Material Significance of Tangibles for Young Children

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ABSTRACT
The purpose of this paper is to investigate how young children associate materiality and meanings and how it can benefit tangible interaction design. To study this, we developed a research prototype, *Stampies* that allows playful tangible interactions. *Stampies* consists of tangible objects made out of different materials (wood, felt, silicone, and plastic) and an iPad drawing application. We describe results from our empirical study involving 19 children aged 4 to 7. The study indicates that children associate materials with meanings through "material essences", feel, and tactile preference. We conclude with design implications for tangible interaction for children.

Author Keywords
Materiality; Meaning; Children; Touch screens

ACM Classification Keywords
H.5.2. User Interfaces: Interaction Styles.

INTRODUCTION
In 2008, Ishii [5] proposed the idea of the 'tangible bits' and articulated a model for its utility to user interfaces, arguing that TUIs (tangible user interfaces) serve the function of making "digital information directly manipulatable with our hands, and perceptible through our peripheral senses by physically embodying it". Since then, a large number of research projects have looked at exploiting physicality for purposes of education and learning, information visualization, entertainment, social communication, performance, etc. [14], especially for applications targeted at young children (e.g., [2, 6, 12, 19]). Commercial toy products as well, like *Skylanders* [1] and *Invizimals* [15], and educational applications, like *Tiggly* [7] and *Fisher Price Stamp On* [4], have expanded digital experiences into the physical realm.

However, a 'tangible bit' does not present only the affordance of its mere persistence and physicality, but brings with it a range of material properties (e.g., size, shape, texture, temperature, weight) that can be associated with digital representations to convey information [8] and to create personal meanings. TUIs provide immediate tactile feedback to the user, potentially facilitating or reinforcing the uptake of the digital representations.

We investigate how the materiality of objects is perceived by young children, and how it can benefit their digital interactions. This paper first presents an overview of arguments for the association of materiality and meaning, and then describe a study with children aged 4 to 7 to explore the issue using a digital drawing application that is coupled with physical '*stampies'* as our testbed.

MATERIALITY AND MEANING
The significance of materiality to thinking has been advanced by such philosophers as Merleau-Ponty and Gibson, who conceived of perception *as* behavior [13]. Gibson's notion of affordances, through Norman's [10] reframing of the concept, has been used extensively in HCI to guide user actions and understanding. We posit that the influence of materiality is particularly prominent for children.

Studying project work of 37 children aged 8 to 11, Ormerod and Ivanic [11] describe how they made use of physical characteristics of objects in their meaning-making practices, for example embedding broken egg shells and feathers in a project on birds. Vygotsky's [17] studies with toddlers demonstrated the importance of object iconicity in their cognition: the children could not think of a toy model of a bench as a bench if the model was placed upside down, or a bucket had to be drawn as such ∪ for the child to be able to identify its representation (for the child, ∩ cannot be a bucket). In a study on how play objects affect imaginative play in 3½ to 5 year-olds, McLoyd [9] found that high structure objects (objects whose "identity and functions ... most preschoolers are aware of", e.g., dolls, trucks) significantly generated more pretend play themes than low-structure objects (objects that were "less specific and unique", e.g., boxes, pipes).

While these studies investigate the shape and form of artifacts with children, 'graspable media' (using Ishii's term [5]) is multi-dimensional. In a survey of material-centered interaction design research, Wiberg [18] defines four interrelated levels of analysis that have been adopted to understand materiality: at the level of *materials*, attention is paid to the particular material properties (what is it made of?) and character (what can it be used for?) of the object. At the level of *details*, one looks at the aesthetics and quality of the object. At the level of *texture*, one studies how material properties are communicated through the material surface

TEI '15, January 15–19, 2015, Stanford, California, USA.
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http://dx.doi.org/10.1145/2677199.2680583

and appearance. And at the level of *wholeness*, the overall composition and holistic meaning conveyed come into play.

Thus the study of materiality moves back and forth between the micro and the macro. We are precisely interested to understand the relationship between the two, and whether the association can be extrapolated into digital interactions to benefit a child's learning or creativity with technology. In other words, 1) can the micro-level characteristics (material properties and texture) of an object intrinsically convey meaning to a child?; and 2) does the association of the object (based on its micro-level properties) with particular meanings help the child in digital interactions?

