# Exploring the space of near-future design with children

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### ABSTRACT

This paper describes a series of user-centred design sessions conducted with children of varying ages to explore near-future applications of sensor-based technologies. We explain how a review of each session resulted in redesign of the activity and the identification of modifiable aspects of the design process, that when changed, result in richer understandings of possible applications and underlying values. From this we identify modifiable aspects: problem statement, ideation, technology introduction and outputs. We discuss the potential advantages of a "saltationist" (one that jumps around) approach to an exploration of the space of design activities as opposed to a more incremental and evolutionary approach.

### Author Keywords

Ubiquitous computing, children, user-centred design, participatory design.

### ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

### INTRODUCTION

Ubiquitous computing (ubicomp) [1] and associated toolkit technologies [11] are maturing to a point where we can seriously start to think about what applications we want to design and use in our everyday lives. This moves ubicomp from the realm of some unknowable future to a very near future. A challenge now is to understand what applications people want ubicomp technologies applied to and how they could become integrated into our everyday lives [6].

While there has been some previous work looking at engaging adults in design explorations around ubicomp [16,22], there has only been limited work in engaging children. The compelling arguments for the use of children in the design of interactive applications more generally is well documented [1,2,8,9,23,26]. There have also been attempts to involve children in the user centred design (UCD) of future applications [27].

What we are interested in here is not so much the specific ideas children might have but rather how to meet the challenge of engaging children in discussions around near-future possibilities, when we are exploring a relatively open 'opportunity space' rather than engaging in 'problem focused' design, and when there is a specific set of technology components and infrastructures that are both novel to the children yet also constrain design possibilities.

While existing UCD and participatory design (PD) techniques with children might provide pointers for how to engage in design explorations in the face of these challenges, there remains an opportunity to explore a more systematic elaboration of approaches.

In this paper we describe four different design studies undertaken with 22 children taken from different age groups. We as designers were seeking to work with children to discover new and valuable applications for them using sensors, actuators and display technologies which form a subset of ubicomp technologies. Our starting point for these design activities was a 'virtual skipping application' which used several components commonly associated with ubiquitous computing applications. The application was composed of a force sensor, a web camera and an RFID reader with accompnanying tags. The application was constructed using the Equator Component Toolkit (ECT) [11]. It was our hope to pick up on a developing theme in ubicomp research; the creation of 'toolkit' [11,15] interfaces that would allow and encourage configuration and exploration of sets of ubicomp components into user-defined applications. To this end we embarked on a series of design explorations with children, starting with the skipping application and evolving our approach in subsequent design studies. In redesigning our activities in response to outcomes from previous trials, we found ourselves reflecting on our initial goals, and the kind of outputs one might expect from such near-future participatory design. We were also lead to reflect on the weaknesses of a process in which we amend our methodology in an incremental linear fashion at such an early point, when we had a relatively poor understanding of the nature of the opportunity/problem space that we were exploring.

The contribution of this paper is to begin an articulation of the different approaches that can be taken to meeting the challenges of near-future design with children. We give an account of the findings from each design trial and how these findings led us to modify subsequent design trials. We suggest that there is potential benefit of a non-incremental, saltationist approach to the modification of design trials in response to findings as a method of more richly exploring the design space. This saltationist approach draws an analogy between developments in design process and theories and debates in evolutionary biology. In current evolutionary thinking, as maintained by "gradualist" theorists such as Dawkins [7], the belief is that important features – such as the eye or the horizontally opposed thumb in primates – evolve in tiny incremental and gradual steps. However, it has been argued by earlier "saltationist" theorists such as Schindewolf [25], that the evolutionary process allows for jumps across the possibility space. Here identify aspects of the design activity – problem statement, technology introduction, ideation and outputs - which can be modified to create new design activities that enable and alternative to gradualist explorations. That create the possibility of different jumping off points in the space of all possible design activities.

The structure of this paper is as follows: we first discuss related work before outlining the conduct of four design studies aimed at better understanding the design space of future applications of ubiquitous computing. After describing each of these studies, we go on to discuss their impact on our understanding of the process of conducting UCD activity of near-future technologies with children.

