“... a load of ould Boxology !”

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Abstract
This paper documents the design process for an augmented children’s play environment centred on that most ubiquitous and simple of objects, the cardboard box. The purpose of the exercise is to show how computer technology can be used in innovative ways to stimulate discovery, play and adventure among children. Our starting point was a dissatisfaction with current computer technology as it is presented to children, which, all to often in our view, focuses inappropriately on the computer *per se* as a fetishized object. Shifting the focus of attention from the Graphical User Interface (GUI) to familiar objects, and childrens interactions around and through these augmented objects, results in the computer becoming a facilitator of exploration and learning. The paper documents the journey from initial design concept, through a number of prototype implementations, to the final implementation. Each design iteration was triggered by observation of use of the prototypes, and reflection on that use, and on new design possibilities. By augmenting an everyday artefact, namely the standard cardboard box, we have created a simple yet powerful interactive environment that, judging from the experience of our ‘users’, has achieved its goal of stirring childrens imagination.

Key words
Education, play, augmented reality, pervasive computing, disappearing computer, assembly, cardboard box.

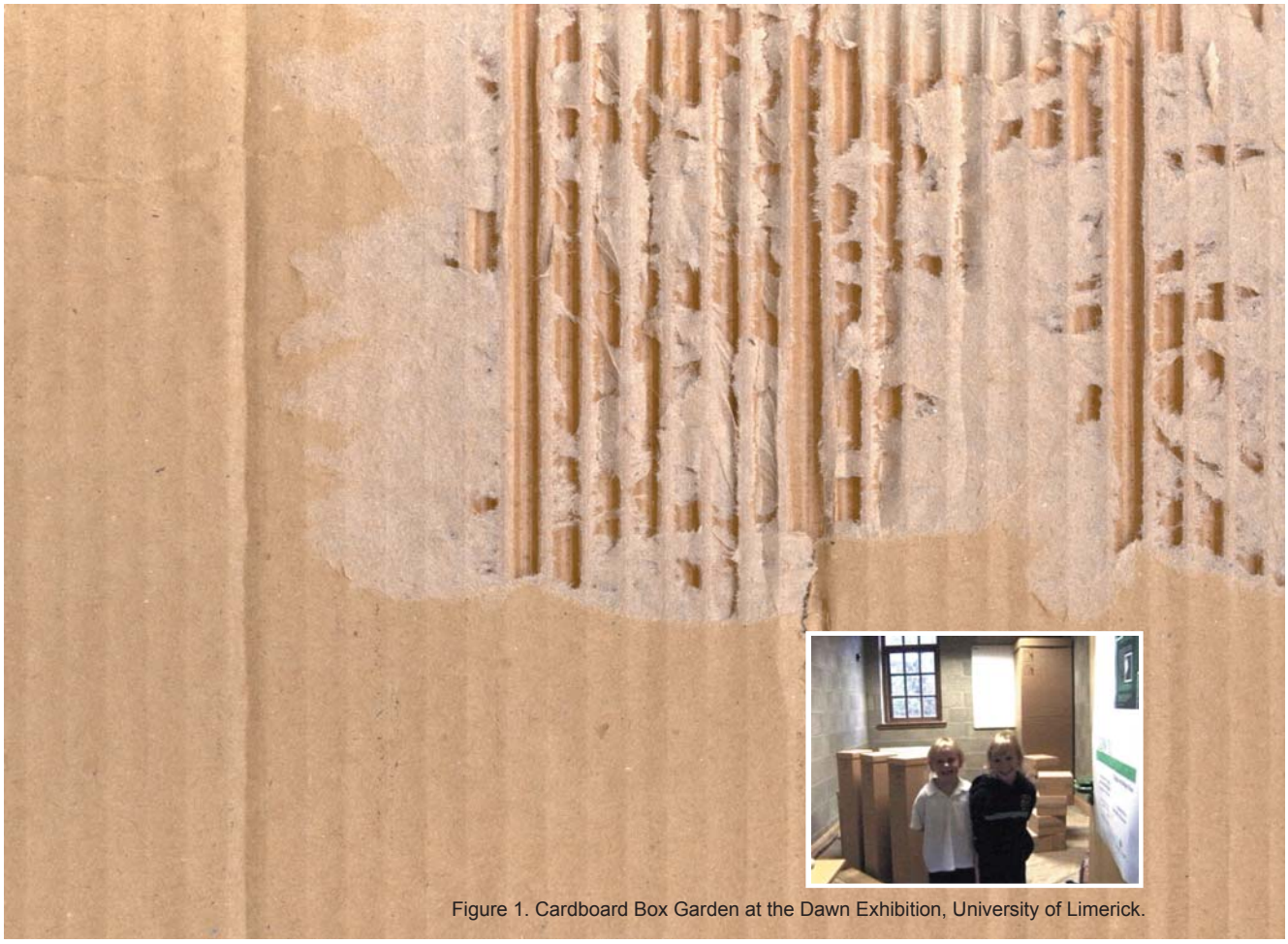


Figure 1. Cardboard Box Garden at the Dawn Exhibition, University of Limerick.

Introduction

"My birthday is on in a few weeks time and I want you to come with your boxes so that my friends can play with them." This girl, planning her 8th year birthday party, then picked up her 'motorbike', which was actually a ruler pushed through two paper cups, and sped off to a variety of 'motorbike' sounds. The little girl and her sister had played with the Cardboard Box Garden (CBG) at the Digital Arts Week Now (DAWN) exhibition held at the University of Limerick, Ireland in September, 2001. The Cardboard Box Garden was the final implementation of an initial design concept - the Cardboard Box Interface (CBI). The CBI was an attempt to use an everyday object - the box - as the interface to the computer for children, thus removing the standard human-computer interface of windows, icons, screen, keyboard and mouse. Children enjoy being physically active, to shout, and touch, and move, and share experiences with friends, and not be chained to a desktop, "interacting" with text or images through pointing and clicking on a screen. Our ideas for the CBI as an alternative to the standard graphical user interface (GUI) evolved into a more complex assemblage - a play space we have termed the Cardboard Box Garden (CBG). The final CBG prototype is a sound installation piece made-up of fifteen boxes, varying in shape and size. (See Fig. 1). The fifteen boxes are split into four different