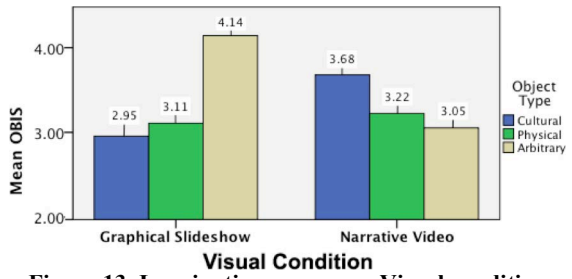

Figure 13. Imagination scores per Visual condition

only the body). The one-way univariate analysis of variance test of enactment conditions on scores of imagination yielded a significant difference, $F_{(1, 10.24)}$, $p < .005$, $\eta = .165$, such that scores for the body-based condition (M = 5.93) were higher than for the object-based condition (M = 3.63). Effects of the personality covariates were non-significant.

Visual Conditions: We compared the use of graphical story illustrations (in slideshow format) with that of a video of a human storyteller as stimulus. There was no significant difference between the two visual conditions on scores of imagination (graphical condition, M = 3.40; narrative video condition, M = 3.32). However, a very interesting observation can be made when imagination scores are classified on visual conditions by object types. As shown in Figure 13, the scores for the slideshow condition *increases* from the cultural to the physical and to the arbitrary object. For the video condition conversely, the scores *decreases* from the cultural to the physical and to the arbitrary object.

DISCUSSION

Our results show a complex picture. From our analysis of the distribution of the different types of micro-actions (MAs) (Figure 10), we observed that there is a clear trend of an *increasing number of object actions and a decreasing number of body actions as the object type becomes more abstract*. The trend repeats for all of the different objects, except for the cultural pickaxe. Based on observations and our interviews with the children, we posit that the cultural pickaxe produced a greater number of object actions and much fewer body actions because of its construction. The pickaxe head was made of a foam material that incited the children to use the object as a 'play object' (e.g. swinging the pickaxe in the air to hear the 'swish' sound) instead of as a task-oriented storytelling support. We suggest that the arbitrary object produces the least number of MAs because it creates an uneasy situation whereby constraints are placed by the presence of an object to be used, but the object does not provide any specific affordances to trigger broader imagination. In contrast, for the physical pan for example, the flat circular head prompted the action of adding condiments in the pan in the child. The body condition, which did not have any object constraints, produced a more equal spread of types of actions, hinting at greater diversity in imagining.

The number and type of vignettes (in Figure 10 (Right)) shows the ability of the child to string together MAs to construct mini-stories throughout their enactment. We observed a trend of *decreasing number of vignettes as the object type becomes less specific* across the pan and pickaxe objects. The trend follows through for the lantern, except for the body condition. It may thus be that the cultural objects support more coherent actions that are less driven by the perceptual cues of the object but more by generated ideas. The specificity of the object frees up cognitive resources for the child to imagine at a higher level (in terms of story bits instead of base actions). What is surprising however is that the body condition generated the highest number of complex vignettes in the pan and pickaxe cases, but the highest number of simple vignettes in the lantern case. There may be two possible reasons for this: it may have been caused by the incidentally high personality scores of the children in the body condition, or by the fact that the lantern is an object with a bucket-like handle whereas both the pan and the pickaxe afford more knife-grip-like handles. We therefore are unable to draw any firm conclusions with regard to that result.

The significant interaction effect of *Object × Object type* suggests that the object type makes a difference in the broader imagination of the child. The imagination scores strengthened our analysis of the enactments by taking into account the consistency of the child's imagination through the drawings and post-interviews. *Broader imagination*

differs significantly across object types, when differences among objects are taken into account.

There were two distinct groups of children in terms of object type patterns: *one driven by the physical affordances of the object* (III and IV in Figure 12) and *one led by the semantic dimension of the object* (I and II). This is in line with Norman's [39] concept that an object can possess both 'real' and 'perceived' affordances at the same time. Real affordances are brought about by the constraints of the physical, tangible object (what is true), whereas perceived affordances are what the user sees as possible with the object. Our finding however is not entirely consistent with the results of McLoyd [24], Elder & Pederson [25] and Pederson et al. [26], who found that more specific objects help young children to imagine better in terms of object substitution and pretend play. This suggests that perception and imagination increase in sophistication as children grow older, allowing them to adapt to circumstances or to adopt particular tendencies. For instance, we observed that the patterns were very consistent within child. It may be that the real or the perceived affordance takes precedence depending on the object and context of use.

With regard to our exploratory investigation of the varying enactment and visual conditions, it seems that children in the body-based condition had far greater broader imagination than those in the object-based condition. Further, it appears that *object type and visual condition may compensate for each other in terms of broader imagination support*. The graphical slideshow can be said to have provided somewhat more specific details to the children, and thus the arbitrary object was sufficient for them to imagine. The narrative video however provided no visual stimuli related to the story at all, and so the cultural object played a much more important role to support the child's imagination. This may be explained by several communication theories such as the media richness theory, and supports Mayer's [40] cognitive theory for learning with multimedia.

The key study findings can be summarized as follows:

- The more specific an object, the fewer the number of object-oriented actions, and the higher the number of complex story vignettes.
- Depending on the child, broader imagination is best supported by objects with either the greatest semantic range or with the greatest structure.
- Enacting with an object may lead to a focus on object-oriented actions at the expense of action diversity in story enactments.
- Enacting without objects may lead to greater broader imagination given the appropriate personality profiles.
- Graphical visual stimuli may compensate for less specific objects to support broader imagination in the child.

These have significant implications for the design of physical objects in creativity-support systems, more specifically for the essential activity of storytelling, for children throughout the Fourth-grade Slump period.

LIMITATIONS

We present the findings of our study with a few limitations in mind. First, although we were able to draw strong conclusions for object types, the sample size used was too small to enable us to draw firm conclusions with regard to the enactment and visual conditions. Second, although we were careful to moderate collected data with personality and performance indicators from those who know the children best (i.e. parents and teachers), it is still possible for conclusions from studies with different samples to show some variance. Because of the complexity of the question, it warrants further study. Third, since we were unable to find any measures of imagination that suited our purpose, we generated broader imagination scores from in-depth analysis and coding of three different data sources. We acknowledge that the assessment, while still highly valid, was partly interpretive in nature. This also shows that the evaluation of imagination is a rich field of study that has yet to be resolved.

CONCLUSION

This paper investigates the relationship between physicality and imagination in the context of storytelling. It satisfies the goal of contributing to an empirical basis for the design of embodied systems to nurture creativity in children throughout the Fourth-grade Slump. We manipulate the specificity of objects on three levels to determine how each support broader imagination. Effects of object affordances present a very complex picture. Interest in the empirical study of imagination seems to have lessened in recent years. Although our work contributes significantly to this important area of human higher thought, much remains to be investigated.

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