The added value of wearables to encourage free-play

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Abstract

Free-play is key in the cognitive and emotional development of children. Yet, opportunities for free-play are diminishing. Previous studies have designed digitally augmented open-ended toys and playgrounds to encourage free-play. Wearables, despite their rising popularity and potential for fostering free-play, have received scant attention in research on digitally augmented free-play for children. This paper shows how four qualities of wearables (individuality, natural interaction, ubiquity and intimacy) were incorporated in the design of three wearable playful *accessories* aimed at school-aged children (age 6-12), and how these qualities enabled the accessories to foster rich and diverse free-play experiences. The results open up design opportunities that can potentially help wearable toy designers and researchers to create future playful wearables.

Keywords: design for wearability, design, prototyping, user-centered design.

Introduction

In this paper, we show how four qualities of wearables,individuality, natural interaction, ubiquity and intimacy, were incorporated in the design of three wearable playful *accessories* aimed at school-aged children (age 6-12), and how these qualities enabled the accessories to foster rich and diverse free-play experiences. We discuss the results in terms of design opportunities, which can potentially help wearable toy designers to envision future playful wearables.

Wearables are everyday objects, augmented with digital technologies, which one can wear unobtrusively. Unlike structured games; with fixed rules, toys empower children to play without predefined goals or rules. This type of play is widely known as free-play or children-driven play. Free-play is spontaneous, collaborative, open-ended, physical and socially active. Some free-play patterns include *fantasy play* (e.g. pretending to be a doctor), *motor play* (e.g. climbing) and *social rule-based games* (e.g. hopscotch), in which rules are socially negotiated, rather than fixed or predefined. By playing these games, children learn about adults' life, how to deal with rules, and improve their social skills, amongst others. Thus, free-play is key in the cognitive and emotional development during childhood[1]. However, opportunities for free-play are diminishing. The rising popularity of screen-based and structured entertainment and an ever-growing number of extracurricular activities are factors that account for this decline [2].

Previous research has examined how to encourage open-ended, fantasy, social and physically active play by augmenting playgrounds or toys with sensing and reacting technologies, some examples include [3, 4]. We have adopted a different approach. Free-play does not solely take place in playgrounds or toy rooms. While going to school, shopping with their parents or during the typically boring moments of everyday life, school-aged children tend to look for free-play opportunities. Given the advent of wearable technologies, we examine how wearables can provide school-aged children with enjoyable free-play experiences that contribute to their cognitive and emotional development. In past work, we co-designed with school-aged children three *Playful Accessories* (*PAs*): *Statue*, *FeetUp* and *Wearable Sound (WS)* and evaluated the evocative power of *WS* to encourage free-play [5, 6]. *PAs* take advantage of the fact that children can see an opportunity for free-play in a twig, a piece of fabric or a paper bag. By exploring the physical qualities of everyday objects, children become immersed in their own physical and creative challenges [7]. However, after exploring such objects, children continue looking for other free-play opportunities, and interactive objects can give them rich opportunities to expand their creativity. *Statue*, *FeetUp* and *WS* function primarily as clothes or accessories. Yet, they are augmented with sensing and reactive technologies that respond to children's movements in a personalized and stimulating manner. *Statue* is a belt pouch augmented with an accelerometer, lights and a piezo speaker, it blinks and emits sounds when the child/player moves. *Statue* supports the augmentation of social rule-based games. *FeetUp* are shoes augmented with a pressure sensor, lights and a piezo speaker, which emit light and sound when jumping. *FeetUp* encourages physical and motor play. *WS* is a bracelet augmented with a bend sensor that reacts to body movements with diverse sounds, encouraging motor and fantasy play.

In this article, we evaluated the evocative power of *Statue* and *FeetUp* to encourage free-play, and we (re)analysed and classified the fieldnotes taken by the observers during the evaluation of the three *PAs* in an attempt to understand (i) what qualities of wearables foster positive free-play experiences, (ii) how *Statue*, *FeetUp* and *WS* support these qualities, and (iii) how the mechanics and qualities of wearables relate to free-play dynamics. According to this analysis, we present a set of design recommendations for the development of wearable objects to encourage free-play, which include exploiting the individuality of the interaction to exploit children's creativity and let it flow spontaneously social interaction, building on natural interaction to support common play movements, take advantage of the ubiquity of wearables and the intimate connection between the user and the device.