groups with each group supporting a specific sonic task. The 'Recording group' contains three boxes. When opened, each of the boxes records a separate audio sample. By analysing the frequency and amplitude, the input sound is converted into one of three musical instruments, a piano, xylophone or percussion. The 'Play group' is again made up of three boxes, and each one is paired to a 'Recording' box. The three pairs of boxes are each assigned a particular musical instrument. Opening a 'Play box' will cause the sound, which

was initially generated by the child, to be played back. Once the desired musical sounds are playing, the children can also alter the volume and tempo by stacking and pushing other specific cardboard boxes. Building upon the natural characteristics of a cardboard box, children are able to create and alter their own music in a playful manner, without being distracted by the 'computer".

In this paper, we provide a brief account of the motivation for the original design concept, namely a desire to provide children with an expansive and non-threatening play environment that makes use of computer technology, but does not fetishize the technology. Subsequent sections of the paper chronicle the evolution of the design concept, from initial design sketches (e.g. Fig. 2) through to a number of implemented prototype Cardboard Box Interfaces - CBI-1 to CBI-3 (e.g. Fig. 3-13), leading to the final Cardboard Box Garden system CBG-1 (Fig. 14-19). For each prototype, we document the design intention, the resulting prototype implementation, and the feedback from users of the prototype. We also present some picture clips of more extended use of the final prototype, which was obtained from 2 exhibitions.

1. Against the fetishism of the computer in primary education

In the current 'computers for schools' climate, primary and secondary schools are being fitted with the latest computer technology. As the computer makes its presence felt within the area of education, more often than not, it is packaged into programmes about the technology, and the objective is that children must learn 'about computers' in order to secure a job in the technologically-empowered 21st Century. Even when there is an attempt to use the computer more as a tool in the curriculum, uses rarely go beyond researching information on the Internet, typing-up assignments or running so-called 'educational' CD-ROMs. These common computer tasks all involve the use of personal computers, with children interacting almost exclusively through the all-too-familiar WIMP-type Graphical User Interface (GUI). Does this rather limited screen-based point-and-click type interface really fit comfortably into the activities of young children? The age in which children are being exposed to the computer is becoming younger and younger. Kindergardens have even installed computers to "make our children (feel) comfortable" with them later in life (Stoll 1999, pg.70). Is this all the computer has to offer within early education?

