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Intuitive Use of Tangible Toys

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Abstract

Interfaces for children have continued to evolve in terms of complexity, with toys ranging from traditional tangible interfaces to apps with digital interfaces and hybrid toys with mixed physical and digital interfaces. However, there is limited research done to investigate their potential for intuitive use.

This research study compares a tangible toy and an equivalent toy in the digital world (app) for intuitive use. Non-parametric Mann-Whitney U test results showed that the tangible toy was more intuitive than the intangible counterpart. Tangible systems are less complex to use and they require less time to encode and retrieve associated knowledge to use them intuitively. They are associated with low domain transfer distance and easily discoverable features. Intangible interfaces, on the other hand, require greater complexity and time to encode and retrieve associated experiential knowledge. Intangibles are associated with larger domain transfer distance and undiscoverable features which affects their intuitive use.

Design implications and future work are discussed, emphasising the need for investigating aspects that make tangible systems intuitive to use.

Keywords: Intuitive Interaction; Tangibles; Intangibles; Sensorimotor

Children are interacting with ever evolving complex devices and interfaces. Traditional interfaces such as mouse and keyboard are being replaced by interfaces such as touch screens and gesture based interaction (Manches, Duncan, Plowman, & Sabeti, 2015). Children are increasingly using interfaces that allow them to transfer familiar skills such as grabbing and moving objects from the real world to the virtual, for example virtual reality systems, Natural User Interfaces (NUIs) and Graspable User Interfaces.

The term 'tangible interfaces' was first introduced in Human Computer Interaction to mean physical representation and manipulation of digital data (Ishii, 2008). As products and appliances became more intelligent, tangible interfaces gained popularity in other disciplines such as Industrial Design, Product Design and Interactive Arts (Djajadiningrat, Wensveen, Frens, & Overbeeke, 2004). Hornecker & Buur (2006) use the term 'Tangible Interaction' to describe the meaning of tangibility in all disciplines. Tangible interaction includes user interfaces and interaction that draw on tangibility and materiality of the interface, physical embodiment of data, whole body interaction and the embodiment of interface and user interaction in real spaces and contexts (Hornecker & Buur, 2006). We used this definition for 'Tangible Interaction' in the research study presented in this paper.

Tangible interfaces and systems are referred to as direct (Ishii, 2008), easy to learn and natural (Sapounidis, Demetriadis, & Stamelos, 2015), fast, simple and effective (Jacoby et al., 2009), in other words intuitive to use (Mihajlov, Law, & Springett, 2015) and thus have been suggested to be ideal design solutions for children.

There is ongoing research into the role of tangibles for children, the objective being to facilitate engaging intuitive use of the products. Sapounidis et al. (2015) developed a tangible system for children called T-ProRob that replaces an inbuilt graphical interface to program Lego's NXT robot. The tangible system performed better than the graphical interface in terms of time to accomplish the tasks, number of programming errors and ease of debugging and correction. Seo, Arita, Chu, Quek & Aldriedge (2015) developed 'Stampies' to investigate how young children associate materiality and meanings that allows playful tangible interactions. Stampies consist of tangible objects made out of different materials (wood, felt, silicone, and plastic) and an iPad drawing application. They found that children associated materials with meanings through material essences, feel, and tactile preference.

Research has shown that tangible systems are efficient in terms of simplicity, learnability and speed of completing tasks, which are the characteristics of intuitive interaction (Blackler, 2008). Despite the various research and theoretical frameworks related to tangibles and Intuitive use (Hornecker & Buur, 2006; Antle, Corness, & Droumeva, 2009; Israel et al., 2009; Bakker, Van Den Hoven, & Antle, 2011; Olson, Atrash Leong, Wilensky, & Horn, 2011; Mihajlov et al., 2015; Sapounidis et al., 2015; Seo et al., 2015), there is a lack of (a) empirical research comparing tangible systems and intangible systems for intuitive use and

(b) research investigating the aspects that contribute to intuitive use in tangible or intangible systems.

Thus, this work compares tangible and intangible toys for intuitive use and provides empirical evidence that justifies further investigation into aspects that facilitate intuitive use for children.

Background

Children start playing with tangibles when they are very young, but tangibles are replaced with digital technology for learning and playing as they grow older. However, there is a growing number of studies exploring the use of tangibles for children. Tangibles allow children to explore the artefact and in the process they learn the use of the product. This behaviour of exploring and learning comes naturally to children (Montessori, 2013). Montessori (2013) developed materials and activities to help children develop their sensory capabilities. The objective was that the materials would put children in control of their learning process, enabling them to learn through personal investigation and exploration. Based on this concept, Resnick et al. (1998) developed digital manipulatives to teach complex scientific concepts to children. They embedded computational communication capabilities in traditional toys to facilitate physical manipulation. Physical manipulation of objects enables users to describe their actions in a physically shared space.