Related work: free-play augmented with digital technologies and wearables

As already noted, a number of toys and playgrounds have been digitally augmented with sensing and reacting technologies to encourage spontaneous, open-ended, physical and social play. Significant examples are the *Cardboard box garden,* which is a sound based installation made out of cardboard boxes to stimulate discovery, play and adventure [3], and *ColorFlare,* which is a hand-held flashlight supplied with 6 different light colours, which can be exchanged by shaking the devices [4]. Wearable technologies, despite their great potential to support free-play experiences, as we argue next, have received little attention in research on digitally augmented free-play among children. *TagURIt* is a *wearable* version of the tag game. *TagURIt* uses proximity sensors to detect when the chaser reaches a target, and through Lumalive displays on garments, a token appears on the chest of the chaser on duty. According to its authors, this system makes the "children's game more challenging" [8, p. 1147]. *Dancing in the Streets (DITS)* is based on the popular arcade game *Dance, Dance Revolution*™. Players wear 3-axis accelerometers around their ankles, which help *DITS* detect dance movements and send information on the movements to a smartphone, where the game is controlled and graphics are displayed [9]. These wearable systems present children with physical challenges that could enrich, and be easily incorporated in their free-play. Yet, children's interactions with these wearable technologies have not been studied. Consequently, their effectiveness to encourage free-play has not been understood. Nor has the relationship between the wearable qualities and free-play opportunities.

Three wearable playful accessories: free-play experiences

Statue, FeetUp and *WS* were designed by adopting a research-through-design approach, which "employs methods and processes from design practice as a legitimate method of inquiry" [10, p. 310]. In research-through-design, researchers "need to describe how their problem framing and their perception of a preferred state changed over time." [10, p. 316]. We have already framed the problem and our initial perception of a preferred state, and argued for the potential of wearable accessories to encourage free-play in previous sections. In this section, we present the system, including sensors and actuators, of each PA and the user study conducted to evaluate its potential for free-play. In the user studies, we carried out a number of playful sessions, which were attended by at least two researchers and one monitor/teacher as participant observers. After each session paper-based notes were taken. These notes were reviewed by all researchers, who, using an iterative and open form of thematic analysis [11] , individually categorized and classified their notes in terms of the wearable qualities and the free-play experiences.

Statue

System: *Statue* is a belt pouch that emits sounds and light when the child who is wearing it moves [5]. Children could use it for its packaging function, e.g. to store personal belongings on their way to school. *Statue* uses a *Lilypad* microprocessor and an accelerometer to sense user's movements. It has a number of LEDs and a piezo speaker providing audio-visual feedback. *Statue* uses the *x* and *z* axis of the accelerometer to detect movements, but ignores the vertical (*y)* axis to allow children to beat the system if they move slowly enough along this axis.

Study: We conducted an explorative study with 24 school-aged children, who participated through 4 groups. The sessions took place in two after-school centres. Two researchers and two teachers participated as observers.

Results: Observers reported that all children integrated *Statue* quickly - they chose a game to play in less than a minute - and successfully into their free-play. Each group of children played 2 or 3 games. All groups played different games, ranging from those related to being a statue (i.e. Blind man's bluff, Freeze tag, Red light/green light, Musical statues and Serious faces challenges) to adapted versions of their everyday games with statue rules (e.g. Hide & seek, Cops and Robbers, Simon says and a Slow race)(Figure 1). Thus, *Statue* allowed for the scaffolding of free-play. *Statue* evoked games based on social rules;it helped children to practice social skills through rule negotiation. *Statue* also seemed to encourage fantasy games. The computer-like sound feedback encouraged two participants in a group to move like robots.

Figure 1: Children playing 'blind man's bluff' augmented with *Statue*. The sound feedback guides the blind man and made the game more difficult for the other players. Children had to come up with new strategies to confuse the blind man.

FeetUp

System: *FeetUp* is a pair of shoes that emits sounds and light when the child who is wearing them jumps (lift both feet off the ground)[12]. *FeetUp* contains a *Jeenode* microprocessor and pressure sensors located in the sole. The microprocessor has a radiofrequency (RF) system used in connection to the pressure detection. *FeetUp* includes some LEDs and a piezo speaker, for audio-visual feedback.

