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This play, however, is an affirmation of life—not an attempt to bring order out of chaos nor to suggest improvements in creation, but simply a way of waking up to the very life we're living, which is so excellent once one gets one's mind and one's desires out of its way and lets it act of its own accord.

—John Cage, "Experimental Music"

In his 1958 essay "Experimental Music," included in the book *Silence* (Cage 1961), John Cage talks about the transcendent qualities of creating and enjoying music. As we grow up, we lose serious pursuit of play, the important activity through which children explore and understand the world around us. This is particularly true of music, the appreciation of which has tended to become more convenient but more passive through the increased availability of recorded music.

Digital technologies offer a rich potential to fulfil the ideas that Cage envisaged for creating and manipulating sound and music in new and different ways. The present article describes work that attempts to exploit these possibilities through interfaces that are not intended to be musical instruments, but that allow the kind of "purposeful purposelessness" that Cage refers to in "Experimental Music"—a type of playing with music and sound that is in turn explorative and engaging, intuitive and enjoyable. Some established notions of musical instruments have been ignored or challenged. Conventional musical instruments generally suggest traditions and a seriousness that quickly precludes non-musicians from using them. A number of new musical interfaces for musicians have been developed (Paradiso 1997 offers an historical review), but I wanted to work on projects designed for everybody, with a particular focus on those who do not perceive themselves as musicians.

The effort to develop interfaces that are simple, playful, and enjoyable situates these projects in an

PLAY!: Sound Toys for Non-Musicians

arena similar to that of the Iamascope (Fels and Mase 1999) and Musikalscope (Fels, Nishimoto, and Mase 1998). Other related work includes the Jam-O-Drum (Blaine and Perkis 2000), which takes the idea of a drum circle as a starting point for developing a rich and intuitive interactive space for collaborative music play. The Squeezables (Weinberg and Gan 2001) work toward new means for musical interaction and collaboration with a series of objects that offer a simple gestural interface. The sound interactions have been designed to give novice users an intuitive and responsive instrument. Another collaborative environment, Augmented Groove (Poupyrev 2000), allows players to manipulate and mix pieces of musical content and pre-composed sequences of notes to motivate the notion of "computer-supported improvisation." Finally, for his ability to appropriate and re-map the everyday object (as well as traditional musical ones) to create a musical interface seemingly out of anything, Perry Cook remains an inspiration (e.g., Cook 2001).

My work was conducted while studying the Computer Related Design Masters course at the Royal College of Art in London. I outline four projects, broadly considering some of the contributing elements of interaction design, sound design, and system development. By examining the development process, the article attempts to reveal some important issues and to reach some generally useful conclusions about creating new interactive sound and musical interfaces. This article will be largely descriptive. As Perry Cook has pointed out, in many cases "musical interface construction proceeds as more art than science, and possibly this is the only way that it can be done" (2001).

Piano Cubes

This Way Up

The original aim of the *Piano Cubes* project (see Figure 1) was to create a simple physical interface

Figure 1. Piano cubes.



using very basic sensor technology, and then to design some form of sonic interaction to work with the interface. I wanted to explore this as a prototype process for creating sound objects and to uncover some of the issues involved in their design. It was decided to use a number of tilt switches to create the interface. The operation of the tilt switch is very simple: sealed inside a small metal cylinder is a ball bearing or drop of mercury. At one end of the cylinder are two contacts. Depending on the orientation of the cylinder, the mercury or ball bearing makes or breaks the electrical contact of the switch. Four tilt switches were mounted on a basic cube-like frame and arranged in such a way that they could deliver information about the left-right or front-back tilt of the cubes.

The tilt switches were wired into a Basic Stamp microcontroller chip that was programmed to read the switches and communicate the tilt status via a serial connection to a Macintosh computer running the Max MIDI programming environment. The

Max patch on the computer processed the basic tilt switch information to generate a stream of note events. These were sent via an external MIDI interface to a sound module to play the piano sounds. The audio output of the sound module was played through a conventional amplifier and speakers.