Olson, Atrash Leong, Wilensky & Horn (2011) described a set of tangibles developed to control a toolbar in an application running on a Microsoft Surface tabletop where children place one of the blocks on the tabletop to activate specific functionality in the application. This was to facilitate children working together on the tabletop. Children were able to use a familiar concept of using blocks in an unfamiliar environment, which allowed them to focus on the task at hand and avoid disputes while working together.

Tangibles go beyond just physical manipulation; several researchers have explored tangibility in full-body interaction environments. The success of these environments depends on the effectiveness of the mappings of the body movements to an abstract concept. Antle (2011) described ‘Sound Maker’, which maps quality of body movements to changes in percussive audio output. The system tracks users’ speed, amount of activity in their movements, relative position of users (proximity) and the flow of the movements and maps them to the musical parameters tempo, volume and pitch. They tested the system with children and found that children rated the system as easier to learn and intuitive. However, the researchers observed that children were unable to discover the proximity-pitch mapping. Discoverability of mappings requires further investigation and research (Antle, 2011).

Some researchers have explored the use of NUIs in full body interaction environments. Gerling, Livingston, Nacke & Mandryk (2012) describe the use of gestures in a full body interactive game for the elderly. They developed a game that allows elderly people to collectively come together and play a game using a set of simple gestures such as clapping hands, raising an arm, etc. Elderly people found the game fun to play and gestures easy to play with. The gestures were simple to learn and easily discoverable.

The experiences associated with tangibles described above- engaging, familiarity, discoverability and easy to learn are those associated with intuitive use of a product (Antle, 2011; Blackler, 2008; Macaranas, Antle, & Riecke, 2015; Seo et al., 2015). Thus, there are indications that tangibles, both physical manipulators as well as full body interaction systems, facilitate intuitive use.

Intuition is a mode of thinking (Kahneman, 2011) that is effortless and fast and uses prior knowledge (Blackler, 2008). Intuitive use of products and interfaces is based on prior knowledge and past experience and users use their experiential knowledge subconsciously (Blackler, 2008; Hurtienne, 2009). When function, location and appearance of features are familiar to users and they are consistent with other parts of the design, it results in an intuitive use (Blackler, 2008).

Hurtienne (2009) showed that sensorimotor knowledge abstractions, called image schemas facilitate intuitive use by mapping representations of recurring dynamic patterns of bodily interactions to functionality in an interface. For example, the UP-DOWN schema is derived from everyday experiences such as throwing a ball up in the air and climbing up the stairs. Moving a slider up on a control increases the volume and moving it down decreases it. Hurtienne (2009) identified around 40 schemas based on human experiences to be used to facilitate intuitive interaction in interfaces.

There is ongoing research that investigates the effectiveness of NUIs in intuitive mapping of a natural input action to an activity in tangible interactive systems (Mihajlov, Law, & Springett, 2015; Macaranas, Antle, & Riecke, 2015). The effectiveness and efficiency of these intuitive mappings depend on the sensorimotor knowledge derived from everyday experiences (Israel et al., 2009). Mihajlov et al. (2015) found that simple touch gestures such as a drag gesture were easily learned and retrieved by older people who had no prior experience with touch based interactions. Older people are familiar with a drag gesture from their real world experience such as dragging objects. However, older people found a rotate gesture difficult to use as it was not something that they used in their everyday lives.

There is limited research that investigates intuitive use of physically manipulated tangible systems and interfaces. Bakker, Van Den Hoven, & Antle (2011) developed Moving Sounds (MoSo) tangibles to study how tangibles can support learning of abstract sound concepts such as pitch, volume and tempo in children. MoSo is a physical manipulative system equivalent to the full body interaction, embodied metaphor based system, ‘Sound Maker’ (Antle, 2011). Bakker et al. (2011) identified embodied metaphors used by children aged 7-9 years to represent pitch, volume and tempo. An embodied metaphor is a projection of a schemata (such as small-big) originating from bodily experiences (such as jumping low and jumping high) into a conceptual domain (such as volume). Tangibles were developed to represent each of the embodied metaphors identified. For example, a puller artefact was used to represent near-far embodied metaphor, near representing low pitch and far representing high pitch. Children were successfully able to reproduce sound samples using the artefacts after a few minutes of exploration (Bakker et al., 2011). Bakker et al. (2011) pointed out that the effectiveness of the embodied metaphors in 'Sound Maker' depends on how successfully children are able to discover the metaphors and translate them into an appropriate physical action. Physically manipulated tangible interfaces exhibit features that are easily discovered and activated by children (Bakker et al., 2011).