Study: *FeetUp* was evaluated in two afterschool centres with 24 school-aged children in 6 groups. Two researchers and two teachers conducted structured observations of children's free-play experiences.

Results: Observations confirmed that *FeetUp* encouraged mainly motor play. Most children started exploring/playing with the device individually by, for instance, jumping while dancing or doing gymnastics. Three participants taught their groups *capoeira* -a traditional dance in Brazil-, breakdance and how to move as a ninja. While these new activities were not as popular as gymnastics or dancing, they drew the attention of half of the children. The other three groups played by imitating each other or doing funny things (See Figure 2). They used *FeetUp's* feedback to prove their jumping skills in the activities. They used the sound to prove their achievements, or counted the number of beeps reached while jumping. Observations indicated that all children integrated successfully *FeetUp* in free-play activities. Despite being an individual wearable device, *FeetUp* encouraged children to both share their jumping activities and create their own games (See Figure 2).

Figure 2: Two girls playing with *FeetUp*. They were making sounds in a rhythmic way by touching their feet.

WS

System: *WS* is a bracelet, which can be attached to arms or legs that responds to body movements with a wide range of sounds. Examples of these sounds are the noise of a car engine or the chirping of birds. *WS* draws upon a fabric based bend sensor to detect any bend variation. *WS* also consists of a *Jeenode* microprocessor which has RF that can send signals to a PC. The sensor and the microprocessor are connected through conductive elastics and conductive Velcro. Users can select which sound to play from a list of 30 sounds in the bracelet or in the PC, and the computer plays a note of the sound selected with every change in the bend sensor using a Pure Data patch [6].

Study: We evaluated the evocative power of *WS* to encourage free-play in Ars Electronica Festival 2012, wherein more than 250 people (100 of which were children) played with *WS* [6]. Three researchers and one monitor took descriptive notes of their observations during the sessions. They were also video-recorded and logs of participants' age, gender, position of the sensor, sound preferences and time spent with the *WS* were generated. We drew upon a play observation scale [13] to code the behaviour of a random subset of 30 school-aged participants. The video coding characterized the type of activity performed by the observed child in every 10" video segment. The play observation scale allowed us to measure whether the child was (not) playing with *WS*, interacting with the computer, exploring the artefact or whether s/he was involved in motor, rhythmic or fantasy play. Videos were coded by 10 video observers and validated with the inter-observer reliability test of the coding scale.

Results: According to video observers, *WS* encouraged free-play amongst 66% of the sample. 65% of free-players engaged in fantasy play, e.g. pretending to be a bird. *WS* also encouraged motor play (e.g. dancing, jumping or just tumbling and imitating each other) amongst 85% (Figure 3). The elbow was the part of the body where most participants wore the sensor, because it supported natural interactions – the elbow is involved in many histrionic movements. Exploring the different sounds challenged children's imagination by allowing them to find personal connections with the accessory [4].

Figure 3: (a) A dad and his daughter are creating their own game. They created sounds by touching each other. (b) Two girls moving as an octopus with the sound of bubbles.

On the added value of four qualities of wearables to encourage free-play in playful accessories

The research-through-design process carried out on *Statue, FeetUp and WS* revealed the way in which four key qualities of wearables (individuality, natural interaction, ubiquity and intimacy) encouraged free-play. In this section, we focus on how the mechanics of each wearable's quality gave rise to free-play experiences. We argue that the results can be understood as recommendations for designing other wearables intended to encourage free-play.

Individuality

Mechanics of individuality: Wearables build on systems that track individual user's behaviour. Thus, one of their qualities is that users interact individually with them.

How does individuality lead to free-play? By supporting individuality, school-aged children are able to engage in the natural transitions of play, which go from solitary to parallel and associative play [14], supporting collaboration, which is a key ingredient of free-play.

How do *Statue*, *FeetUp and WS* support individuality? While the interaction with *Statue* (and the other *PAs*) was individual, children use it to create social games, defining their own social rules of interaction to create a wide range of social free-play activities. A noteworthy example is the game "blind man" played when wearing *Statue*; children created new rules and came up with new strategies to augment it involving the individual statue feedback in their game.