My initial intention with this primitive prototype was to play with rhythmic aspects of music, and so the switches were mapped to play a number of drum sounds when tilted in various directions. The results were disappointing. Owing to the nature of the tilt switches, it is impossible to precisely anticipate the point at which the cube is sufficiently tilted to activate the switch and play the sound. To create a satisfying interface for playing rhythms in real time, precision is an essential requirement.

This problem called for a different approach. Instead of using the cube to trigger individual sounds (similar to a traditional musical instrument in which an action produces a sound), I decided to use

the tilt information to control other aspects of a small piece of musical content: a simple four-note arpeggio played on a piano and looped repeatedly. While the cube was tilted right, the arpeggio was continuously and diatonically transposed in step-wise motion up the C major scale; tilting to the left moved the arpeggio downward. Tilting the cube forward or backward increased or decreased the tempo.

The results were more promising. The cube offered an interesting way to play with the texture of the music while the interaction remained simple. However, the interface could be quickly mastered, presenting few surprises to keep the player engaged beyond the first minute of use. In order to enrich the sound interaction while trying to preserve the simplicity of the idea, I decided to introduce another cube exactly like the original one that would separately control another arpeggiated piano line. Using two cubes introduced a new variable, the interplay between the two pianos. To increase musical coherence, the tempos of the two arpeggios were locked together.

By now the sound design was beginning to work well, but as more people played with the cubes, it became clear that the physical form of the objects was compromising the result. The form of the objects and the sound interaction they offered did not work well together. A new form was needed to map the action (the physical feel and movement) more closely to the result (the sound output). To this end, I enclosed the tilt switches within two square jam jars filled with golden syrup. This change greatly improved the feel of the cubes. The weight of the glass jars more readily suggested the tilting nature of the interaction, while the slow movement of the syrup worked well in physically reflecting the changes in the sound.

Some Syrupy Issues

The final cubes were well received. *Piano Cubes* offers an interaction in which the player is not responsible for difficult musical responsibilities like striking the correct note at exactly the right time. Instead, tilting the jars offers control of parameters

that are more global—tempo and overall pitch—in a role closer to that of an orchestra conductor.

Changing the form of the cubes to work more intuitively with the resultant sound transformed the project from some inconclusive explorations into the sound toy I hoped to create. I felt that this validated my approach and suggested a process by which other sound toys could be developed. There was a playful and surprising aspect to using the jam jars that underlined my strong desire for these sound toys not to be perceived as musical instruments in the traditional sense. I was more concerned with creating an interesting and thought-provoking piece than with developing a highly refined prototype.

This project raised a number of issues to consider in the development of such sound toys:

1. How can software environments like Max be used to program a rich and engaging interaction with these simple interfaces?
2. What sort of content or sound design, and how much of it, is needed to produce objects that allow us to play with the sound in a satisfying way?
3. How can sound be mapped to physical interfaces to make the interface more intuitive to use, and how important is this?
4. How do the interface and interaction evolve together? How does the interface suggest a certain interaction, and in turn, how does that interaction suggest changes to the interface?

The Bullroarer

The next project involved creating a musical interface that reinvents a bullroarer. Bullroarers are aerophones that historically were among the earliest sound objects. A piece of hollowed wood or bone is spun around on the end of a length of rope or twine to produce a characteristic whirling sound. Totemistic cultures of Australasia believed that the spirits of their dead ancestors dwelled in the bullroarers they had made; the objects' sounds became their ancestors' voices. More recently, Am-

Figure 2. Bullroarer detail.



erindian tribes are thought to have developed bullroarers primarily as toys.