## RELATED WORK

Working with children as informants and participants in the design process is becoming a well explored area [1,2,8, 9,23,26]. For example both Druin [9] and Scaife and Rogers [23] discuss in different ways the various roles that children can play throughout the design lifecycle. While there might be some disagreement in how children are involved, in both cases as with many others, the design focus is relatively well established, e.g., designing a collaborative storytelling system [3] or an interactive tool for learning about ecology [23]. Indeed, Scaife and Rogers acknowledge the difficulty of involving children in more open-ended, future directed work which is one the central themes of this paper: "On one hand, the kids come up with many wonderful suggestions that the design team would not have come up with[…] on the other hand, many of their ideas are unworkable in computing terms."[23]

There has also been a strand of design activities involving children that seeks to inform design by observing children's immediate intuitive attempts to control an application [12]. Other approaches seek to understand children's attitudes and understanding of technologies by asking them to draw computer programmers and computer programs [24]. While we are therefore aware that there are a considerable number of design activities reported in literatures about ubiquitous computing and interaction design for children that are similar to the activities which we describe below, our interest is to outline the ways in which design activities such as these can be constructed and combined to explore the unique space of future design.

The issue of what problems ubicomp technologies are best suited to and what people want to live with is also becoming an area of active research interest and considerable work has been done on trying to engage adult users in design discussions exploring possibilities. Various approaches include scenario development using Calvin and Hobbs cartoons as a medium [20], and using component 'jigsaw' pieces where people are asked to build applications with representations of sensors and actuators [15]. Similarly, Alborzi et al [1] also ask children to prototype with cards with sensors and actuators drawn on them but are doing so with a specific design goal in mind for storytelling. Technology probes are another approach to engaging people in discussions about future technologies where people are asked to live with a novel technology for a period of time as a source of inspiration for new ideas [16]. Our use of the skipping application, described below, is similar to a technology probe but is not left in context with our participants.

Future design has also been a focus of interest in the participatory design community. Future workshops is one technique that has been used with adults, for example as part of the larger methodology of the Envisionment Workshop [10] for the design of new commercial products. Others have also explored the use of future workshops with adults and in particular have used role playing and wizard of oz prototyping, e.g., 'experience prototyping' [4] as participatory design techniques. Other work has been done on the design of more open-ended future technologies with children and adults [27] but as an iterative and increasingly focused activity, described in terms of a "spiral of design ideas with each revisit building on and pushing forward earlier conceptions". The metaphor of future design as an iterative, spiraling process has also been used by Buur and Binder [5]; they further acknowledge that "new conceptual frameworks for interactive products such as ubiquitous computing and tangible interaction open new and uncharted terrain for product design" [5].

However, techniques such as future design workshops or iterative spiraling approaches are more useful at the concept stage of design rather than early ideation that we are interested in. Also, in each case referred to above, a single design process was described. Set amongst this work, we might characterize our own work as being concerned with expanding and informing the very earliest stages of design, the pre-iterative phase before the methodologies which spiral towards specific solutions begin. What we are interested in here is how we might employ different approaches while still in the open design phase to help open up the design space and understand it from multiple perspectives. We go on here to describe the four studies we undertook and the reflections that led to the next study.

## STUDIES

### Interactive Skipping Background

The Interactive skipping application that formed the basis for the first two design studies was initially built as an interactive exhibit to be shown at two different science / art exhibitions. The application was built using the ECT toolkit

[11] as a platform, using inputs such as radio frequency tags, pressure sensors and a webcam.

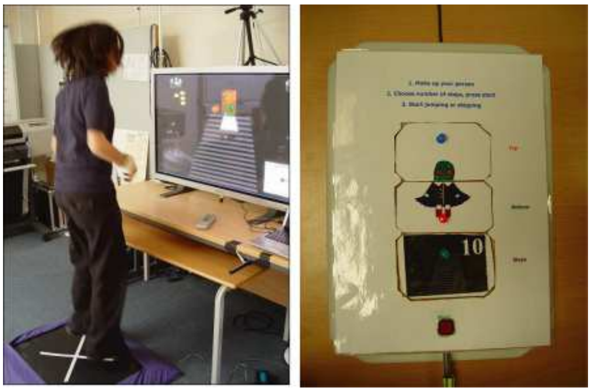

**Figure 1 a) Girl jumping up the stairs as a mixed up monster. b) RFID body part tagged tokens**

The application involved children jumping on a platform to make a cartoon character climb some stairs as projected on a screen. First they configured a mixed-up cartoon person by choosing body components from a ghost, a big green monster, and a vampire (in keeping with a Halloween theme appropriate to the time). Each body was in three parts, designating particular ways of jumping: speed, force and the number of skips/jumps. Each of these input 'body' components was represented as a tangible token made out of wood with an embedded RFID tag. Once configured (see Figure 1b), the children would then press a start button while looking into a web-cam which took their image. By jumping on the pad in front of a large screen, they could make their mixed up person (monster) move up the stairs by jumping or skipping as decided by their choice of body parts. Players were also given on-screen feedback with displayed messages such as "go faster" or "jump harder". The game was finished when their on-screen person reached the top step at which point the child's face was superimposed on the mixed up body.