We wish to fundamentally review and question this role of the computer in our children's educational environment. In doing so, the process of creating a radically new form of computer interaction can be initiated, one that may fit more comfortably into the learning environment of the child. For instance, the personal computer in its current form is notoriously poor when it comes to bodily interaction (see Ishii & Ullmer, 1997). Healy (1990) also notes: "Body movements, the ability to touch feel, manipulate, and build sensory awareness of relationships in the physical world" are crucial to children's development. From an interactional point of view, the physical limitations of using a GUI can become a barrier to a more engaging experience. Through active play children construct knowledge and acquire life skills. However, if we compare what can be called active play to computerised forms of play we notice that these two types of play are utterly different. Whilst active play tends to involve several children collaborating in various ways, using a variety of "at-hand" physical objects and materials to create a story, computerised 'play' tends to be much more static and usually involves a single child at the computer, or at best one child controlling the keyboard and mouse, in a rather limited 'point and click' fashion, with another child or two "collaborating" in a rather passive form, providing comment on the actions of the computer user.

We wish to radically re-think this form of human-computer interaction in order to create a more engaging, real-world form of interaction. In what follows we document our attempts to break "out of the box" of the desktop Wintel environment, while maintaining an interest in using that most fundamental of childrens toys - the cardboard 'box'. Our conception of the Cardboard Box Garden is an attempt to provide a more suitable human-computer interface. However, it is not simply the interface that we wish to re-configure, but also the larger interaction environment. To this end, we have, from the outset of our design, attempted to create assemblies of boxes with a variety of different interaction possibilities for children. We wish to create a playful environment, filled with interactive artefacts that can be explored and appropriated by children for their own ends. Thus our design brief became - " how can we combine elements of computer technology to create a playful learning environment that allows for exploration, discovery, and for collaborative physical activity.?" The remainder of this paper charts our attempts to satisfy this design brief.

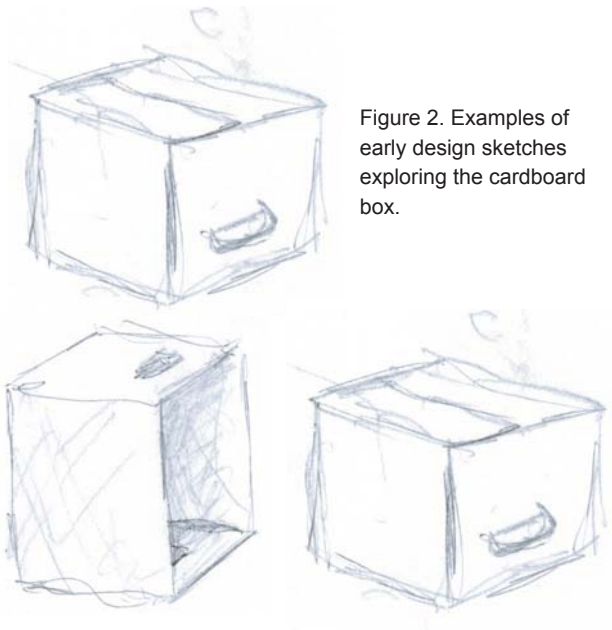


Figure 2. Examples of early design sketches exploring the cardboard box.

2. The Design process

2.1 Initial Ideas for Alternative Interfaces

Realising that the focus of play should be moved away from the computer, back to the child, led us to investigate the attraction children have for simple play items - tin cans, sock puppets and cardboard boxes. Children already have a well-established relationship with cardboard. Being an inexpensive material, it is widely used to create very imaginative playthings. Intrigued by the cardboard box, the next step was to set about examining its natural characteristics, for example, questioning how people use cardboard boxes. We were attempting to ground our design ideas on the affordances of everyday objects, so as to create interfaces that would be experienced by our users as 'natural' and 'intuitive'. As Norman (1988) notes: "When affordances are taken advantage of, the user knows what to do just by looking".

Considering the possibility of making an interface out of real-world objects, the best place to start is by understanding how these objects function. Having an insight into how a cardboard box is used proved to be a valuable exercise, as it was through these observations that the full complexity of these artefacts was understood. The use of cardboard boxes is seen on both a primary and secondary level. On the primary level a box is created in a factory with a specific task and product in mind. The secondary level is when another user recycles the box. It is normally within this area that people are most familiar with cardboard boxes, for example, in a home or office environment. Studies were carried out in the factory, home and office to understand how people interacted with this simple object. Establishing some basic principles on box interactions led to the effective use of these affordances in the prototyping stage.