However, despite these claims, there is a lack of empirical research that compares tangibles and intangibles for intuitive use. Prior research has focussed on full body interaction systems and intuitive mappings between embodied metaphors and actions. This research study provides empirical evidence for intuitive use of physically manipulated tangibles and lays the foundation for further investigation into the aspects that make these tangibles intuitive to use. The data collection and analysis methods are explained in the next section. The results are then explained followed by discussion of implications to design and future research.

Experiment Design

A between-subjects experiment was carried out to understand the intuitive use of tangibles and intangibles in children. The variables (dependent and independent) for this experiment are shown in Table 1.

Table 1 Dependent and Independent Variables for the study

Independent Variable	Dependent Variables
Type of Toy – Tangible or Intangible	Percentage Intuitive Use
	Percentage Layers Added
	Latency to Decide

Type of Toy was chosen as an independent variable with two categories – Tangible and Intangible. The dependent variables - *Percentage Intuitive Use*, *Percentage Layers Added* and *Latency to Decide* were measures of Intuitive Use. The dependent variables were measured using Observer XT 12. *Percentage Intuitive Use* was calculated from the number of intuitive uses coded in Observer XT 12 for each participant. *Percentage Layers Added* was calculated by counting the number of layers added over and above the 18 layers of blocks that participants started with. The number of layers added by each participant was noted down during the experiment. *Latency to Decide* is the mean of time taken by each participant to decide which block to remove in each turn.

Tangible and Intangible toy and the game description

Children were observed playing a game of Jenga. Half the children played with a tangible toy (Figure 1(a)) and the other half with an intangible app (Figure 1(b)).

(a) (b)

Figure 1 (a) Tangible toy and (b) Intangible Jenga app from Natural Motions Inc.

The tangible toy consisted of 54 wooden blocks. The game was set up by stacking all blocks in layers of three placed next to each other along their long sides and perpendicular to the previous layer. The intangible toy was an Android app on a tablet which had exactly the same game setup of 18 layers of blocks as the tangible toy except that the blocks were digital.

Two children played together in a team against the researcher. All three (two children and researcher) took turns to play.

Each turn in the game involved taking one block out from any layer of the stack, except for the one just below an incomplete top layer and placing it on the topmost layer. The game ended when the stack fell completely or if any block fell from a stack. The team that made the stack fall lost the game.

Participants

The study was conducted at a local school and at the People and Systems Lab at Queensland University of Technology (QUT), Brisbane, Australia. 108 children in the age groups of 5 to 11 years were randomly selected. 56 children (28 pairs) played with a tangible toy and 52 children (26 pairs) played with an intangible toy. All children and their parents volunteered to participate in the study by signing appropriate consent forms.

Setting and Procedure

Experiments were conducted in a classroom and a lab, which were arranged such that children felt comfortable and at ease during the experiments. Children (with their parents) first filled out a questionnaire about their age, gender and familiarity with similar toys and apps.

Figure 2 shows children playing with the tangible toy (Figure 2(a)) and an intangible app (Figure 2(b)).

(a)

(b)

Figure 2 Children playing with a Tangible toy (a) and an Intangible app (b)

Children were then instructed that they would be playing together in a team against the researcher. The rules of the game were explained to the children. The children were instructed that they have to work in a team, help each other as and when needed and use anything that is available to them to help them in the game. They were then asked whether they would like the game to be set up on the table or the floor so as to mimic a natural setting of their playtime. The session lasted for 40 minutes to one hour. The entire game play was video and audio recorded for analysis. Two digital video cameras were used to record the activity. For the experiments with the tangible toy, one camera was placed in front of the children and the other on the side to capture the interaction and facial expressions during the playtime from all possible angles. For the experiments with the intangible app, one camera was placed in front of the children to capture facial expressions and the other behind the children, focussed on the hands of the children as they interacted with the tablet. The game play was followed with a retrospective interview where the children were shown the video of their game play and asked to talk about how they played the game.

Analysis

Two data collection methods were used for this research study: audio-video recordings of the game play and retrospective interviews. The interaction of children with the toy and the app during the game play was coded for the *Type of Use*: *Intuitive Use*, *non-Intuitive Use* and *Partial Intuitive Use* using the coding heuristics described below.

Coding Heuristics

Intuitive use involves utilising knowledge gained through other experience(s), is fast, and generally non-conscious (Blackler, 2008). The coding heuristics employed to code for intuitive uses are derivations of methods outlined by Blackler (2008).

Unconscious reasoning - Intuitive use involves actions and decisions which cannot be explained or verbalised (Blackler, 2008). Children were considered to be reasoning unconsciously when they could not explain why they chose a certain block or how they removed and/or stacked the block. One of the participants, when asked how he chose the block for removal, said,

"I don't know. I just did it"

Another participant chose a block to remove after tapping at the blocks looking for a loose block. This participant when asked the same question, said,

"I removed this block because it will balance the stack"

Although the participant did explain why he chose the block, the verbalisation did not match his action. Such behaviour was also coded as Intuitive Use.