It is worth discussing further the relation between social and digital networks. *FeetUp*'s and *WS'* use of networking (RF) does not aim to interconnect users; interaction remains individual, and children effectively incorporated the *PAs* in their everyday (social) play. We conducted an experiment with *WS* comparing the individual version of the PA with an interconnected version. In the latter, audio feedback was provided only when (at least) two participants interacted with *WS* at the same time. Twelve groups, each with 2 to 4 children, took part. In contrast to the wide range of game types enabled by the individual version, including sensory, fantasy, construction and challenge games, in the interconnected version, challenge games predominated. The dominance of one type of game reduces the toy's play value and its potential to encourage free-play, as 'play value' relates to the affordance of different types of games[15]. Thus, in our study, interconnectedness reduced *WS* play value.

Natural interaction

Mechanics of natural interaction: Wearables (should) support natural movements through natural interaction. They (should) allow users to keep physically and socially active while doing everyday activities. This wearability depends on the sensors and actuators used. Body state, motion and some feelings can be detected through sensors in direct contact with the body. Sounds and vibrations are actuators that can be perceived by users in a more or less non-intrusive way.

How does natural interaction lead to free-play? Body sensors used to provide unobtrusive feedback in natural interaction draw children's attention to the motor and social challenges of their everyday games, which are key ingredients of free-play. The interactive feedback can also challenge them to modify their everyday games, encouraging new free-play opportunities.

How do *Statue, FeetUp* and *WS* support natural interaction? The input of the three *PAs* came from body movements; an accelerometer in *Statue* detected movement or its absence, a pressure sensor in *FeetUp* detected jumping, and a bend sensor in *WS* detected joint movements. *FeetUp* had the most challenging natural interaction. The user study showed that children had to be very creative to incorporate *FeetUp* in their games, most likely because jumping is part of some, but not too many games they play. *Statue*, however, was integrated in folk games wherein pretending to be a statue is part and parcel of the play experience. *WS* was mostly used on the elbow and not on the knee. The interaction with the elbow encouraged histrionic movements, which are key elements of fantasy play (Figure 4), while knee use generated difficulties. While *Statue* supported rule and open-ended games, *FeetUp* supported motor games, and *WS* supported motor and fantasy games. Understanding the type of support the natural interaction lends to the games allows us to understand the extent to which a diversity of free-play games is encouraged.

Sounds are part of natural interaction, and the three *PAs* provided sound feedback. *Statue and FeetUp* also provided visual feedback, which, despite being widely regarded as the most predominant channel, turned out to be less relevant in game experiences than sound feedback. School-aged children could not look at their blinking shoes while jumping or keep track of all the *Statues* that were blinking at the same time. As participants put it, "I couldn't see the blinking but we all hear the sound," or "One can hide the lights (with his/her hands) but you still have the sound". The relevance of sound feedback encouraged us to focus on movement-to-sound interaction to develop *WS*. Through a participatory design process, we explored several sensors supporting movement-to-sound interaction. We decided to use a bend sensor, rather than a pressure sensor or motion sensors, because bend sensors, made of antistatic fabric, allow for more flexible interaction as children can integrate the natural body movements of their free-play in the augmented experiences. Bend sensors were also observed to support rhythmic and fantasy play, and body challenges.

The idea of natural interaction through wearables challenges interaction design to shift from creating (software / hardware) user interfaces to augmenting natural play behaviours with wearable devices. This augmented play behaviour can potentially be integrated in everyday playful activities.

Figure 4: Two examples of natural interaction based on histrionic movements of arms. On the right, a boy is pretending to drive a sports car. On the left, a boy is pretending to play a guitar.

Ubiquity

Mechanics of ubiquity: The ubiquity of wearables means that one (can) carry them ‘anywhere, anytime’. Everyday garments or accessories can be endowed with the added value of an interactive secondary function as a toy, through sensing and reactive technologies.

How does ubiquity lead to free-play? Although the ubiquity of wearables is not an especially interactive quality, it allows children to interact with the *PAs* spontaneously, at unexpected moments and in several places. When children are separated from the oversupply of structured entertainment, they often complain about being bored. Given the ubiquity of the accessories, boredom can be turned into creativity. This opportunity for free-play ‘anytime, anywhere’ means that boring moments can be turned into playful ones and that the scarcity of free-play time can be reversed.