The Bullroarer (see Figure 2) was developed in collaboration with a fellow student, Mark McCabe, who had already been working on a version of the interface. Mark's Bullroarer incorporates a slider potentiometer on the end of a two-meter piece of rope. The moving contact of the slider is weighted so that when the rope is spun around, the slider is pushed outwards by centrifugal force. An elastic band provides an opposite force that pulls the slider back when it is not being spun. As a result, the potentiometer value is proportional to the speed at which the Bullroarer is spun. In an arrangement similar to the previous project, a Basic Stamp microcontroller reads the potentiometer's value and sends it to the computer, where a Max patch generates a series of MIDI commands to control an external sound module.

This was a good interface with which to try out some alternative approaches to sound design. It offered a simple yet very physical form of interaction,

in a single continuum from the non-whirling state to the maximum-speed whirling state. The project explored a number of sound "patches" for this continuum of physical activity.

Early Moves

The aim of the first iteration of the sound design was to explore the interface's viability. *Bullroarer 1* was a sound patch created as a kind of whirling drone that would in many ways emulate a physical bullroarer. The interface controlled an analog synthesizer. Initially, I worked on timbral control: as the Bullroarer is spun, a note is played that becomes harmonically richer as the spin increases. To make the sound output richer, additional notes in a major chord are introduced the faster the bullroarer spins. At the maximum speed, a slightly discordant pitch modulation is introduced to the sound. This seemed to work well musically. The resulting sound was satisfyingly mapped to the

physical input, while the sound created was rich enough to be engaging in the short term.

Next, more elements of musical content were incorporated into the sound design. For the next sound patch, *Float*, as the speed of the Bullroarer's spin increases, different notes along a musical scale are played. For *Phasing*, the bullroarer plays through a sequence of notes at a tempo relative to the speed of the spin. The sound used incorporates a strong echo effect, thus as the speed of the bullroarer changes the notes move in and out of phase with each other. At a certain speed, the notes play on top of each other to create a strong rhythmic syncopation, while at another speed the pattern seems to turn into chaos. Both these sound patches were improved by adding some elements of timbral change used in *Bullroarer 1*, so that not only were the musical notes changing along the continuum, but so was the sound quality.

The Bullroarer seemed to work well as an interface that can combine overtly physical interaction with the manipulation of sound. Nick Skilbeck, a musician and composer who tried the Bullroarer, noted that much of the engaging appeal of traditional musical instruments derives from the physical interaction and the investment of physical as well as mental energy in playing them. In terms of the physical interaction, the sound designs that incorporated a continuous change in sound along the physical continuum (*Bullroarer 1*) felt more pleasing than those that depended on reaching particular speeds before a distinct event occurred, like the playing of a note (*Float*). This is presumably because the continuous sound change provides constant, rather than intermittent, audible feedback about the speed of the spin. However, the sound designs like *Float* that incorporated musical elements seemed to offer a bigger, more interesting space to explore.

As a musical interface, the bullroarer is perhaps too simple, with effectively just one control axis. However, there are a number of possible ways to enrich this experience. More sensors could be added to create new axes of control, but this would depart from the attractive simplicity of the original interface. The most promising direction at the time seemed to be a system in which a number of bull-

roarers could be played collaboratively by a group of people.

A Collaborative Approach

A number of new issues emerge when designing sound toys for groups of people as opposed to single users. I had been very impressed with the work of Toshio Iwai, who, in his piece *resonance of 4* (described online at www.iamas.ac.jp/~iwai/artworks/resonance.html), creates a very simple and restrained computer-based sound piece that can be played by four people. This piece works extremely well because it is possible to play the piece effectively by oneself or in a group. The main challenge for the sound design of a system to be used by a number of people is that each player's sound must work musically with the others.

The first stage of these multi-player pieces was to work on a sound patch for two bullroarers. *Float2* (see Figure 3) used two very different analog synthesis sounds for each Bullroarer, to strongly differentiate the two users. Even using the very simple interaction of *Float*, with two voices instead of one, the overall sound picture becomes much more entertaining.