Degree of Certainty – Intuitive use is associated with high degrees of certainty, confidence and expectation with respect to correct use of a feature (Blackler, 2008). However, there is no correct or incorrect way of playing with a toy. Thus, when participants were certain and confident that the stack would not fall because of their choice of block for removal or during the removal and stacking of the block, the behaviour was coded as Intuitive Use. One participant, while describing how he removed the block, said

"I know the stack will not fall because it is balanced."

The above statement not only shows that the participant is certain and confident of her decision but also is reasoning unconsciously because she is unable to verbalise the actual reason and then gave a metaphorical reason, being in balance is equivalent to not falling.

Latency – Unconscious reasoning in intuition is associated with faster decision making. Blackler, (2008) coded correct use of a feature with not more than 5 seconds of hesitation as Intuitive Use. Since play is not associated with correct use, latency was measured as time taken to decide irrespective of whether that decision results in a win or a loss. When a participant made a decision within 5 seconds (Blackler, 2008) and when the decision was made with a degree of uncertainty and unconscious reasoning, the behaviour was coded as Intuitive Use. The time that each participant took to decide which block to remove from the stack in each game turn was measured using the dependent variable *Latency to Decide*.

The audio and video data was coded with caution; every observation was checked twice and at times thrice. When behaviour showed signs of Intuitive Use as well as Non-Intuitive Use, it was coded as Partial Intuitive Use. For example, one participant clearly verbalised his behaviour (Non-Intuitive Use) but was certain and confident about his decision (Intuitive Use),

"I picked a loose block so that it easily comes out…It will not fall for sure."

All coding was done by one researcher and to avoid observer bias, data were coded twice with a break of 15 days in between each coding. Reliability analysis was carried out in Observer XT 12 to determine if there was an agreement between the two sessions of coding carried out by the researcher. Cohen's kappa (κ) is a measure of agreement between two sets of coding. Cohen's kappa (κ) statistic can range from -1 to +1 and was found to be 0.85. Based on the guidelines from Altman, (1990), a kappa (κ) of 0.85 represents a strong strength of agreement between two sessions of coding. Furthermore, since $p = .000$, kappa (κ) coefficient is statistically significantly different from zero.

Results

Observer XT 12 was used to code the audio and video data. The coded data were exported to Excel and analysed using SPSS. Table 2 shows the median and mean values for the dependent variables corresponding to the IV *Type of Toy – Tangible and Intangible*.

Table 2 Median and Mean values of Percentage Intuitive Use, Percentage Layers Added and Latency to Decide for each Type of Toy – Tangible and Intangible

Type of Toy		Percentage Intuitive Use (%)	Percentage Layers Added (%)	Latency to Decide (sec)
Tangible	N	56	56	56
	Std. Deviation	14.9	24.48	5.71
	Median	100.0	55.27	7.41
	Mean	94.39	56.71	9.53
Intangible	N	52	52	52
	Std. Deviation	20.26	13.46	13.40
	Median	68.34	13.89	10.07
	Mean	63.25	16.31	13.75

Comparative mean values of *Percentage Intuitive Use*, *Percentage Layers Added* and *Latency to Decide* for Tangible and Intangible types of toy are illustrated in Figure 3

