Embodied Metaphor Elicitation Through Augmented-Reality Game Design

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ABSTRACT
In this paper we present our experience of eliciting metaphors through the process of game design with children. For the purpose of determining a set of user interactions desired in children's augmented-reality experiences, we have conducted a study in which children used craft materials to design augmented-reality games. Game interactions and mappings between physical and virtual worlds were then analyzed to reveal metaphors in children's thinking. We describe the wide range of elicited metaphors, and argue for the use of game design as a process for metaphor elicitation.

Categories and Subject Descriptors
H.5.1 [INFORMATION INTERFACES AND PRESENTATION (e.g., HCI)]: Multimedia Information Systems — Artificial, augmented, and virtual realities; K.8.0 [PERSONAL COMPUTING]: General- Games.

General Terms
Design, Experimentation, Human Factors.

Keywords
Embodied cognition, metaphors, game design, children, augmented-reality, mixed-reality.

1. Introduction
We approach cognition from the view of embodiment, adhering to the philosophy that human thought is grounded in the body and its interaction with the external environment. Through this view, we assume that some cognitive schemata are developed from gestalts of physical experience, which Johnson [1] calls *image schemata*. We use the term *metaphor* to refer to similarity relationships between mental concepts (ex: "the mind is a machine" [2]), and specifically *embodied metaphor* to refer to relationships between a concept and an embodied schema (ex: "happy is up" [2]).

Embodied metaphors are believed to underlie aspects of human cognition [2], but they are difficult to elicit from children, since children may not be conscious of them [3]. Various methods have been presented for eliciting metaphors: asking experts is one method [3], another method is to ask children to act out concepts by using their body [4], and another is to interview children directly [8]. In this paper, we present the use of game design as a process of eliciting metaphors for augmented-reality (AR) interactions. We are interested in studying the relationship between metaphor and user interactions in augmented-reality environments, for several reasons. First, interaction with an AR interface requires the user to understand the relationship between physical actions and virtual reactions; thus, it is important to understand what metaphors children are familiar with, in order to create understandable interaction metaphors. Second, the physicality of the AR interface can allow the use of interaction metaphors that leverage embodied schemas, potentially revealing or enhancing a user's embodied knowledge; thus it is important to understand how embodied knowledge is present in AR interactions.

In this paper, we present the results of a user study of children generating games using arts-and-crafts materials. The study analyses children's proposed couplings between physical and virtual game content, and discusses how this creative process reveals children's understanding of metaphors.

2. User Study
We conducted a user study to investigate what kinds of interactions are desired by children when playing in augmented-reality experiences. The study involved the AR SPOT system [5], which is a children's tool for authoring augmented-reality experiences, based on the Scratch programming environment. A primary aim of the user study was to determine how children would like to interact with the augmented-reality games they create. Peripherally, we were interested to understand why the interactions made sense to children, and to identify how knowledge of the physical world is transferred in children's expectations of augmented-reality (AR) experiences.

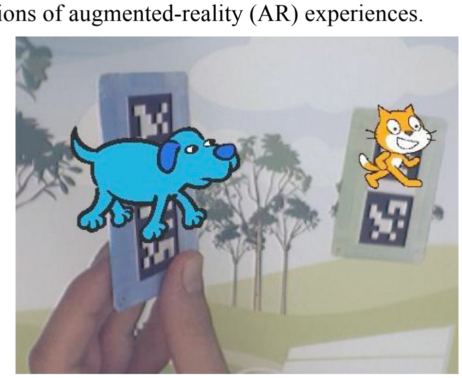

Figure 1. The augmented-reality view of a SPOT game, showing a virtual dog and cat overlaid on the physical blue and green playing cards (from [5]).

In the SPOT system (shown in Figure 1), children program the behaviors of virtual sprites (2D graphical entities appearing on a computer screen), which respond to the movement of physical cards. User's physical motions can be directly or indirectly coupled to the behavior of virtual actors. An example of direct coupling is a virtual dog being carried by the physical card; while an indirect coupling is the dog's size being changed by the rotation of the physical card.

The study was conducted with a classroom of grade 5 students (12 students in total, ages 11-12 years), which had previous experience with Scratch, but had never seen the AR system. The study lasted 45 minutes, and consisted of three phases.

