Visualizing the Positive and Negative Affordances in the Home Environment During the First Year of Life Using Augmented Reality

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Abstract

This study sheds light on J. J. Gibson's theory of "affordances" by presenting a competent visualization of how infants perceive and act in their everyday home environments, with the aim of preventing accidents and promoting development. Gibson described affordance as a unification of an environment's action-relevant properties and an animal's way of life. To visualize infants' affordances in their natural settings, this study adopted Augmented Reality (AR) technology, which enhances a user's perceptions of and interactions with his/her real environment. In this study, we developed an AR application for iPads and iPhones. We conducted longitudinal observations of two infants from 4 to 12 months of age at their homes in Tokyo, Japan. The findings of these observations revealed 10 typical objects that appeared most frequently among the everyday items found in people's homes. Those objects were assigned to vision-based markers in order of the actor's age and were incorporated into the application. This AR application prototype system was implemented in two ways: (a) Objective-C and OpenCV and (b) openFrameworks and Vuforia. Our informal user study showed that (a) was more suitable regarding recognition time. However, (b) was much broader in terms of the interface design.

Keywords: affordance; visualization; infants; everyday environment; augmented reality

Introduction

Affordance is a fact in the environment as well as a fact embodied by the act. The ecological psychologist James Gibson proposed the theory of affordance referring to the mutuality of animal and environment. The most familiar living environment is a "home," which includes various affordances. The process of perceiving affordances is not the same for all people sharing the same space and objects as others' bodily features differ from ours. Still more, an infant differs from an adult.

Most studies have examined the affordances for infants outside of their homes, either outdoors or in a laboratory setting (Adolph, 2008; Adolph & Eppler, 1998; Broberg, 2013; Gibson, 2000; Heft, 1988, 1997; Kyttä, 2002, 2004). Even though many different approaches have been proposed, concrete problem analysis and corrective strategies for use in everyday environments have not been fully clarified. Furthermore, according to Gibson (1979), environmental affordances are what it offers the animal, what it provides or furnishes, either for good or ill. To correct this, the current study proposes a novel approach to preventing accidents and promoting infant development based on the theory of affordances, which unites our understanding of action, awareness, and knowledge between the self and the environment.

Empirical research concerning individual affordance has been advanced based on a series of pioneering studies by Adolph (1995), Gibson and Walk (1960), Stofferegen (2000), Turvey (1992), Warren (1984), etc. However, generalization methods have not been thoroughly established (Gaver, 1993a, 1993b; Mark, 1995; Mark et al., 1997; Warren & Whang, 1987). In particular, little is known about natural settings, such as the "home."

In this study, we explored the suitable method for an everyday home environment in order to better visualize infants' developmental resources. Technology that enables the visualization of our environments has remarkable current real-world applications. First developed over 40 years ago, Augmented Reality (AR) is one such technology that enables the seamless merging of virtual content with the real world (Azuma, Billinghurst, & Klinker, 2011). AR enhances a user's perceptions of and interactions with the real world (Azuma, 1997; Carmigniani & Furht, 2011). Furthermore, developing this technology to work with mobile devices is one of the biggest and fastest growing relevant AR research areas (Azuma, Billinghurst, & Klinker, 2011; Wagner & Schmalstieg, 2009). While mobile AR has become commonplace, there is a need for more research into how to adapt this technology to our fundamental experiences.

Therefore, the purpose of this study was twofold: 1) to present an analysis of the affordances of infants' home environments based on longitudinal observations during the first year of life and 2) to propose a new way of visualizing infants' affordances by creating an AR mobile application prototype for iPhones and iPads to provide parents and surrounding adults with better understanding.

Methods

Observation

The longitudinal observations were conducted with two healthy male Japanese babies, who were observed in their homes during the first 18 months of their lives. Each family used a digital video camera to record their baby's actions at their home on a weekly basis. This application focused on data collected between 4 to 12 months of age (the total recorded time was 75 h).

Design and Development

(1) Paper prototypes. (2) Designing the app using Adobe Illustrator CS6, Photoshop CS6, and Shade. (3) Designing the marker recognition using OpenCV and Vuforia. (4) Writing an iOS application using Objective-C. GUI and user interactions were developed using Objective-C.