2.2 The box as an input device

Studying the box prompted questions like, where do people place their hands when lifting a box? Or what happens when you open a box? The answers were all very basic, for example, the lid is moved, or the inside of the box becomes visible. The purpose of these questions was to begin to develop ways in which the user's interaction could trigger other responses. Through a creative misuse of existing input devices, users could potentially interact with computer technology through boxes. Our reflections prompted outline sketches of boxes and their characteristic features (Fig. 2), subsequently leading to the construction of a number of prototypes, focusing on using the cardboard box as an input device. As an example of the exploratory ideas examined, we shall now outline three distinct design ideas that were prototyped, before our final implementation.

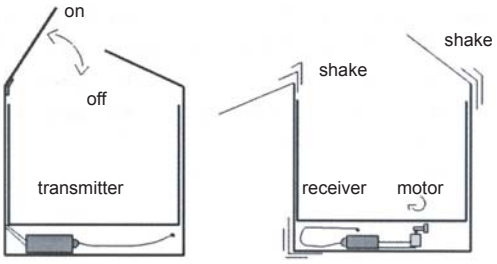


Figure 3. Initial sketch of the Vibrating Boxes. (top right)
Figure 4. Diagram of Vibrating Box prototype. (above)
Figure 5. Vibrating Boxes in action. (right)

2.3 Prototype CBI-1: The Vibrating Boxes

The first prototype was created to explore a simple action-reaction scenario (Fig. 3-5). The natural affordances of opening and closing the lid of a box was used as the action, whilst making the box look as if it contained something was going to be the reaction. The purpose of this was to explore the possibility of using cardboard boxes to engage the users attention on a very basic level. Using a switch mechanism from a musical birthday card, the opening of a hinged box was turned into a simple on/off switch. Wanting to preserve the visual aesthetic of the box, the prototype was made wireless by cannabilizing some parts from a radio-controlled car. In the first box the hinge switch was connected to the transmitter. In the second box the receiver was connected to a small motor. The motor's axis was weighted slightly to one side. When turned on, the box vibrated because the motors centre of gravity was off centre. A false bottom was created in both boxes by

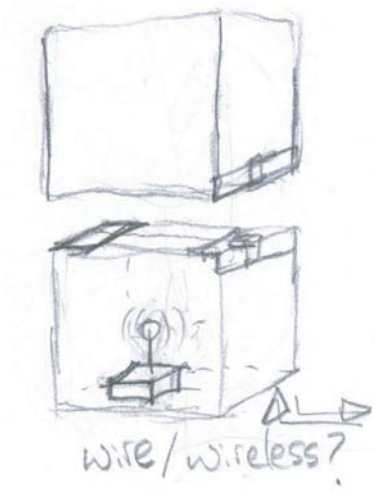
placing a second identical box inside. To the user these were two normal empty boxes.
When the user would open the first box the second would begin to shake, and emit a slight noise. All the users who would curiously open the second box to investigate the shaking were surprised to see the box empty.
Some users would physically pick the box up to investigate and feel the shaking sensation. After the mechanics of the piece were explained quite often the user would return to the box for some further interaction. To some users the box had developed a kind of personality, this once normal everyday object seemed to react to its partner being opened and closed. When interacting with the boxes it became apparent that they were a self-contained system. Furthermore it was noted that both the input and output were inter-referential (Draper, 1986), as the shaking of the second box (output) caused the user to investigate it by opening the lid (input). Monitoring the lid movements as a method of capturing the users interaction clearly worked with this prototype. When investigating a box, more often than not the lid is opened to see what it contains. In doing so this natural instinct to investigate served to arouse more curiosity. It was through the construction of this prototype that the cardboard box showed the potential it had of creating a simple yet imaginative interface.

2.4 Prototype CBI-2: Stacking Boxes

Building upon what was learned from the vibrating box prototype, a second action-reaction piece was created to explore the affordance of stacking multiple boxes. Whilst the vibrating box was made wireless through the use of a radio controlled car, an alternative possibility is to use the physical connection afforded by stacking (See Fig. 6) . When stacked, the electrical connection between two boxes can be realized physically through the use of conductive tinfoil strips. Placing a battery pack in one box and connecting this to a metallic surface on the outside made half of a circuit. In a similar sized box, a motor is connected to the corresponding tinfoil patches on the exterior (See Fig. 7) When the user places one box on top of another, the circuit is complete and, as a result, the whole stack of boxes begins to shake. The piece is visually wireless yet when the boxes physically touch they are connected. Taping the lid closed offered a subtle restraint to discourage the user from opening the box. The connection created by stacking the boxes is much more physical than the first prototype. The interaction tended to happen whilst the boxes were in the user's hands or lap, which amplified the surprise of the vibrations. Yet again the users returned to investigate this simple but addictive form of interaction. In both the vibrating prototypes, whirring from the motor was audible, which played a role in locating what was happening. This use of sound as a cue prompted the design our third prototype system.