First, the SPOT environment was presented; during this phase, children were exposed to interactive examples of AR experiences created with the tool. The examples were not complete games, but instead were simple prototypes, intended to give children a sample of interactions that could be programmed with the SPOT environment. The examples typically showed the physical cards connected to virtual game sprites through literal representations and actions (ex: a raindrop carried on the physical card slipped off when the card was tilted); some of the examples were more abstract, where actions performed on the physical cards did not have an intuitive effect in the virtual world (ex: the color of a virtual circle was changed when two cards were brought close together). The examples showed a very small subset of potential interactions that can be programmed through the system, and were presented only as samples of different possibilities for connecting game content to physical actions.

In the second phase, children were paired in 6 groups, and tasked with generating potential ideas for AR games that they would like to see build using the system. Each group was provided with a set of physical cards that they could use for controlling their game, a set of images that would make the elements of their game (people, animals, pencils, fruits, geometric shapes, etc), and craft materials that would be used to build a paper presentation of the game (colored pencils, scissors, glue). Children were free to design any kind of game they desired, using any kind of interaction they envisioned, and the only constraint was that at least one of the physical cards should be used to control the virtual game content. During this game design phase, the groups of children appeared to have much fun working independently, and were able to craft games without significant facilitator involvement.

Finally, each group of children presented their game idea to their classmates through a show-and-tell session. The presentations were video recorded and used as data for the present analysis.

3. Metaphors Elicited

Each pair of children created one game, in which the movement of the physical cards served as input to the game. A total of 6 games were produced, spanning a range of game themes and interaction mechanics. By qualitatively analyzing the couplings between physical and virtual worlds, some aspects of these children's metaphorical knowledge can be revealed. Table 1 lists the variety of interaction metaphors generated by the children in this study.

Moving physical cards was the input mechanism for all games. With exception of one game, the majority of games were "concrete", involving realistic objects performing physical interactions. In these games, the player controlled a virtual actor that had to collect and/or avoid other entities (as example, in one game, the player controlled a virtual dragon and gained points by moving the dragon to virtual food). In the one "abstract" game, virtual characters were not used, as this game resembled the Breakout game where the player controls a virtual paddle that bounces balls toward a wall.

Observing the mappings created in children's games can lead us to speculate about what knowledge schemas children employ when experiencing mixed-reality applications. As in [6], children in our study frequently leveraged physical phenomena such as collisions and gravity. This unsurprisingly indicates that when using the body to directly control an interface, children appeal to previous knowledge of interacting with physical objects. In some cases, children associated tilting motions with directing the virtual actor to move or fire in a specific direction. This may indicate that children used knowledge of "pointing" in a direction of interest; or, that children may be leveraging knowledge of video-game controllers. In one game, children associated the motion of rotating a card with changing musical timbre; in this case, the children may be employing the metaphor "card is like a radio control knob", using previous experience with knobs in audio devices. Embodied metaphors may have been revealed through two instances in our study. In one, a child suggested coupling sound volume to the distance between a card and the computer's camera. This may indicate a metaphorical connection between to the CLOSE-FAR schema; or, this connection between volume and closeness came from experiences with physical sound sources, as bringing a squeaking toy closer makes it sound louder (such experiences can also function as origins of the embodied metaphor). In the second instance, children coupled the rotation of a card to the speed of their game. This interaction may have been chosen simply because children employed knowledge of rotating volume-control knobs, indicating that children metaphorically understand "speed as volume". Or, the observed interaction may connect to an embodied schema related to rotating objects with the body: rotating a card may be related to twisting an object (such as a water tap, arm, or branch), and can be seen as increasing strain, connecting to a STRAIN-UNSTRAIN schema.

Table 1. Mappings between physical and virtual actions in children's games. Italics indicate the use of metaphor or embodied schema.