We had hoped in the course of the public events to engage children and adults in a discussion about how they might re-configure the application but because of the popularity of the exhibit, this was not practical. Instead, we decided to use the application as a form of experience probe (as opposed to technology probe [16] which tend to be used in context rather than in a lab) to explore children's ideas for the use of sensor-based technologies.

#### Study Overview

The interactive skipping study was the first of four studies as summarized in **Table 1** and reported in the following discussions. We will present each study in turn, reflecting on the experiences of each study and showing the changes made to the subsequent design study. Each of the studies was conducted in our laboratory and broadly consisted of a technology introduction phase followed by some form of idea generation (ideation). Sessions lasted 1.5-2 hours each. Participants were recruited from local schools with which we have existing relationships. Teachers accompanied the children but did not participate. All sessions were video recorded. A qualitative analysis was conducted on the notes, video tapes and the outputs produced by the participants in the sessions.

| STUDY | PARTICIPANTS |
|---|---|
| 1: Interactive skipping | 7-8 year olds<br>session 1: 4 girls; session 2: 3 boys |
| 2: Interactive skipping - modified | 13-14 year olds<br>session 1: 3 girls; session 2: 4 boys |
| 3: Technology Introduction | 13-14 year olds<br>session 1: 4 boys |
| 4: Technology Invention | 11-12 year olds<br>session 1: 3 boys, 1 girl |

**Table 1 Overview of Studies**

In all of the studies, we asked children to visualize their ideas through drawing as a form of lo-tech prototyping. An appropriate interpretation of lo-tech prototyping for children is a technique that has been widely adopted e.g. [9, 23]. Druin [9], for example, argues that drawing is particularly effective with children as they can find it difficult to express abstract ideas. All of the studies were also conducted with groups of peers to help encourage discussion together.

#### Study 1: Interactive Skipping as Experience Probe

The aim of our initial study was to explore whether children could sufficiently understand the components, or at least the effect of components, that went into creating the interactive skipping experience and so come up with new ideas to reconfigure it. Motivation for the study of end-user configuration comes from the realization within the ubiquitous computing community that whatever ubiquitous computing solutions we might see in the future, they are unlikely to arrive all at once, as a *fait accompli*, but rather piecemeal so that configurations of technology will change continually over time [22]. It follows from this observation that newly-added technology will often need to be configured to work with existing technology and that there may be an opportunity to create a configurable interface that will allow users to do this themselves rather than requiring them to rely on experts. Several efforts have been made to address this problem directly with the production of visual and tangible interfaces that facilitate end-user configuration [10,20].

In this study, our aim was to explore the children's understanding of the interactive skipping application – here we call it an experience probe in that we aim to use direct experience with it to stimulate to discussion and ideas. Further we wished to explore how this understanding might be used to create a configurable interface which would encourage the creation of other experiences by allowing the reconfiguration of similar components.

We had 2 sessions with participants, one with four girls and another with three boys, all 7–8 years old. We invited the children to "try out" an embodied interactive experience involving jumping on a platform to make a cartoon character climb some stairs which were projected on a screen. With each group we worked with each child in turn; we invited the first child into our laboratory, explained to them the workings of the interactive skipping rope. We told them the 'back story' about the witch and the mixed up body that accompanied the game and showed them how to select the tokens that would make up the mixed-up cartoon person and let them play with it.

A second child was then brought in and the first child was asked to explain to the second child how the game worked. The aim of asking the first child to explain the game to the second child, and then ask the second child to explain the game to the third child, and so on, was to encourage the verbalization of an understanding of the game between children in their own language and vocabulary. The second child was then given an opportunity to play the game with the first child watching and encouraging them. When finished, the first child was then asked to go into another room where they were given paper and coloured pens and asked to draw examples of how they might change and develop the experience – this was the 'problem statement' to focus their design explorations. This pattern continued until all four children had had an opportunity to play the game and to draw pictures of different things they would do if they could. The children were then brought back together and asked to explain their drawings. We then invited them to reflect on how they thought the experience worked.

*Study 1 Results*

The children clearly enjoyed making the mixed up cartoon person climb the stairs and showed delight with the captured image of their face being placed into the face of the mixed up person. They were keen to have many repeated turns using different combinations of body parts. However, we saw little attempt to understand exactly what different types of body parts meant in terms of the game. Instead their exploration seemed to be solely aimed at completing the task. For example they would experiment with jumping harder or softer or faster or slower, but not in a reasoned way with respect to their on-screen representation and did not experiment with where to jump on the mat. In all, we saw little evidence of the children seeking to understand the workings of the technology.