2.5 Prototype CB-3: "Do+Re+Mi" Boxes

By combining the basic principle of the stacking boxes, using



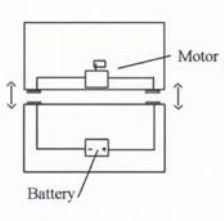


Figure 6. Initial sketch of the Stacking Boxes. (top)
Figure 7. Diagram of Stacking Box prototype. (right)
Figure 8. Photo of the Stacking Boxes being used. (left)

sound instead of physical vibrations, a more intricate box prototype was created using parts from a dismantled musical mat (Noddy musical mat, Blyton Toyland, Systema). In its original state, the musical mat allowed children to trigger a variety of everyday sounds and the musical scale[1] (See Fig. 9). Using the latter, tin foil strips were again wired to the exterior of the boxes, this time in a more complex manner, which resulted in a specific note being assigned to each box.

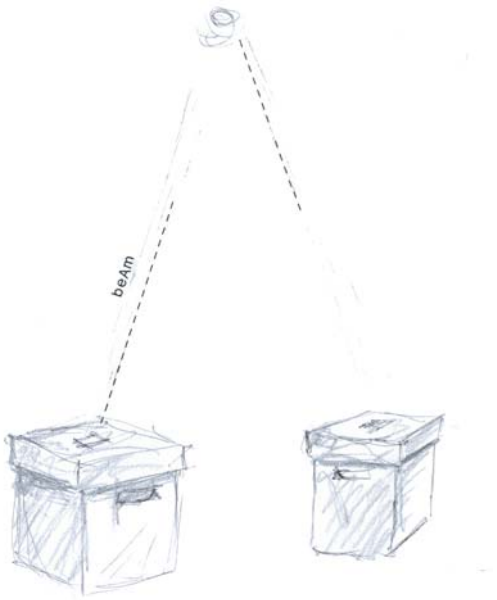
Figure 9. The Noddy musical mat, Blyton Toyland, Systema used in Do+Re+Mi prototype.

The box, which was at the base of the stack, contained all the electronic parts. When the user placed a box on top of the base box a note would be played. When another was placed on top, a second note would play. If the user wanted the pitch of the notes to go up in sequence, they would have to investigate each of the boxes to find out what they played. Then they would be able to play the notes in order of preference. This prototype has an extra element within its design, as not only was it physically interesting to interact with, but the boxes had the added dimension of a sonic puzzle. The boxes were seen as containers of sound - when moved and stacked they released their sounds. Using sound as an output was similar to using physical feedback, as it did not detract from the physical or visual qualities of the cardboard boxes.

2.6 Additional Mock-ups

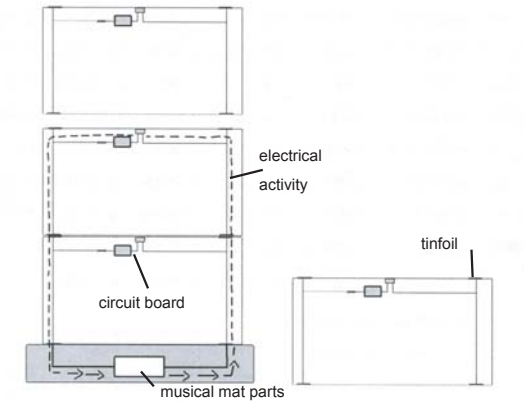
In addition to the 3 prototypes described above, we performed a number of other exploratory human-box interaction "experiments"(Fig.13). The Russian Doll prototype involved placing boxes inside other boxes; whilst other box reactions examined features such as making suspended boxes bounce. One of the more eccentric explorations was an attempt to make a box float. After stripping the interior of the box, leaving only its outer shell, a helium balloon was added in the hope it might float. Sadly it did not. Some of these ideas were very experimental, however it was felt that they were worth investigating in these early stages of the investigation.