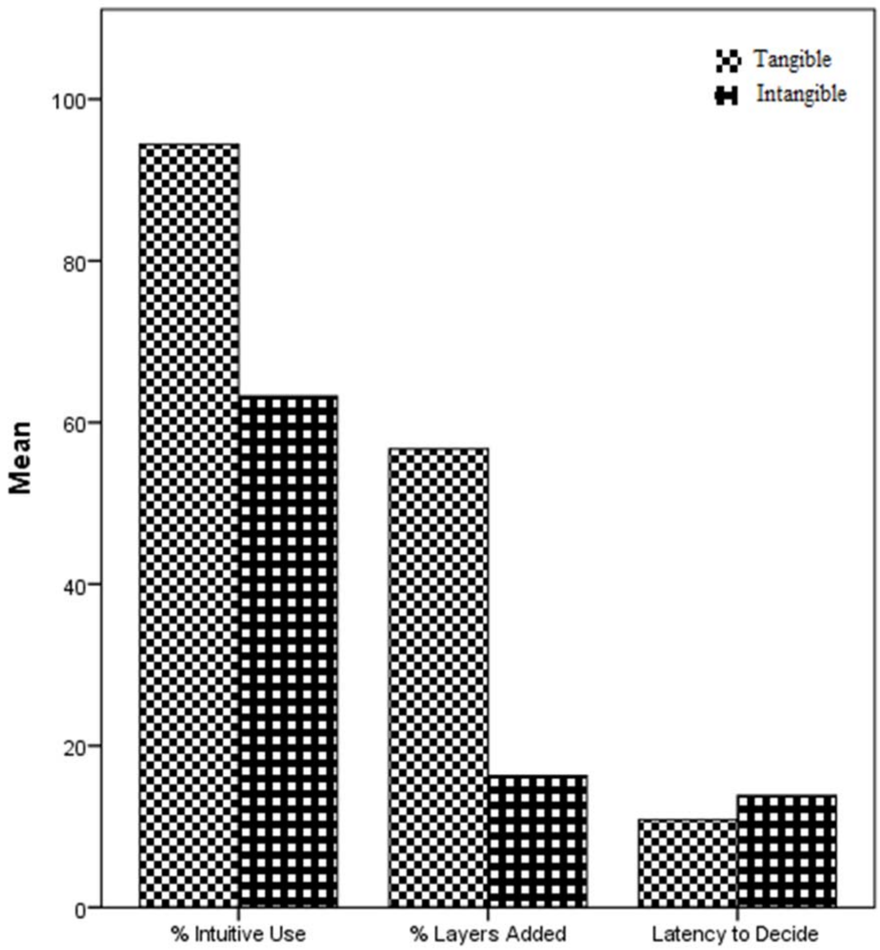


Figure 3 Comparative mean values of Dependent Variables for Tangible and Intangible types of toy

Tangible toy scored higher than the intangible app in terms of *Percentage Intuitive Use* and *Percentage Layers Added*. The Tangible toy on the other hand scored lower than the intangible app for *Latency to Decide.* These results are presented in Table 3 and Figure 3.

A Mann-Whitney U test was run to determine if the differences in *Percentage Intuitive Use, Percentage Layers Added* and *Latency to Decide* between the tangible and intangible toy are statistically significant. The Mann-Whitney U test works by ranking each score of the dependent variables (*Percentage Intuitive Use, Percentage Layers Added* and *Latency to Decide*), irrespective of the group they are in (Tangible and Intangible), according to its value, with the smallest rank assigned to the smallest value. The ranks obtained for each of the groups - Tangibles and Intangibles are averaged separately. This results in a mean rank for Tangibles and Intangibles (Table 3).

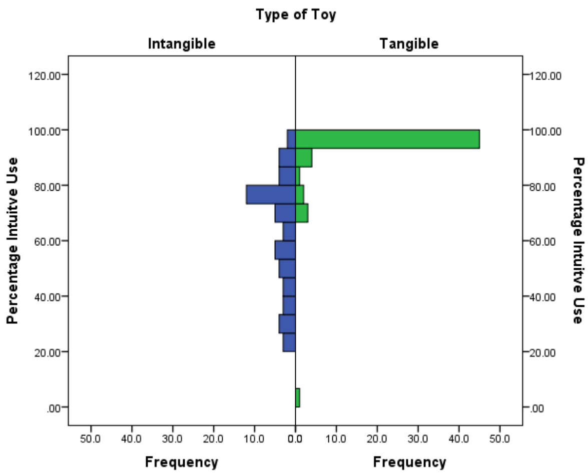
Table 3 Mean Rank values of Percentage Intuitive Use, Percentage Layers Added and Latency to Decide for each Type of Toy – Tangible and Intangible

Type of Toy	**Mean Rank Values**		
	Percentage Intuitive Use (%)	**Percentage Layers Added (%)**	**Latency to Decide (sec)**
Tangible	77.07	77.24	49.05
Intangible	30.19	30.01	59.23

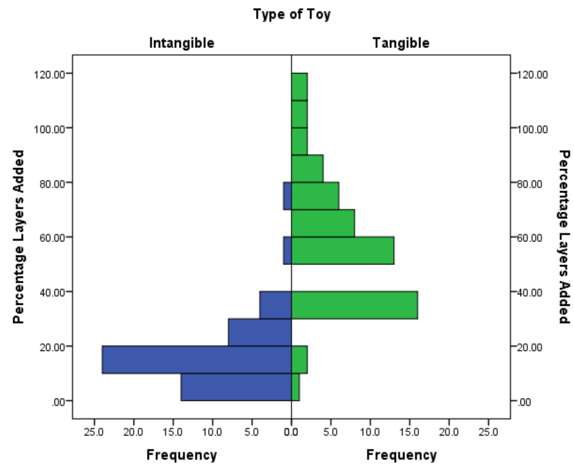
A histogram of rank values of *Percentage Intuitive Use, Percentage Layers Added* and *Latency to Decide* for Tangible and Intangible type of toy is presented in Figure 4. If the shape of the rank distributions is similar, which is the null hypothesis of the Mann-Whitney U test, the mean rank will be the same for both Tangibles and Intangibles. However, Tangible toy has higher mean rank values for *Percentage Intuitive Use* and *Percentage Layers Added* (Table 3) and lower mean rank value for Latency to Decide in comparison with the Intangible app. It is this difference in mean rank that is tested by the Mann-Whitney U test for statistical significance. The shape of the rank distributions of *Percentage Intuitive Use* and *Percentage Layers Added* for Tangible and Intangible toy were not similar (Figure 4(a) and 4(b)). The shape of the rank distribution of *Latency to Decide* was similar for both the toys (Figure 4(c)). The Mann Whitney U Test statistic of the dependent variables is presented in Table 4.