When it came to asking the children for their thoughts on creating different types of experiences, they all concentrated on changing the elements of the back story where the same jumping characteristics were used but to different effect. For example, Girl E explained her drawing as the following: "in the game that you are doing I am changing the mixed up monster into a mixed up animal, it has to climb up the tree instead of going up the stairs when it gets to the top it eats the fruit." All of boys drew games with more aggressive elements such as swords and bombs, as in Figure 3. An interesting exception to changing the back story was put forward by Girl C, where the interaction with the game became a mouse that had to climb a Windows menu but still using jumping to initiate the movement, demonstrating an understanding that she has been bodily interacting with a computer.

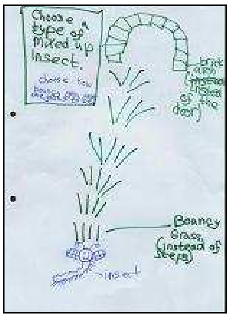


**Figure 2 Girl H (7 yr old)**


**Figure 3 Boy S (7yr old)**

Only one participant, Girl H, showed some initial understanding of the coupling between the configurable components and the jumping experience (Figure 2). In describing her drawing she talked about different levels of bouncy grass that her insect had to navigate to visit the Queen Fairy: very bouncy, quite bouncy and little bouncy. She also manipulated features of the top and bottom parts of the mixed up insect, suggesting that a top with wings would make the mixed up insect lighter and therefore would require lighter jumps, whereas if the insect had more legs, such as with a centipede, then the mixed up insect would become heavier. This showed some evidence of understanding the relationship between the body parts chosen and the type of jumping required.

When asked how they thought it worked, none of them showed any understanding of the relationship between the configurable body part tokens and the interactive elements of the experience. For example, when asked explicitly what he thought the body tokens might be for, Boy B replied "it doesn't have anything to do with the thing [jumping], it's how you jump it."

*Study 1 Reflections*

While a fun experience, our overall assessment of this initial trial was that the interface had not sufficiently suggested distinguishable components used by the game either at an experience level or a technical level for children to engage in reconfiguration discussions. For the next study we decided therefore to make the interface components more obvious. We did this both at the token level and the display feedback level, with the aim of making more explicit the meaning behind the choice of body part as well as how they were jumping.

At the token level, we made two changes. The first was with the top half tokens which were embedded with an amount of lead corresponding to the force characteristic of that body part to give a tangible sense of weight. This ensured the heaviest token (the monster) matched the jumping requirement to jump with the greatest amount of force in order to advance up the stairs. The second change was to have the words "slow", "medium", or "fast" written next to the bottom half of the cartoon representations.

At the feedback level, we added two instrument displays to either side of the main GUI. We used a thermometer-style graphic to give feedback as to the force of jump which was being detected. This was marked as "Too Hard", "Too Soft", and "Just Right". We also added a speedometer graphic, the dial of which was labeled, "Too Hard", "Too Soft" and "Just Right".

Even though some suggest that children 7-10 make the most effective prototyping partners [8], we were concerned that in this instance, the task might have been too difficult and so decided in the next study to use older teenage children.

**Study 2: Interactive Skipping (modified) with Older Children**

For study 2, we conducted two design sessions with 13-14 year old children – three girls and four boys. We made use of the modified skipping application as described above in the hope that our participants would be better able to understand the components that went to making up the skipping experience and so explore ideas for novel re-configurations.

*Study 2 Results*

The teenagers engaged as fully with the skipping application as had the 7-8-year olds. As with the earlier groups, there was little evidence in their explanations and peer discussions of any real understanding of how the experience was working.

When it came to the new design ideas we asked them to draw, it was noticeable that all but one referenced their modifications to their experiences of existing games technologies such as Play Station 2 (PS2), Xbox or Dance Mat. TeenBoy T (Figure 4) for example, explicitly placed his drawing within a PS2 bounding box and suggested the use of the dance mat and Eyetoy; he also suggested having "a running option as well as a jumping one", showing some idea of different forms of bodily interaction with technology. TeenBoy M developed a vampire boxer character and suggested making it a multiplayer competitive game to get up the stirs first. Overall, the boys' modifications brought in more violent and competitive elements, and in discussion referred to explicit games they were familiar with. The girls also made reference to familiar games but with friendlier characters. For example, TeenGirl S (Figure 5) kept the back story the same but used elements from 'Super Mario' game to change the vertical stairs to a horizontal scrolling presentation. TeenGirl N brought in elements from the Sims game, developing characters with life points and levels.