Once a repertoire of box interactions were developed the design process began to focus on how the scenarios be



[1] The Interaction Design Centre is involved in a number of research projects involving interactive objects for children, and thus has a wide variety of "toys" available, much to the consternation of the University accounts administration!

Figure 10. Initial sketch idea of Do+Re+Mi prototype. (top left)
Figure 11. Photo of Do+Re+Mi prototype. (top right)
Figure 12. Diagram of Do+Re+Mi prototype. (below)
Figure 13. Sketch example of another prototype (below left)



developed and enriched with the addition of a computer, without detracting from the boxes themselves. The role of the computer was seen as a facilitator of an activity. Allowing the computer to become part of the action - reaction scenario meant that while the overall interface may become much more sophisticated there is no need for the basic interactions to become any more intricate. Isolating a number of familiar box interactions, a decision was made to explore the creation of an interface, which used the boxes as containers of sound. The design now moved into a phase where the notion of "assembly" - of boxes, interaction sequences - became important, as our focus was on creating a box " garden" - for children to explore.

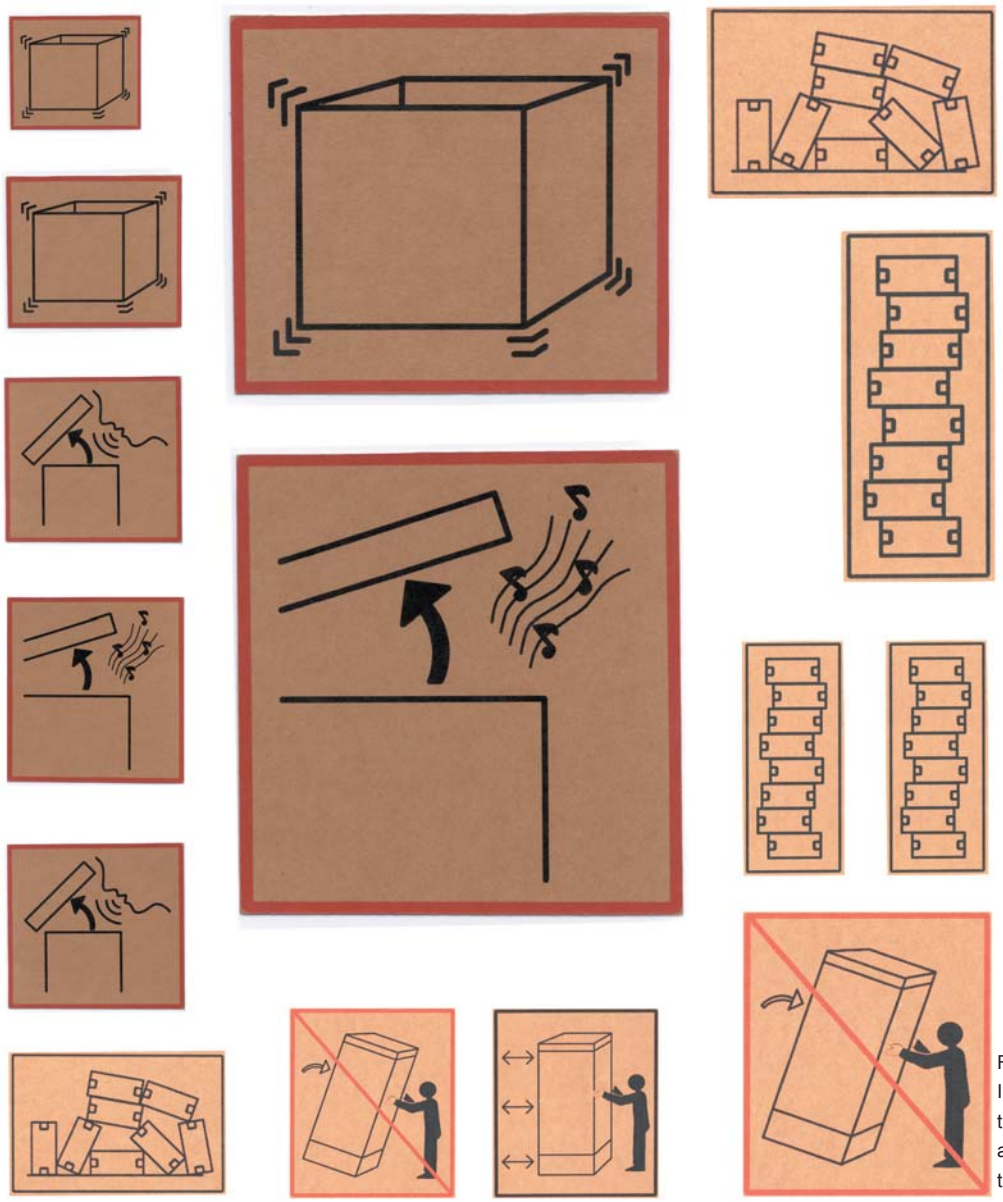


Figure 14. Illustrations that were attached to the CBG.