Physical Action	**Virtual Action**	**Knowledge / *Metaphor***
Card moves (3D)	Actor moves (2D)	Carrying physical objects
Card moves (3D)	Actor moves (1D)	Dragging physical objects
Card moves closer to user's view	Actor volume increases	Moving toward sound sources OR *CLOSE-FAR schema*
Card is tilted / shaken	Actor/object falls off	Dropping physical objects
Card is popped	Actor jumps	Throwing physical objects
Card moves, touching a physical or virtual object	Actor/object collides and / or is hurt	Colliding physical objects
Card is tilted	Actor moves in direction of tilt	*Card is like a game console controller* OR *Card is Pointer*
Card is tilted	Actor fires in direction of tilt	*Card is like a game console controller* OR *Card is Pointer*
Card is rotated	Game speed increases	*Card is like a volume control knob* OR *STRAIN-UNSTRAIN schema*
Card is rotated	Musical object changes timbre	*Card is like a radio control knob*

We have found Fishkin's taxonomy [7] to be useful in classifying observed couplings. The taxonomy considers two dimensions of tangible interactions: physical distance between input and output, and the match between representation and action in the physical and virtual worlds. From the observed children's games, we note that interactions that are literal and tightly coupled in terms of input/output distance (eg: carrying a virtual actor on a physical card and tilting to cause the actor to fall) do not reveal metaphors since they directly mimic the physical world.

Further, we observe that children frequently decided to create experiences with literal elements, thus yielding a limited amount of metaphors. It is possible for AR games to contain more abstract metaphors, as presented in Table 2, and it is likely that such metaphors may have emerged if the game design activity was less open ended.

4. Activity Constraints

Our analysis indicates that children make use of a variety of metaphors when interacting in AR games, and it is plausible that designers can leverage this aspect in understanding intuitive interaction mappings. By further constraining the game generation task, it is possible to investigate various facets of children's metaphorical thinking:

Constraining the game theme or game elements can lead children to create experiences where interaction metaphors relate to specific concepts. For instance, asking children to create AR games where music is generated may lead to embodied metaphors similar to those found in [4]; similarly, asking children to use game elements which represent numbers or functions may lead to metaphors employed in mathematical thought.

Table 2. Examples of other possible metaphors and their AR interaction mappings.

Metaphor	Virtual Action	Physical Action
The mind is a container	Virtual "thoughts" are put in / out of a virtual mind	Physical card moves in/out of a virtual area
Happiness is a substance	Virtual "happiness" is poured out of a container on people	Physical card tilts the virtual container
Love is a force	Virtual boys are attracted to a girl like magnets	Physical card moves the virtual girl
Grades (ex: "C", "D") are objects	Virtual grade objects are blocked from falling on a test	Physical card movement blocks the virtual grades
Pitch is upward movement	Pitch of a virtual instrument increases / decreases	Physical card moves up / down
Power is active movement	Power of a virtual gun increases	Physical card carrying gun is shaken

Constraining the types of user interactions in the game can cause children to reveal specific embodied schema. For instance, telling children that a game can only detect actions of "shaking" will lead children to control games by shaking motions – for example, mapping a shaking motion to making a character flap its wings, making a music instrument play louder, or causing a paintbrush to draw more colors; these could indicate metaphorical mappings between "body activity" and concepts like "flight", "volume", and "colorfulness".

Changing the craft materials and/or game technology may also cause children to explore different kinds of mappings. For instance, providing 3D objects instead of 2D cards for the craft activity would cause children to more readily explore the embodied schemas of ABOVE-BELOW, IN-OUT and AHEAD-BEHIND. The representations of the craft materials may also influence the metaphors created – if children are provided with abstract 2D shapes to use as controllers in their game (such as geometric shapes rather than concrete objects), they may be biased to design more abstract games such as Tetris. Changing the game technology will also cause children to explore other kinds of metaphorical mappings – for instance, a game which reacts to temperature may reveal children's use of a HOT-COLD schema; technologies where the whole body can be used may reveal metaphorical mappings to a BENT-STRAIGHT schema, etc.

5. Conclusion

The activity of game design through arts-and-crafts materials can be used an enjoyable method for investigating children's metaphorical thinking. We have conducted as a study where children used craft materials to brainstorm augmented-reality games. Through our analysis of physical-virtual interaction couplings, we have identified several metaphors present in children's thinking. In future work, we will investigate if manipulations of the game-design task activity can be used to highlight more specific aspects of metaphorical thinking.

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