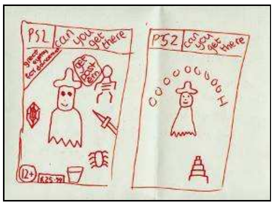

**Figure 4 TeenBoy T (13 yrs old)**

**Figure 5 TeenGirl S (13 yrs old)**

When asked how they thought it worked, they all showed some understanding of the RFID body token choices influencing how hard and fast they had to jump: "the lightest and fastest is what you want" (TeenBoy Z). When we showed them the unmodified body tokens from Study 1, they agreed that the modified ones made the token-jumping relationships much clearer. They also readily understood the on-screen displays: "that's your force and that's your speed" (TeenBoy T), and had suggestions for better gauges and dials. Interestingly, this discussion of how the system worked led to a further round of ideas that started to make much more creative use of the games components. For example, the boys came up with a collective idea for a snowboarding game that made use of the pressure pads to correlate with the act of snowboarding and then modified the input tokens to manipulate the difficulty of the game through choice of board and weight of character. The girls' discussions led to new ideas for keep fit and learning applications for younger kids "where they don't realize they are learning", showing a move away from game experiences.

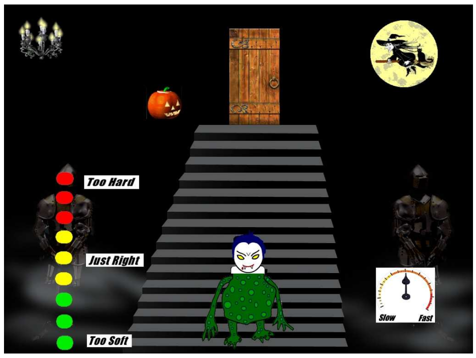


**Figure 6 - GUI used in Trial 2**

*Study 2 Reflections*

Overall the skipping application proved engaging and enjoyable, and as an experience probe it encouraged good discussions with reference to familiar and similar applications – in this way it helped us understand more about their relevant cultural contexts and experiences. However, it also proved limited in opening up different types of design ideas. The changes to the representation of speed and force made the interactive elements of the experience easier to understand, but this improved knowledge did not translate to more diverse use of the technology. The experience also seemed to be too close to their experiences with other commercially available games and most of their suggestions were not very far removed either from the current skipping design or from other games they were familiar with. It was only after more explicit discussions of the workings of the game that they started to explore more diverse scenarios.

In response to these findings we decided to try a different approach for the next study, changing both the starting point in the technology experience and changing the problem domain, as discussed in the following study description. This was our first "jump" across the design space and it was motivated by a feeling that incremental changes to our initial design were unlikely to produce radically different results.

Given that the discussions of 'how things worked' promoted more diverse explorations, we decided to start the next study by showing the participants explicit examples of component technologies and see whether they would be able to understand these and come up with new ideas themselves. This is similar to an approach taken by Alborzi et al [1] with StoryRoom where they give children cards of sensors and actuators to configure though that work was for a specific problem-focused scenario for story telling.

In response to the games-influenced set of ideas, we decided to change the problem domain away from computer games and focus on a domestic setting from a child's perspective. Games, we found, invited a stereotypical genre of response based on strong popular culture, whereas the home, though something that children are intimately familiar with, is one where they are not so engaged in and constrained by technical and practical challenges. The home is also the focus of much design work within the ubicomp community more generally e.g., [15,20].

### Study 3: Technology Introduction, Ideation

In this third study we asked a group of four boys (13 – 14 year olds) to discuss and reflect on arrangements of sensors and technologies, using the home as an application setting.

We conducted the session in two broad phases. The first was a technology introduction/familiarization phase. We asked the group to collectively discuss sensor technologies and their application from examples they could think of. We seeded this discussion with three examples to facilitate the conversation; these seeding applications were: a temperature sensor used in a thermostat, an infra-red sensor used as part of a burglar alarm and a speed-triggered digital camera used in vehicle speed traps.

After this open ended discussion, the teenagers were then shown four different sensors connected to a computer displaying numerical data reflecting their state. We used the phidgets [14] hardware toolkit for this hands-on demonstration and showed the workings of the light, pressure, touch and accelerometer sensors. We then asked the teenagers to create a list of chores or tasks which they disliked doing about the house. We were interested in having the group site their applications within the home, so we provided them with a plan of a typical bungalow home reminiscent to the board game "Cluedo"™, and asked them to think of possible sensor based applications and draw them on to the top of the board. The group were split into two groups of two and given some time to develop their ideas. After a while we invited them back to talk through their sensor arrangements with each other, encouraging them to describe the application as well as the technology.