Table 4 Mann-Whitney U Test Statistic of Percentage Intuitive Use, Percentage Layers Added and Latency to Decide for Tangible and Intangible types of toy

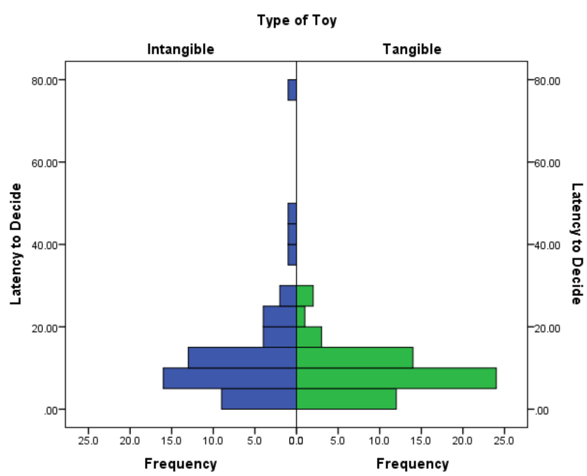
	Percentage Intuitive Use	Percentage Layers Added	Latency to Decide
Mann-Whitney U	192.0	182.5	1158.0
Wilcoxon W	1570.0	1560.5	2698.0
Z	-7.909	-7.848	-1.695
Asymp. Sig. (2-tailed)	2.590×10^{-15}	4.218×10^{-15}	0.090
Cohen's d	0.77	0.76	0.17



(a)



(b)



(c)

Figure 4: Rank distribution of (a) Percentage Intuitive Use, (b) Percentage Layers Added, (c) Latency to Decide for two groups of toys: Tangible and Intangible

Percentage Intuitive Use scores for the Tangible toy (mean rank = 77.07) were statistically significantly higher than for the Intangible toy (mean rank = 30.19), U = 192, z = -7.909, $p \approx 0$ ($p<0.05$), d=0.77. *Percentage Layers Added* scores for the Tangible toy (mean rank = 77.24) were statistically significantly higher than for the Intangible toy (mean rank = 30.01), U = 182.5, z = -7.848, $p \approx 0$ ($p<0.05$), d=0.76. The Mann-Whitney U test only tells if the differences between the groups are significant. Effect size (also called Cohen's d value) tells the size of the difference. Based on the guidelines from Cohen (1992), the differences in *Percentage Intuitive Use* and *Percentage Layers Added* between Tangible and Intangible toys are strong as indicated by Cohen's d-value, d=0.77 and d = 0.76 respectively.

Latency to Decide was not statistically significantly different between children playing with a Tangible toy (mean rank = 49.05) and those playing with an Intangible toy (mean rank = 59.23), $U = 1158$, $z = -1.695$, $p = 0.090$ ($p>0.05$), d=0.17. Cohen's d-value, d= 0.17 indicates that the difference in Latency to Decide between the two groups is trivial.

Discussion

The results strongly suggest that physically manipulated tangibles are more intuitive than intangibles. But what makes tangibles intuitive to use?

Any action is a result of what we sense and perceive. The spatial layout of the blocks in the tangible toy prompted children to tap on the block. But when they sensed that the block was not loose, some children used two hands to remove the block so that the stack did not fall down while others looked for another loose block and continued tapping at the blocks. This suggests that children were using direct perception i.e. perceiving from their senses and their actions in real time as well as their experiential knowledge of Jenga and other block toys and games. On the other hand, children sensed the visual elements in the intangible app and acted only in accordance with their experiential knowledge.

Intuitive use is fast and thus it was expected that children would take longer to decide with the intangible app (Blackler, 2008). But there was a trivial difference in *Latency to Decide* for both the toys and this difference was not significant. Children were neither pushed to commit to a strategy nor were they given a time limit to finish the game. Children explored the environment and socially interacted with the other players. One child, while deciding which block to remove from the stack, talked about a uniform free day at school,

While deciding which block to remove by tapping on the blocks,

Child 1: "….why are you wearing yellow socks?..."

Child 2: "…we can wear any colour of clothes but not uniform…"

Child 1: "..but why are you wearing yellow?..."