How do *Statue*, *FeetUp* and *WS* support ubiquity? The three *PAs* were meant to be digitally augmented clothes or everyday accessories; hence ubiquitous. *Statue* is a belt pouch. *FeetUp* are augmented shoes and *WS*, because of its fabric concept, can be worn as a t-shirt. All three *PAs* can be used in their standard function as clothing or accessories throughout the day, but also can become toys and inspire free-play in moments when the child is bored.

Intimacy

Mechanics of intimacy: The personal connection of users and wearable devices might come through sensors measuring, for instance, heart rate, changes in sweating or respiration, and detecting body movements. Players wearing these devices can access these and other data and enhance their play experience with a personal hint, building up intimacy. The transformation of an everyday object through very direct interaction can also build intimacy.

How does intimacy lead to free-play? According to Piaget, the development of intelligence in childhood rests on exploiting individual creativity through ‘reflective abstraction’, i.e. the creativity arising from an individual’s own interactions with objects [7]. Body sensors allow children to quantify their body activities, thus it provides a new –quantified- level to interact with their body as the object of play. The quantified body provides data that can connect children with their own actions, and the personal connection can elicit emotional responses, both of which trigger creativity.

How do *Statue*, *FeetUp* and *WS* support intimacy? The intimate connection of user with the quantified self, supported personal play experiences, for instance, by choosing sounds fitting their taste with *WS* or trying their preferred jumping activity with *Feetup*. *WS* provides a palette of sounds to explore the intimate connection with body movements. This leads to a large diversity of games; for instance, one boy used *WS* to scare his family. He did so when pretending to be a bear with the sound of a thunder. Other singular examples can be seen in Figure 3.

The intriguing behaviour of *Statue,* which could be cheated, was discovered as a result of its intimacy with the user/player, and the children enjoyed finding this out.. However, one might expect intimacy to emerge as a result of using the accessories daily, but we did not explore this aspect.

Reflecting on the contributions and actionable design opportunities

Whilst sports, health and fashionable clothes are thus far the most common areas for which wearable applications have been developed, we attempted to understand, design and develop wearables with an added value of playfulness given the scarcity of free-play opportunities among school-aged children. Children today tend to have structured forms of play as part of their busy, scheduled lives, often becoming glued to a digital screen. We believe that the results presented in this article will entice researchers to work towards widening the free-play opportunities for school-aged children through wearables, as we have shown interesting positive experiences with Playful Accessories.

School-aged children can wear *PAs* most of the time and play with them and other children whenever/wherever they can. We have discussed the mechanics of three *PAs* and the specific way in which four qualities (individuality, natural interaction, ubiquity and intimacy) incorporated into their design enable different and diverse enjoyable free-play experiences among children. The issues raised invite us to consider the interaction with wearables from a different perspective, where intimacy, for instance, might take on a dominant role in play experiences.

How do our results help designers and researchers to create and explore future wearable toys and accessories? To begin with, it is important to stress that we could identify how different qualities of wearables relate to free-play experiences and the mechanics of *PAs* by working closely with school-aged children and 'putting them first' in the design and development of our *PAs*. Wearable toys, accessories and free-play need to be studied outside labs. In addition to methodology, the results presented in this paper open up a number of design and research opportunities, especially:

(a) Taking advantage of the individuality of wearable objects to support the natural transition from individual to parallel and group activities [14]. The results encourage us to argue for moving from using digital networks that define basic rules of interaction amongst co-players [4], to enabling children to create all their rules of interaction based on the individual feedback of interactive devices. The games they create define the social interaction rules,

(b) Supporting natural interaction [16] by augmenting natural play behaviours, which are a key component of free-play, with the use of body sensors and unobtrusive actuators. This should allow children to move freely and to keep eye contact with their peers.

(c) Capitalizing on the ubiquity of wearables by augmenting everyday objects with secondary playful options.

(d) Exploiting the intimate connection of wearables with children's bodies by involving bodily information that users cannot quantify accurately themselves in their interactive experiences [17]. This motivate users to engage in 'reflexive abstraction' which is key to encourage creativity [7].

These results do not necessarily apply only to children. A wider reflection about the interplay of the mechanics of wearables, interaction qualities, and experiences can help us improve the everyday lives of children, youth, adults and older people.

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