#### *Study 3 Results*

Throughout the discussions the boys seemed keen to engage us in our topic of sensors and applications needing little encouragement to come up with suggestions and insights. During the first phase where we familiarised the group with typical applications of sensor arrangements and showed them the workings of four particular sensors, the group appeared comfortable with the sensor / actuator model. They showed an understanding of both discrete and analogue sensor outputs and quickly related the numerical outputs to the sensor state.

However, asking them to come up with their own applications using the sensors they had just seen demonstrated they didn't appear to use their understanding of the workings of specific electronic devices but rather used terminology describing the mode of interaction. For example one application they discussed was the use of sensors to detect if a pinball machine had been shoved or moved and so put the machine into its "Tilt" state. They were unsure as to whether or not a touch or pressure sensor was used and preferred to talk about the "detection of movement of the machine", the actual choice of sensor technology being of secondary importance. They knew or assumed that such a movement could be detected and they used this level of understanding of the technology to inform their designs.

In the second phase about home solutions however, they seemed to make more direct use of the sensors they were shown. Each pair came up with a number of application suggestions (e.g., see Figure 7), pair A producing seven ideas and pair B four ideas. Interestingly, a number of the applications concerned safety or security issues, e.g.: a force sensor on the window to alert people if the window is left open when you leave the house; a sensor on the ironing board to prevent the clothes being burnt. Other ideas concerned privacy, e.g. an 'accelerometer' about the bathroom door to notify you when someone is approaching. Another common theme concerned personal assistance, e.g. a moisture sensor placed outside which senses when it is about to rain so that you can then bring in the washing from the washing line. One pair spent considerable time designing an assistance application for bed making. They placed a force sensor on the bed to detect when the bed is vacated when the bed can be made using the automatic bed maker. This particular idea led to much discussion among the whole group about how such an application would work and the logic required to make sure that the bed wasn't made when you just got up to go to the bathroom.

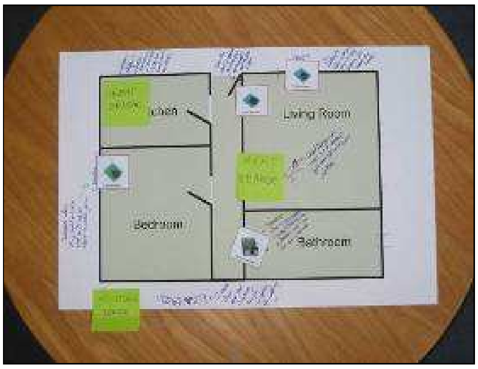


**Figure 7 Sensors on Cluedo Board**

*Study 3 Reflections*

Overall, the teenagers in this study were very quick to understand the particular sensors and interact with them. When it came to thinking of general sensor applications, they mostly worked at the level of effects of families of sensors, or modes of interaction.

The study was productive in terms of ideas produced, and also ideas that to some degree used the technology we introduced to them. In analyzing the results we came to realize that the value of these suggestions was not so much in the specific application suggestions, but rather in the set of values which these inventions supported. Security and automation are commonly discussed as an important area of application in ubiquitous computing [20], but the inventions that the children described gave a more nuanced and detailed picture of what aspects of security were important to them. For these children technology that supported security and personal assistance would be technology that stopped them getting into trouble.

Similarly, privacy is regarded as an extremely important consideration in the design of ubiquitous computing applications [21]. Again, the design of the children's applications provided interesting additional detail, highlighting the importance of privacy *within* the home and the way that very simple ubiquitous computing technology may support these needs.

We therefore felt that this study provided valuable data which could be used in the design of ubiquitous computing applications. The children were not as constrained in their ideas by previous experience as they were with the games. The introduction of the technology also seemed to result in a better understanding of sensors and their innovative use.

However, since the method of technology introduction is such an important aspect of the design of future technologies, we wished to examine, if only for the purpose of comparison, the effects of placing no restrictions on the kinds of technology that might be used. Therefore, in the next and final study, the technologies used are far-future technologies imagined by the children themselves.

**Study 4: Technology Invention, Ideation**

The fourth study was conducted with a different group of children (three boys and one girl, aged 11-12), over four broad phases. Our initial problem statement was intended to move the children away from existing experiences with technology. We asked them to "Write or draw as many different things [technologies] as you can think of and how they are going to be different in the future." They then discussed these together as a group.

As with the group in study 3, in the second phase, the children were asked to individually make a list of household chores. We talked through all of the items on each of the lists with the children. We then asked the teenagers to work in pairs to solve an example from this problem list by using any of the "fantastic" technologies of the future that they had previously generated. This resulted in a series of ideas that focused on either a robot or a computer completely solving the stated problem.