Children demonstrated this social and exploratory behaviour for both tangible and intangible toys which affected the *Latency to Decide* dependent variable. This suggests that any time measure is not relevant when investigating toys unless children have been told to finish as quickly as possible.

Design Implications

As discussed above, children were using direct perception i.e. perceiving from their senses and their actions in real time as well as their experiential knowledge. Blackler (2008) explained the use of this experiential knowledge to facilitate intuitive use in product design through a continuum of intuitive use. The elements of the continuum are ordered by complexity of cognition and design, as the products and interfaces become more unfamiliar, the complexity involved in design to make these interfaces intuitive increases. Figure 5 shows intuitive use of tangibles and intangibles in relation to Blackler's (2008) continuum.

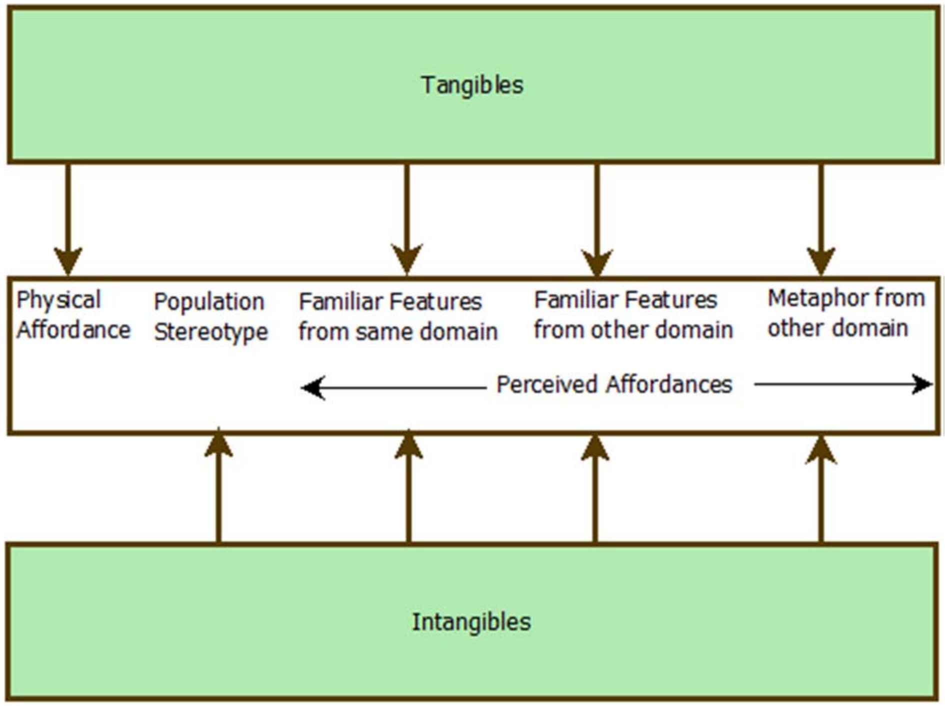


Figure 5 Tangible and Intangible relations with the continuum of Intuitive Use (adapted from Blackler (2008)).

In Blackler's continuum, the simplest form of intuitive use is through physical affordance which is derived from embodied knowledge of the world established early in life, also referred to as sensorimotor knowledge (Hurtienne, 2009). Encoding and retrieval of sensorimotor knowledge is fast and it is acquired very early in childhood. At the next level of complexity, population stereotypes (such as clockwise to increase or red for stop) is the second most accessible form of intuitive use. At the next level of continuum is the knowledge of features from the same domain and other domains which is derived from using other products and tools. This is equivalent to perceived affordances. Intuitive use of a completely new product or feature requires application of Metaphors. Metaphors allow retrieval of analogies from past experiences and the mapping of the retrieved information into the use of the new feature. The higher end of the continuum contributes to high complexity in design for intuitive use (Blackler, 2008), requires maximum encoding and retrieval time and the number of people possessing this knowledge is smaller compared to physical affordances (Hurtienne, 2009). Effectiveness of the metaphors depends on how successfully they can be discovered and translated into an appropriate action (Bakker et al., 2011). If the mappings are designed appropriately, the design of Metaphors for intuitive use can be less complex (Blackler, 2008).

Children develop spatial and material knowledge of the environment and objects early in their development (Spencer, Blades & Morsley, 1989). This contributes to their sensorimotor knowledge. Tangibles offer physical affordances to grasp, hold, push and pull because of their natural spatial and material properties. Children mapped physical properties of the tangibles (such as looseness of the blocks) onto decisions and actions (for example to remove a block). Children also used their prior experience playing with tangibles such as wooden blocks to estimate whether the stack was balanced or out of balance. Intuitive use of tangibles thus uses physical affordance and familiar features (perceived affordances) on Blackler's continuum of intuitive use (Figure 5). In other words, tangibles use lower end of the continuum in their intuitive use, but there is a predominant use of physical affordances. This means that there is minimal complexity required in the intuitive use of tangibles and the encoding and retrieval of associated knowledge requires less time.