Augmented Reality Movies (1) All Augmented Reality movies were based on the longitudinal observations of two babies. (2) Hand line drawings that were created based on the recordings were converted to digital data using Photoshop and Lightroom. They were saved as 448 px × 336 px images. The sequences were animated in Photoshop using the Animation Timeline and were exported as QuickTime Movies. Figure 1 shows the example of an infant interacting with a cabinet at age 11 months, 17 days.

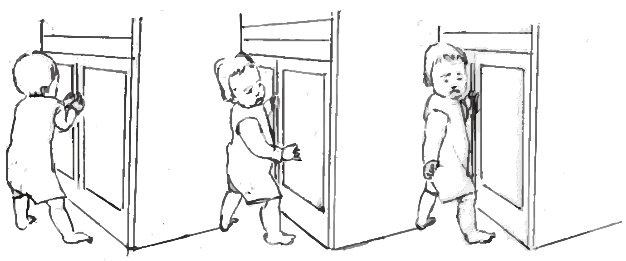

Figure 1: Example of line drawings of a cabinet.

Results

This study proposed an AR application prototype for iPhones and iPads capable of visualizing the affordances of infants' indoor environments during the first year of life. On the basis of these observations, we extracted objects. According to Gibson's classification of objects, we divided them into two patterns: detached and attached objects related to the home's room layouts (Table 1).

Table 1: Classification of detached and attached objects in the home.

OBJECTS	CATEGORY	NAME
Detached objects	Furniture	Bed, sofa, table, dining table, low table, desk, kotatsu, chair (high chair, car seat, highchair reclining), stove, TV, refrigerator, cabinets, closet, cupboard, etc.
	Necessities	Diapers, tissue paper, plastic bags, cloth, mirror, fan, matt, magazine, flyer, vacuum cleaner, cleaner,thong, clothes hanger, thermos, phone, flashlight, PC, keyboard, cart, towel, mat, cushion, carpet, duvet, duvet, mattres, sheets, mattress, clothing, washing, slippers, pillow, remote controller, garbage can, ballpoint pen, ruler, cup, bowl, water bottle, spoon, fork, plate, food（milk, baby food, rice crackers, bolo）book, newspaper, toy box, case, cardboard box, watering pots, paper, tripod, camera, tea, chopsticks, piano, etc.
	Toys	rattle, bib, roly-poly, self-righting doll, finger puppet, duck, merry-go-around, play gym, jolly jumper, ball, candy, building blocks, stuffed animals, etc.
Attached objects	Enclosures/ Corners	wall, fence, tub, pool, sink, Japanese closet, boat, etc.
	Aperture	door (sliding door, hinged door), screen door, window, curtain, bamboo screen, paper sliding screen, etc.
	Steps	steps, threshold, etc.
	Concave-Convex	ceiling light, tap, electrical outlet, knob,

In this prototype, 10 objects—a bathtub, cabinet, chair, cushion, door, futon, sofa, table, threshold, and wall—were extracted as the most frequently found everyday things in the infants' homes. Based on the longitudinal observation, infants' perceptions and actions toward these 10 objects were observed and included not only positive developmental possibilities but also risks of troubles—positive and negative affordances for infants in the home. Concrete examples of those affordances are described in Table 2. These descriptions were embedded in the application as reference for the app's users. The users were able to learn about a home's contents according to three categories: plan of room layout, attached objects, and detached objects. Figure 2 is an example of a detached object. The user can tap to select a category and items, and pop-up windows show the properties of the object for infants. The user can then tap the window's close button or swipe icons to see the next items.

Table 2: Brief descriptions of the positive and negative affordances of detached and attached objects.