Having learned from our experiences in Study 2, where initial outcomes were rather conventional and stereo typical, we asked the children to try again to solve the household problem that they had been given but this time using some of the other technologies from their list. We also asked the children to think about specific parts of the some of the other technologies that they had invented which might be used to solve the problem. The aim of this restatement of the problem was to encourage less stereotypical solutions and ideas which showed some evidence of reconfiguring of technology components.

*Study 4 Results*

Examples of technologies that the children envisioned (Figures 8 & 9) for the future were cars running on water, hover cars, "a TV that when you think of a movie the TV will put it on", robots attending to mundane tasks, "radios [that] will have things to do like play games or look up things". Cities were forecasted to grow and computers were predicted to have artificial intelligence.

As with the other studies, when it came to making use of these technologies, we saw little evidence of the children re-configuring or assembling technologies to make applications. Example solutions to the problem of "cleaning the house" were "Program the house to clean itself" and a robotic butler. When we pushed for a second round of ideation we were encouraged to see at least some evidence of ideas that involved configuration and combination of technology components, e.g., a Hoover and a car combined to automate the vacuuming of the house; using one car to help repair another.

*Study 4 Reflections*

On the whole we felt that the results of this study were less encouraging than those of study 3. This was possibly because of the restricted set of ideas for future technologies that the children produced and these in turn lead to a restricted set of solutions to the household chore problems.

Yet again, this highlights the importance of getting the technology introduction aspect of the design activity correct. Our assumption had been that allowing the children the freedom to think of any technology that they wanted would set them free to generate a wide variety of fantastical technologies from which they could derive novel solutions (from which we in turn could infer possible near future applications). In this instance, this was not the case.

**Figure 8 A robot that fixes everything**

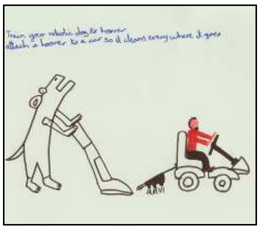

**Figure 9 Hoovering robotic dog**

## DISCUSSION

The overall problem space for our studies was about understanding how current sensor-based technologies might be used for near-future applications for children. Through the feedback and ideas provided by the children, we have begun to understand more about the different types of applications that children could be interested in, e.g. sensor-based games and applications for the home. Within the constraints of a small set of children where we have not explicitly accounted for individual experiences, we have none the less also started to gain an understanding of the kinds of values that these children, at least, regarded as most important, e.g., in the design of domestic applications (security, privacy and personal assistance) and the types of cultural experiences that any new application will be positioned among.

However, for the purposes of the discussions here, we want to focus on what came out of the reflections on each study in starting to identify aspects of the study process that might be manipulated in order to produce new studies. The central contribution of this paper therefore is to highlight these configurable aspects of the design process for future technologies: *problem statement*, *ideation*, *technology introduction* and *outputs* and to argue for a saltationist approach to how we explore a design space.

### Identifying design process aspects

We define each of the four aspects as the following:

- Technology introduction: how technologies that constrain/enable the design space are introduced
- Problem statement: what is it that the participants are being asked to address
- Ideation: the process of generating ideas
- Outputs: the outputs from the design session

Each of the studies took a slightly different path through each of these four aspects. For example, Figure 10 shows the path that was taken through these configurable aspects in study 1, 2, and 3. Study 4 started with problem statement, moving then to ideation that in turn generated technologies that were then used as outputs. However, it is also clear that even though each of the first three studies started with some form of technology introduction, this was approached in different ways, leading to different types of design sessions. In the following discussions, we start an articulation of the different ways that these aspects can be approached as part of a design space exploration.

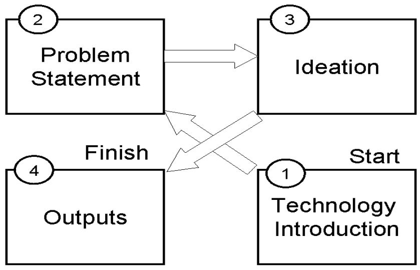


**Figure 10- Path taken through configurable aspects of study 1**

One of the most pressing problems with UCD/PD of future applications of technology is how to introduce the technology. Within the studies presented here we took three different approaches to **technology introduction.** In study 1, the technology was presented as an 'integrated' interactive experience – the experience probe – and we had hoped that curiosity would lead them to think about the elements of the experience and reconfigure them. Study 2 used a similar introduction technique but tried to make the mappings between interactive components and the experience more explicit. In our third study, the technology was introduced in a form of component 'show and tell'. In summary, participants can be shown a variety of existing applications as 'black boxes' and then 'opening up the box' to talk through how various technology components are assembled in the application. Alternatively, participants can be shown examples of component technologies 'in their bare bones' that can then go into building up an application. The different starting points led to different types of discussions; here the 'integrated' experience probe helped uncover similar experiences around games; the technology components led to the children using their more general understanding of families of technology behaviours.