One of the influencing factors in the transfer of previously acquired knowledge is the domain transfer distance, which is the distance between the application domain and the origin of prior knowledge that enables intuitive use (Diefenbach & Ullrich, 2015). Tangibles are associated with low domain transfer distance as the origin of prior knowledge and the application of knowledge both relate to the same physical domain with spatial and material characteristics. Low transfer distance results in less verbalisation and effortless use of the interface (Diefenbach & Ullrich, 2015) which in turn results in intuitive use of tangibles. The result of the low domain transfer distance in tangibles is that the spatial and material features are easily discoverable. This explains the high scores of intuitive use for tangibles in this study.

The intangible app does not have real physical affordances. Children thus relied on their past experience and knowledge acquired from playing with other apps on a touch screen and from playing Jenga and other similar games in tangible form when playing with the app game. They used cultural conventions associated with tablets such as swiping left-right at the screen and conventions associated with tangible blocks and stacks such as tapping at the blocks equivalent to pushing a block in tangible Jenga. Intuitive use of intangibles is associated with population stereotype (e.g. the colour codes in the app) and perceived affordances on Blackler's continuum (Figure 5). Intuitive use of intangible systems is more complex and the encoding and retrieval of associated experiential knowledge could be slower.

Intuitive use of intangibles is associated with higher domain transfer distance as the prior knowledge acquired from the physical domain (e.g. pushing and pulling the block from the stack) applied to a digital domain (e.g. swiping at the touchscreen). The origin of prior knowledge and the application of knowledge relate to different product domains with different technologies and different materials. Some children tried to apply their prior knowledge from the physical domain (e.g. pushing a block in the stack) to a digital domain (touchscreen). In the process, children were unable to discover the features of the app. For example, children could not discover the red, pink and white colour codes on the blocks which were meant to warn the player of the risk of the stack falling over.

Tangible systems are less complex to use and it requires less time to encode and retrieve associated sensorimotor knowledge to use them intuitively. The previously acquired knowledge is transferred from the origin of prior knowledge to the application domain and is often a direct transfer. This results in features in tangible systems being easily discoverable.

Intangible interfaces, on the other hand are more complex to use and require greater time to encode and retrieve associated experiential knowledge. The transfer of prior knowledge from the origin to the application domain is often indirect. The features in intangible systems can be undiscoverable. This explains the high intuitive use scores obtained for the tangible toy and low intuitive use scores obtained for the intangible toy in this study.

Conclusion and Future Research

There have been claims in the literature that tangible systems and interfaces are intuitive to use. This research has provided empirical evidence to support that claim. It made an empirical comparison of tangibles and intangibles for intuitive use in children and concluded that tangibles are more intuitive than intangibles.

Intuitive use of tangibles is derived from sensorimotor knowledge, physical affordances offered by spatial and material features naturally inherent in the tangibles and from prior experience with the physical properties of similar and other tangibles. Intuitive use of tangibles is less complex and the encoding and retrieval of associated experiential knowledge is fast. Intuitive use of tangibles is associated with low domain transfer distance and spatial and material features in tangibles are easily discovered.

Intuitive use of Intangibles relies heavily on perceived affordances, derived from prior experience with similar products and features. The cultural conventions associated with the use of intangibles play an important role in their use. Intuitive use of intangibles is highly complex and the encoding and retrieval of associated experiential knowledge is slow. Intangibles are associated with higher domain transfer distance which results in undiscoverable features and thus non-intuitive use.

A better understanding of aspects that contribute to intuitive use in tangibles can provide a better insight into the role of sensorimotor knowledge in intuitive use of complex interfaces. Future studies will focus on investigating these intuitive aspects in tangibles and will look into ways to use these aspects in design for intuitive use.

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Vesna Popovic (PhD) is a Professor in Industrial Design at Queensland University of Technology, Brisbane, Australia. Her research focus is within experience and expertise, intuitive interaction and intuitive navigation domains. She has made an international contribution to design research where she has integrated knowledge from other related areas and applied to the artefact design (e.g. human factors/ergonomics, product usability, design and cognition, expertise and experience) in order to support and construct design applications. In particular, she has been a founder and Director of People and Systems Lab domain at QUT. The impacts of Vesna's research lies in the cross-fertilisation of knowledge across humanities and technologies to design humanised artefacts/ systems by facilitating the understanding of diverse expertise and experience. Vesna is a Fellow of the Design Research Society (UK) and Design Institute of Australia (DIA). She is the recipient of four Australia Research Council grants (v.popovic@qut.edu.au).