Cognitive load theory [16] may help to explain why exploiting micro-level properties of tangible objects in interaction design may improve performance. Given our limited working memory, minimizing the load on memory may facilitate the extension of thinking at higher levels. Designing tangible objects with specific material properties supports the use of existing schemas that we have of things in our environments (e.g., a desk is made of wood, a plushy toy is soft, etc.) to ease the memory load by facilitating dynamic reassociation. Although there has been significant theoretical work on the issue of materiality and meaning, little work can be found that presents empirical support for its relevance to interaction design.

STUDY TESTBED

To study how children associate different material types (e.g., wood and felt) with meaningful digital content (e.g., graphical representations of familiar objects like clothing and toys) we needed a flexible system that allows for playful interaction by young children, and that features: i) tangible objects whose materiality can be manipulated; ii) a graphical digital application, whose content can be manipulated; and iii) a way to manipulate the association of the graphical content and the tangible objects. Our design took the form of a stamping tool for toddlers that we modeled after the shape of the '*stampies'* objects used in the color-matching prototype developed by Arita et al. [3].

Stampies are objects with a simple standard shape that can be fabricated using different materials (see Figure 2). The bottom of each *stampie* is adorned with a unique pattern of conductive fabric that can be detected as touch patterns by a standard iPad touch screen (see Figure 3). Conductive threads or copper tapes connect this pattern to the upper area of the object, allowing a connection between the screen and the user's hand when it is grasped. The iPad application presents the child with a grid of graphical objects, and allows her to associate a *stampie* with each displayed object by placing the *stampie* over the object in the grid (see Figure 1). Once associations are made, the child is presented with a blank canvas into which she can 'stamp' graphical objects by applying their associated *stampies* to the iPad screen. The child can also 'paint' with the *stampie* by dragging it over the iPad screen, leaving a trail of the concomitant graphical objects.

STUDY MATERIALS AND DESIGN

For the purpose of our study, we created 2 sets of *stampies,* each set with one *stampie* made out of a different type of material (wood, felt, silicone, and plastic). Three types of meaningful digital content were chosen to be tested in the iPad application: colors, colored familiar items, and line-drawn familiar items (Figure 1). Six colors and 16 familiar items (representative of 4 categories with 4 items in each) were used in the study. Table 1 shows the colors, item categories and the representative items used.

For the testing of colors on the iPad, all *stampies* in one set were colored a neutral white to avoid biases. This was done as such: the wood *stampie* was painted with white acrylic paint, needle felted natural wool was used for the felt *stampie*, and white food coloring was added to the cast silicone and plastic *stampies*. The *stampies* from the other set were left with their natural material color (see Figure 2) for the testing of colored and line-drawn familiar items. We thus had a study design of 4 (*Stampie* Material Type) × 6 (Color) and 4 (Material Type) × 4 (categories of familiar items) × 2 (colored and line-drawn). All children underwent a within-subjects study whereby they engaged in all the conditions.

STUDY PARTICIPANTS AND METHODOLOGY

Nineteen children (10 girls and 9 boys), aged 4 to 7, participated in the study. Their parents volunteered their participation through a university mailing list. All of the children had previous experiences with personal touch devices (iPad, Leappad, Kindle, etc.), but none of them had experience with touch screen devices coupled with tangible objects.

Table 1. *Stampie* materials and digital items

Item categories	Items presented on the iPad
Animals	Dog, Cat, Rabbit, Pig
Fruits	Apple, Grape, Orange, Banana
Musical instruments	Piano, Violin, Xylophone, Drum
Clothing	Pants, Skirt, Shirts, Jacket

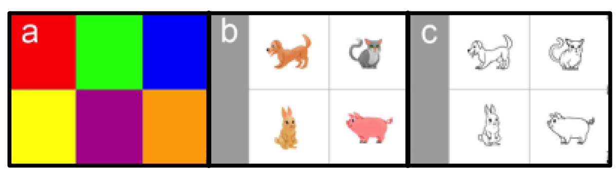

Figure 1. iPad screenshots for the sessions on: (a) colors, (b) colored items, (c) line-drawn items