The content and method of presentation of the **problem statement** is also crucial to the design process. In study 1 and 2 we then moved on from technology introduction to the problem statement – "How would you change this game?". In the kind of UCD that we have characterized as problem-oriented design there may well be some direct link between the goal of the overall design activity – "Design an interface to an online library of children's literature." In attempting to design novel applications of new and little-understood technologies, there is unlikely to be such a direct connection. Part of the work of constructing future-oriented UCD sessions must be the interpretation of an overall problem statement – "Do cool/interesting/useful stuff with sensors" – into more manageable focused chunks. In studies 3 and 4 we gave the children a problem domain but in effect asked the children to come up with their own problem statements around the application area of domestic life. We therefore really allowed the problem statements to come out of an initial phase of ideation.

The focus and wording of the problem statements may well be an aspect of the design session which needs to be refined over many iterations. One observation from our final trial is the that there may be some problems with including the words "future" or "technology" and indeed other culturally loaded terms such as "game" in any part of the problem statement. Children are used to certain received versions of the future from science fiction. Technology is apt to be understood in the narrow sense of consumer electronics. To some degree our final trial saw evidence of the future being equated to robots and computers which were capable of completely automating any problematic task. In future work we would like to experiment more with changing the wording of problem statements to perhaps avoid these received terms. This may well be best achieved with the use of iteration in the ideation phase.

The **ideation** phase can itself be approached in different ways. There is considerable technique involved in the presentation and management of the period in which participants are encouraged to come up with solutions to the problems which have been identified in the problem-statement phase. In our second trial we observed that a second, more interesting and more informed period of ideation occurred spontaneously after we had talked through the participants' initial ideas. In study 4 we tried to use this observation to further inform and structure the process of ideation. In both the problem statement phase and the ideation phase the children were asked, when they appeared to have finished working, to "try to think of just one thing more" and this tended to generate more innovative ideas than they had previously come up with. In future work we would like to gain a much better understanding about what kinds of internal structure are most fruitful in this ideation phase.

In problem-oriented UCD, some of the **outputs** of design activity might be expected to be requirements for an application, and also a series of scenarios for interaction. We have come to understand that the nature of outputs from a UCD process for near future applications is considerably different. The kinds of design activities that we have outlined above tend to elicit the values and cultural contexts of the participants. When asked to change a game offered as a technology probe, 8-year old girls changed the characters to animals and the environment to flowers, boys added knives, bombs and axes.

However, it is not only the job of future design to elicit the current values of participants; it must also discover the possible future value of technologies that are not yet deployed. We must therefore be ready to capture "left-field" and unexpected interpretations, applications and expectations of technology. An example of this from our studies was the girl who came up with an idea to use the pressure-sensitive mat from our technology-probe skipping game as a way of the start menu in the windows interface.

#### Taking a saltationist approach

Having identified different aspects of a design process for future technologies, and begun to identify possible content and approaches for these configurable aspects, we suggest that differing paths can be taken through these configurable aspects as part of a deliberate strategy to more richly explore the design space while it is still in this open phase. We draw an analogy with the early "saltationist" account of evolutionary development. Evolutionary theory now tells us that species cannot jump from one part of the space of possible biological designs to another, they must evolve gradually, one increment at a time. This can of course be effective, but it is also slow. "Saltationist" evolution is not possible in nature, but it is in design methodology; the identification of several configurable aspects of the UCD activities allows the designer to jump around the design space and so, in a short space of time, cover a number of approaches and issues which an incremental or evolutionary approach would perhaps not visit. In this way the space of possible design activities can be more completely explored and in doing so the opportunity space for applications is also more richly understood.

To validate this, future work is required to explore more systematically if and how feedback of the outputs from design sessions might result in iterative improvement of problem statements and ideation methodologies. We also aim to move forward to prototype stage with application ideas which arise from values elicited (such as privacy support within the home).

### CONCLUSION

The process of conducting a study, evaluating the findings from a study and then redesigning the study in response to our findings has led us to identify distinct sections of the study process which can be explicitly manipulated. The four studies that we describe in this paper have explored a space of possible lab-based, UCD activities for the design of near-future ubiquitous computing technologies with children.

We propose that a "saltationist" approach – jumping around the space of possible design activities by manipulating these different sections – can lead to a better, rich understanding of the problem space as it specifically relates to the technologies and future applications than would be possible with more incremental changes to design session activities. Future work can further elaborate these process sections and point to ways they can be manipulated for promoting a more systematic approach to exploring the design space of near future technologies.

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