OBJECTS	NAME	AGE	DESCRIPTION
Detached objects	Cabinet	9 months~	One of the most useful furniture to stand up or walk after 9 months. Around from 11 months after the birth, babies get to be interested in the inside box of the cabinet.
	Chair	4 months~	Chairs for babies are used from 4 months. Normal chair mainly used for assisting to walk, not sit around 12 months.
	Cushion	4 months~	Around 4 months, cushions are most effective objects to support baby's posture and prevent to fall. According to the development of locomotion, block baby's path or become to be an obstacle.
	Futon (Japanese mattress)	0 months~	Futons are designed to be placed on tatami flooring, and are traditionally folded away and stored in a closet.The thickness of the futons are suitable for a baby's learning rolling over from 4months.After 12 months, futon used to play because of its soft and flat surface.
	Sofa	4 months~	For ages 4 months and up. One of the most useful furniture to sit, stand, and walk. Sofa's soft edges and dents are suitable for support to maintain posture.
	Table	9 months~	For ages 9 months and up. Around from 12 months, a table is mainly used for a meal.
Attached objects	Bathtub	4 months~	Around 5 months, bathtub support to reach surroundings in front of the baby's eye easily. Water is also helping to move forward in the 8 months before walking.
	Door	10 months~	For ages 10 months and up. A gap between the door and wall attracted the attention of infants. Around from 11 months, the door is openable and closable.
	Threshold	5 months~/ 7 months~	Reflected room layout and style of house. Threshold divided room to room and make a occlusion and new vistas with locomotion around 7 months and up.
	Wall	5 months~	For ages 5 months and up. Walls assist locomotion including rolling over.

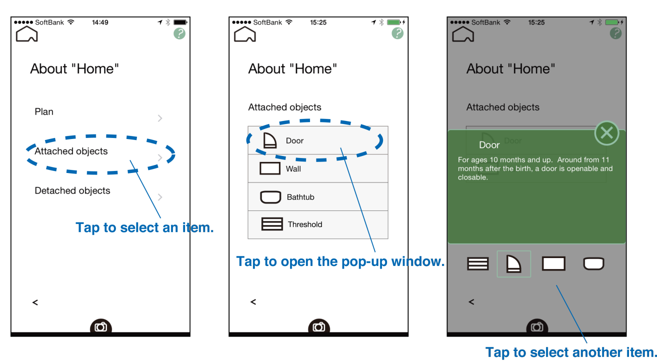

Figure 2: Example of the AR mobile application's views of an attached object.

Regarding marker recognition, two types of pattern-marker codes (Figures 3 (a) and 3 (b)) were created. Figure 3 (a) was made by combining dots and objects' icons using OpenCV. Figure 3 (b) was made using textures and objects' icons using OpenCV. The textures reflected the objects' features.

The AR system recognizes these markers' codes from the captured camera images. Both could be attached to real-world objects at virtually no cost since the marker codes can be printed using laser or inkjet printers.

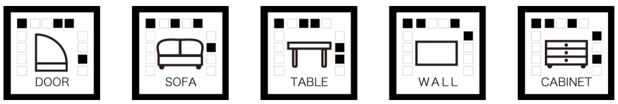

Figure 3 (a): Examples of AR markers. Dot and icon by OpenCV.

Figure 3 (b): Examples of AR markers. Texture and icon by Vuforia.

Overview

Figure 4 introduces the overall information flow of the system. The user begins by setting an arbitrary place marker on the real objects in the real situation. After starting the AR application, the user can capture the marker with his/her device camera. As soon as the camera recognizes the marker, the user can select the age of the actor. Then, the AR movie starts to play (Figure 5).

Each marker includes several AR movies based on 4–12-month-old babies' actions toward the object. Each movie is color-coded according to the actor's age. By selecting both object and age, the user is able to discern the differences in the infants' developmental processes. The application enables the user to simulate infants' affordances toward various objects in their own environments.

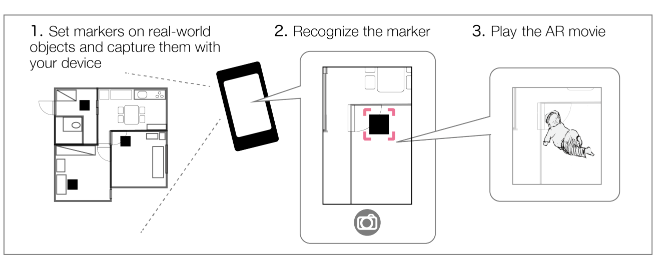

Figure 4: Overview of the AR mobile application prototype.