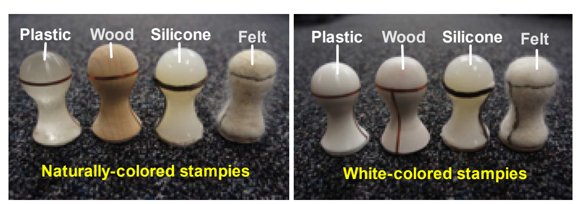

Figure 2. (a) Natural and (b) Neutral *Stampies*

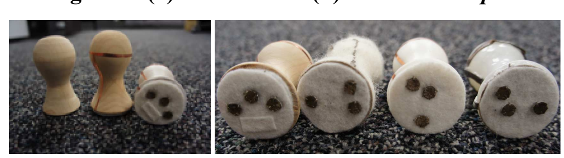

Figure 3. *Stampies* with a unique conductive pattern

At a scheduled time, the child came to a laboratory with a parent(s). The room was set up to be child-friendly with child-sized tables, chairs and toys. After the child was introduced to the researchers and the setting, she was separated from her parent and the study was formally started. The study was made up of 4 stages: i) a familiarization session – the child was introduced by a researcher to a set of *stampies*, and was asked to physically experience them (see, touch, smell, etc.). Any remarks expressing their initial impression of the materials were recorded; ii) a *stampie*-digital item association task – the child was presented with a set of digital items on the iPad, and asked to select one *stampie* for each (Figure 4); iii) a recall task – with only the *stampies* in view, the child was asked whether she could recall what each *stampie* represented; and iv) a creative drawing task – the child was asked to create an artwork using the *stampies* that she had associated with the digital items previously.

The association, recall, and drawing tasks (representing one session) were repeated for the colors, line-drawn items and colored items with the appropriate natural or neutral *stampies*. A session was often repeated multiple times upon the child's request, resulting in a grand total of 94 sessions across all children. The order in which the digital content (colors, line-drawn items, colored items) was presented was counterbalanced such that 9 of the children started with colors first and then familiar items, and 10 of them did the reverse. On average, a child used the system for around 25 minutes in total. While the child took part in the study, her parent was set in an adjacent room, where a second researcher interviewed her about the child's prior experiences with touch devices.

DATA ANALYSIS AND FINDINGS

All sessions were video recorded. A researcher acted as an observer during the study and interview sessions, taking notes of relevant points. Collected data was analyzed using mixed methods (quantitative and qualitative research methods). The independent variable for the study included the colors, colored items, and line-drawn items (grouped into 4 categories – animals, fruits, musical instruments and clothing) chosen by the child to associate with a particular *stampie* type, which was the dependent variable. For the purpose of quantitative analysis, each *stampie* type, color and item category was assigned an ID number. The choices of the children were entered into the SPSS statistical package using the ID numbers (e.g. the choice of a plastic *stampie* for a colored animal was entered as a '3 – plastic' for material type, '1 – natural' for material color, and '1 – animal' for item category.

A chi-square test of association yielded a statistically significant relationship between the colored item category and the *stampie* material type, $X^2(9, N = 119) = 29.00, p < 0.01$. As shown in Figure 5A, wood was more likely to be associated with musical instruments, felt was more likely to be associated with clothes, plastic was more likely to be associated with fruits, and silicone was as likely to be associated with fruits and animals. A chi-square test of association also found a statistically significant relationship between the line-drawn item category and the *stampie* material type, $\chi^2(9, N = 128) = 22.75, p < 0.01$ (Figure 5B). Wood was more likely to be associated with musical instruments, felt was more likely to be associated with clothes, silicone was more likely to be associated with animals or fruits, and plastic was more likely to be associated with animals. No significant association was found for colors.

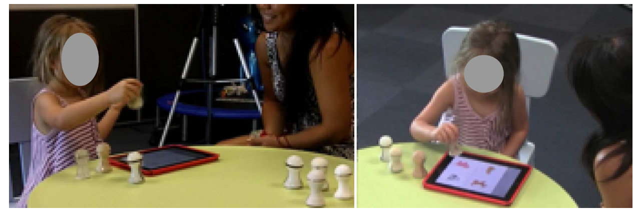

Figure 4. A child engaging with the *Stampies* and the iPad app.

