Eliciting Embodied Metaphors 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. This paper describes the metaphors elicited, and argues for the use of game design as a process for metaphor elicitation.

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, and which we will refer to as embodied schemata. Further, 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 difficult to elicit from children, since children may not be conscious of them [3]. One method of eliciting such metaphors is to ask experts [3], while another method is to ask children to act out concepts by using their body [4]. In this paper, we present the use of game design as a process of eliciting metaphors. We are interested in studying the relationship between metaphor and user interactions in mixed-reality environments, as we believe that metaphors are invoked when a coupling between the physical and virtual worlds “makes sense” to users. Generating interactions in mixed-reality environments through game design may thus be a fun method for revealing metaphorical thinking.

User Study
We conducted a user study to study what kinds of interactions are desired by children when playing in augmented-reality experiences. This study was part of the development of the 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. In the SPOT system, children program the behaviors of virtual sprites (2D graphical entities appearing on a computer screen), which can respond to the movement of physical cards. The cards are flat physical objects whose position, distance to the screen, collision, rotation and tilt can be sensed in the game (Figure 1).

Method: 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. Examples typically used the physical cards to move virtual sprites that used literal representations and actions (ex: a raindrop carried on the physical card slipped off when the card was tilted); some of the examples were 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). In the second phase, children were paired in 6 groups, and tasked with generating potential ideas for AR games. Each group was provided with a set of physical cards which they would use for controlling the game, a set of images which would make the elements of their game (people, animals, pencils, fruits, geometric shapes, etc), and craft materials which would be used to build a paper presentation of the game (colored pencils, scissors, glue). Finally, children presented their game ideas to their classmates through a show-and-tell session.

Results and Discussion:
Each group of children created one game. Moving physical cards was the control mechanism for all games. In all games but one, the player controlled a virtual actor which had to collect and/or avoid other entities. (For example in one game, the player controlled a virtual dragon and gained points by touching the dragon to virtual food). Virtual actors were not used in one game, which resembled the Breakout game where the player controls a virtual paddle that bounces balls toward a wall. The children’s games employed a variety of interactions, coupling actions in the real world with actions in the virtual world. These mappings, along with knowledge that may have been employed in making the mappings, are shown in Table 1.

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

Table 1. Mappings between physical and virtual actions in children’s games. Italics indicate use of metaphor or embodied schema.
Observing the mappings created in children’s games can lead us to speculate about what knowledge children employ when experiencing mixed-reality applications, and can potentially reveal embodied schemas in children’s thinking. We caution that knowledge related to each mapping is hypothetical and has been generated by the researchers’ intuition.

Children frequently decided to simulate physical phenomena such as linkage, collision and gravity (e.g., carrying a virtual object on the physical card, then tilting the card to drop it). This unsurprisingly indicates that when using the body to directly control an interface, children frequently 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 using the metaphor of “physical card is a game-console controller” (since in some TV-console systems, the user tilts joysticks to control the game). 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 interaction, a child has suggested coupling sound volume to the distance between a card and the computer’s camera. This may indicate a metaphorical connection between the concept of volume and the CLOSE-FAR schema; or, this connection between volume and closer comes 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 experienced as increasing strain, showing a connection between game speed and the schema of STRAIN-UNSTRAIN.

We have found Fishkin’s taxonomy [6] to be useful in classifying the observed couplings. The taxonomy considers two dimensions of tangible interactions: the physical distance between physical input and virtual output, and the match between representation and action in the physical and virtual worlds. We find that interactions that are literal and are tightly coupled in terms of input/output distance (e.g., 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. In the produced games, children frequently decided to create experiences with literal elements, thus yielding a limited amount of metaphors. Table 2 gives some examples of other metaphors that could have been created, along with possible interaction mappings.

Further Elicitation through Game Design
Several aspects of the game design activity may be changed to reveal metaphors on specific topics. 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>
<thead>
<tr>
<th>Metaphor</th>
<th>Virtual Action</th>
<th>Physical Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>The mind is a container</td>
<td>Virtual &quot;thoughts&quot; are put in / out of a virtual mind</td>
<td>Physical card moves in/out of a virtual area</td>
</tr>
<tr>
<td>Happiness is a substance</td>
<td>Virtual &quot;happiness&quot; is poured out of a container on people</td>
<td>Physical card tilts the virtual container</td>
</tr>
<tr>
<td>Love is a force</td>
<td>Virtual boys are attracted to a girl like magnets</td>
<td>Physical card moves the virtual girl</td>
</tr>
<tr>
<td>Grades (ex: &quot;C&quot;, &quot;D&quot;) are objects</td>
<td>Virtual grade objects are blocked from falling on a test</td>
<td>Physical card movement blocks the virtual grades</td>
</tr>
<tr>
<td>Pitch is upward movement</td>
<td>Pitch of a virtual instrument increases / decreases</td>
<td>Physical card moves up / down</td>
</tr>
<tr>
<td>Power is active movement</td>
<td>Power of a virtual gun increases</td>
<td>Physical card carrying gun is shaken</td>
</tr>
</tbody>
</table>

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

Conversely, **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".

Finally, **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 potentially cause children to 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 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.

**References**