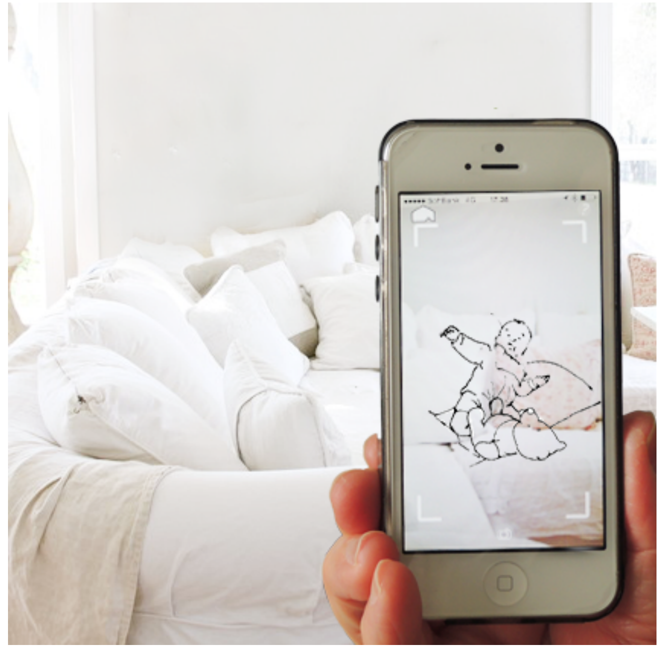

Figure 5: Example of AR animation of an infant (age 7 months, 12 days) with a cushion.

User Experience

Informal user observations formed the basis for this prototype. These observations indicated that marker recognition time is one of the most effective points to use in the prototype development. We measured the velocities of recognition time to compare two types of AR markers under two lighting conditions: (A) fluorescent light and (B) flat surface fluorescent light.

Tables 3 (A) and 3 (B) show the rate of change of velocity related to the illuminance of the surface (vertical and horizontal directions) and the distance between marker and device, in addition to the verified accuracy of marker recognition via an illuminance meter. The findings revealed differences between (A) and (B) of more than 30 cm. In the case of the flat surface fluorescent light, the differences depended on the surface direction (Table 3 (B)). On the whole, (B) shows relatively unstable properties and more effects of the surroundings than does (A).

Table 3 (A): Fluorescent light (FPL36EX-N, 4 tube × 20, 2900lm/tube.

type of marker	surface	lx	20cm	30cm	40cm
(a)	vertical	289	3 s	4–5 s	3 s
	horizontal	330	3 s	4–5 s	3 s
(b)	vertical	290	5 s	×	×
	horizontal	300	5 s	×	×

Table 3 (B): Flat surface fluorescent light (ELF-554P, 4 tube x 1, F55bx/Studiobiax32, 4,100lm, 3,200K.

type of marker	surface	lx	20cm	30cm	40cm
(a)	vertical	916	3–7 s	4 s	3 s
	horizontal	865	2 s	2 s	3 s
	vertical	427	4–5 s	4 s	4–6 s
	horizontal	330	1–2 s	1–2 s	1–2 s
	vertical	57.5	3 s	3–5 s	3 s
	horizontal	53	2–3 s	2–3 s	3 s
(b)	vertical	916	5 s	×	×
	horizontal	865	8 s	×	×
	vertical	427	3 s	×	×
	horizontal	330	3 s	×	×
	vertical	57.5	5 s	×	×
	horizontal	53	3 s	×	×

Discussion

With this AR application prototype, users could put markers on real objects anywhere there is adequate space to paste them. This would make it possible to expand user experience by increasing understanding of infants' actions.

The first years of life are filled with positive and negative affordances that enable infants to develop. These affordances could be changed according to age, motor skills, or object layout. This AR application prototype provides an opportunity to examine the relationship between infants and their environments and to learn from it. Additionally, it allows a more precise look at what may lead to accidents within the app users' own home environments. Moreover, the prototype displays resources that may aid development in the long run.

The target users of this application are not limited to young parents. Its popularity is expected to spread into the educational, design, and cognitive science fields from the context of ecological psychology.

From a usability perspective, 1) the application's UI/UX aimed simple graphic design and standard gestures (tap and swipe) functionality. The way of providing notification of risk information and tips for development continues to improve. 2) A marker-based system would currently be more suitable for users in a variety of situations. It will also be necessary to gather more data in the near future concerning children's actions by sharing this prototype. The goal is to create an AR application global composition system that will allow users worldwide to capture augmented information about real, everyday objects (furniture, door, steps, etc.) in their surroundings without any markers.

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