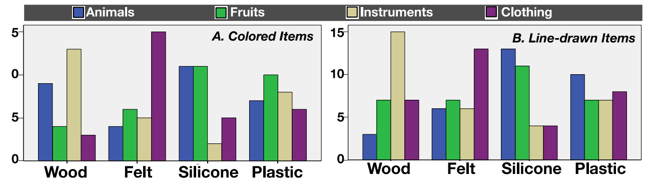

Figure 5. *Material type X Item category* for A. Colored items; B. Line-drawn items

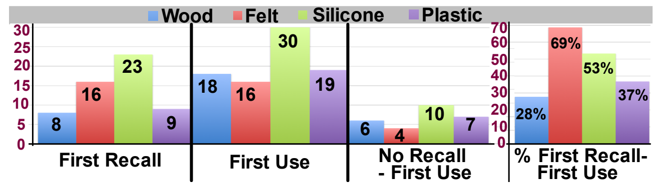

Figure 6 (L) 1. First association recalled; 2. First *stampie* used; 3. First *stampie* used when child could not recall associations; (R) % of first use that were also association first recalled

From video data, we coded the choices the children made with respect to first recall in the 'Recall' task of the study, and first use of the *stampies* during the 'Drawing' stage. We see that (left to right in Figure 6): 1. The children generally recalled the associations for the silicone and felt *stampies* first more frequently; 2. The children used the silicone *stampie* for drawing first most often; 3. When the children failed to recall any *stampie*-object associations (38/94 times or 40.43%), they drew first with the silicone *stampie* most often, and with felt least. This indicates that absent association bias, there is a preference for silicone as a material and a general bias against felt; and 4. Graph 4 charts the frequency of joint recall-use pairs as a percentage of total incidences of use of each material for drawing. Of the number of times the children chose to use the felt *stampie* for drawing, nearly 70% of this choice is accounted for by their vividness of recall of the felt material's association with its graphical object affiliate. This indicates that semantic drawing purpose rather than material preference accounts more for the use frequency of the felt *stampie*.

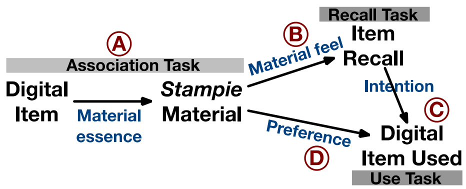

Figure 7. Model of study findings

DISCUSSION

We were interested to investigate whether the materiality of a physical object can have an intrinsic meaning for the child, and whether this association can help the child in interacting with a digital application. Our findings showed that digital items may possess what may be called a 'material essence', making them more likely to be associated with certain types of material than others (A in Figure 7). The associations by the child of wood with musical instruments, and felt with clothing, for instance, were prominent. However, the material feel of the object seems to dominate as the guiding factor for reaccessing the association (B). Silicone and felt were the two 'soft materials' in the set, as opposed to the plastic and wood *stampies*. The unique feel of silicone and felt may explain why their recall of associations for these two *stampies* was the best. Their use of *stampies* for drawing on the iPad appeared to have been led by both the semantic associations and the material feel (C & D). The felt and silicone materials illustrate this best. The children evidently had a tactile preference for the material feel of silicone, and would use it even when they did not have any drawing intention. Although they liked the feel of felt less, they used it for specific drawing content.

There is great potential to enhance the transparency of interfaces and to guide user actions by tapping into the power of materiality in systems for young children. Material essences, feel and liking are all aspects that can guide interaction design for a population that has low access to and understanding of text, language, and culturally-learnt symbols and conventions.

CONCLUSION

We presented empirical research that show how digital items carry meaning that are more readily associated with the intrinsic material essences of tangible interaction objects. Material feel can aid recall, and can be perceptually reaccessed. Specifically, we showed how children make use of material feel and tactile preference during interaction with a digital application. This paper thus contributes to the discourse on tangible interaction by showing the importance of materiality to supporting TUI design through enhanced embodied experience. We extend understanding of TUI design for young children for whom tactile experience is an important aspect of interacting with the world.

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