3. The Cardboard Box Garden

Our final implementation - The Box Garden - is a sound installation piece made up of fifteen cardboard boxes, varying in shape and size. The fifteen boxes are split up into four different groups; each group has a specific sonic task. Collectively the box clusters work together within the MAX software environment to form a real time, interactive, sound-based, installation. The child's physical interaction with the boxes is focused around four physical activities, - opening, closing, stacking and pushing. The child also sings or hums into certain boxes, and then, on opening one of another set of boxes, is rewarded with the output of a melody based on the child's input tune.

More specifically, the 'Recording group' is made up of three boxes. When opened each of these boxes records a short audio sample through a microphone located in the base of each box. Measuring the frequency and amplitude of the recording a MIDI version is created and stored.

The 'Play group' is again made up of three boxes. When the lid of a box is opened the corresponding MIDI sequence that was created from the audio samples will begin play back. This will continue to play in a loop until the lid is replaced.

The 'Stacking group' contains eight identical boxes. These boxes control the volume of the sound that is being played. When the boxes are stacked on top of each other the volume increases, when taken away the volume decreases.

Finally there is one very large box. This box controls the tempo of the sound. When pushed forwards or backwards the tempo increases or decreases respectively.

Implementation details
Each of the boxes is connected to the computer via the MIDI creator. When one of the boxes are opened a MIDI message is sent on a specific MIDI channel to the MAX patch which controls the functions of each box. A MIDI Gesture, placed above head height, is responsible for locating the position of the large box. In the case of the stacking boxes, pressure sensitive pads respond to the changes in weight caused by the stacking and unstacking of boxes. This pad, known as Z-Tiles, is one of the projects currently being researched within the University's Interaction Design Centre in conjunction with Media Lab Europe (Fernstrom, Carugo, McElligott).

3.1 Audience Experiences 1: The DAWN Exhibition at the University of Limerick
The DAWN (Digital Arts Week Now) exhibition of work by students of the Interactive Media and Music Technology programmes of the University of Limerick (Sept. 24-28th , 2001) provided an ideal opportunity to test the Box Garden. It was installed upon a Hessian floor covering in a private room. The floor covering was used both for aesthetic and safety reasons. It hid the wiring from view, as well as shielding wires from any physical contact. At this stage, the choice of instrument was limited, as only the piano setting was available. Over a four-day period, the Box Garden was used by people of all ages. Initial reactions - to the very idea of the Box Garden - were very positive, with people stressing its novelty and simplicity. After the initial novelty factor subsided, people began to explore the environment and use the boxes to create and manipulate sounds. Building upon the natural affordances of cardboard boxes proved successful, as the idea of boxes as containers of sounds, which released their sounds on opening, was quickly grasped by the visitors. The stacking / volume boxes were also understood - for example, whilst talking with Box Garden users, they would often move to unstack the boxes, thus turning down the volume, enhancing the space for conversation. Children who used the boxes best highlighted the creation of a play space. Two young sisters, one aged seven and the other nine, were introduced to the Box Garden. The sisters slowly began to explore the boxes as a pair. After a few minutes they understood what each of the boxes could do and so began to play with the sounds they had created. As they became more confident, the pace of interaction speeded up, to the point that they were both running around the Box Garden. Boxes were pushed and pulled with great enthusiasm The robustness of the space was certainly put to the test on this occasion! Whilst the physical structure of the boxes remained intact, the micro-switches contained within the cardboard were not strong enough, and required constant maintenance, to keep them working. Both of these issues were resolved before the second DAWN exhibition.

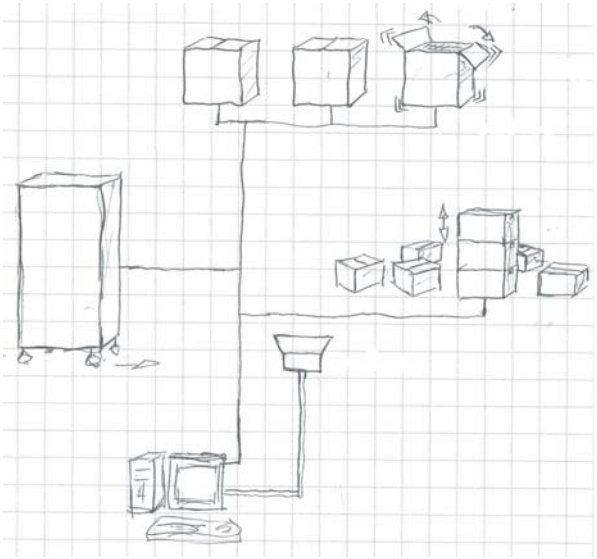


Figure 15. Early sketch of the CBG.

3.2 Audience Experiences 2: The Box Garden interactive exhibit at the October Arts Festival, Ennis, Co. Clare, Ireland
The Box Garden was one of four interactive exhibits from the University of Limerick's interactive media programme selected for presentation at the Ennis October Arts Festival (Oct. 13-20th, 2001). During these ten days, the designers of each piece were also on-site, interacting with the public about the interactive exhibits. The space in which the Box Garden was exhibited was much larger than the earlier exhibit space, allowing the boxes to be spread over a wider area, and giving more of a garden 'feel' to the setting. Some


Figure 16. The CBG at the DAWN exhibition Ennis.


Figure 17. The CBG being used by school children in Ennis.


Figure 18. The CBG attracted a wide variety of users not just school children.

improvements had also been made to the exhibit, enhancing its quality and robustness. Reed-switches replaced the problematic Micro-switches, and the Max patch was refined to allow for three musical instruments, piano, xylophone and percussion. More than 150 primary school children interacted with the Box Garden over the ten-day period. It was striking how such a 'simple' idea could generate so much interest and creativity on the part of the children. They appeared to think more about the sounds they were able to create, from singing and clapping, to recording and distorting their mobile phone ringing tones. Allowing the children to create their own music meant that when the sound was played back they were able to fragment it, and in so doing, they realised how specific parts of the melody were created. Through the use of these simple material objects an increased awareness of tempo and volume was created, and control over the sounds was shifted from the computer keyboard and screen onto the physical actions of the children.

Figure 19. The CBG is in great demand at the DAWN exhibition in Ennis.

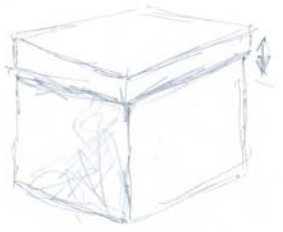


Figure 20 From humble beginnings....

4. Conclusion

Our cardboard box project has its origins in a number of issues of concern to us. The original motive for the whole project was our shared critique of many of the much-hyped "computers in education" projects and attendant publicity for rather trivial uses of personal computers in classrooms. We do not wish to introduce an uninspiring, desk-bound technology as a substitute for the messy reality of the children's school playground. We view the technology as a support tool, as a means to an end. Thus we have attempted to build a playful, interactive space for children that augments current play spaces. Our design ideas have been influenced by several core themes that we have attempted to incorporate in our design thinking. Listing them briefly here, these are:

* Materiality of Objects - the central role of material artefacts in childrens play
* Human Activity - as a fundamental aspect of human being in the world
* Engagement - the need to excite, motivate, enhance the user experience...
* Interaction - human play with objects being seen as a narrative activity, not simple action-reaction (mouse event - action) pairs
* Multimodality - incorporating several sensory modalities - visual, tactual, kinaesthetic, sonic, auditory,..
* Sociality - creating artefacts or assemblies of artefacts that allow for or encourage collaborative activity
* Computer as an augmentation tool, not a substitute for existing practices
* Objects as Assemblies- designing an object world, allowing for object juxtaposition, linking, stacking, etc. And creating emergent behaviours as a result of human actions

In sum, we hope to have illustrated the progression of an idea - the Cardboard Box Interface - from original motivation through to concept design, then the development of prototypes, the iteration of these prototypes, and our resulting Box Garden, all in the space of several months part-time work. We have been encouraged by the audience reaction to our small demonstration system, and hope that it will embolden others to explore the way in which computational devices can add value to existing objects and human activities, while being sensitive to, and building on, everyday practices in the "real" world.

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