For the next stage, *Disco*, I again attempted to work with rhythmic elements in the design. This time, a basic rhythm track consisting of a number of different drum parts and a bass line was programmed into the computer. This was arranged using the first Bullroarer to control the drums by introducing new parts as it spins faster. At rest, no sound is produced; at a slow speed, the minimal rhythm of an open high-hat is produced, and at faster speeds, kick drums, a snare, a fast closed high-hat, and finally a sampled drum break are sequentially added. The second Bullroarer manipulates the filtering of a sequenced bass line from a low murmur to a very resonant pulse. *Disco* proved to be popular, so we decided to create a three-Bullroarer system based on similar sound ideas. In *Disco3* (see Figure 4), one part produces the drum sounds, one part adds the bass line, and the third part plays a number of sampled drum loops.

Figure 3. Float2 for two Bullroarers.



Figure 4. Details from the filming of the three-Bullroarer collaborative piece Disco 3.

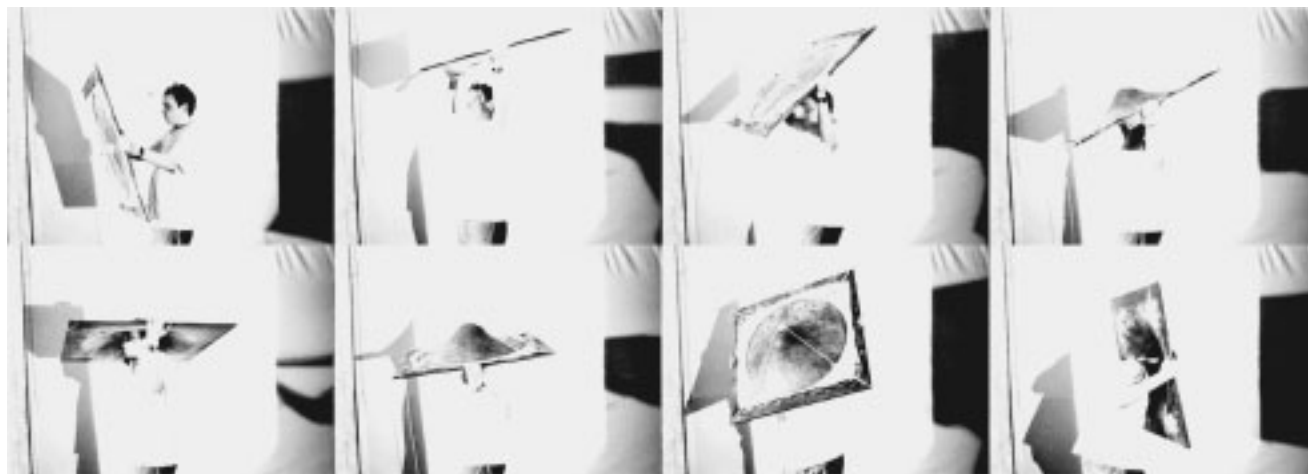


The Final Spin

Once we had created the three-Bullroarer arrangement, we set up all the collaborative pieces for an afternoon in a public space and filmed them being used by a variety of people. The Bullroarers were unusual enough in appearance that people wanted to try using them despite the air of performance that the lights and filming conferred on the proceedings. Of *Disco 3*, some felt that it was too easily mastered, while others were not completely convinced they were controlling anything. A common problem was determining who was changing

what. This suggested that clearer ways are needed to demarcate each Bullroarer's sound. One possibility would be to give players a chance to learn the sounds of their own interfaces, but this would be difficult within a public group situation. Finally, the piece successfully attracted people by offering the chance to play intricate music using a simple interface. Although playing the Bullroarers was easy and fun, their simplicity caused people to stay engaged with playing them for only a few minutes. We had created toys rather than musical instruments, but this fit our original philosophy for the work. Hence, an issue that emerges but remains

Figure 5. Mark McCabe using *Stretch!*.



undeveloped in this body of work is how to create interactive systems that can grow with the user's skills while continuing to offer fresh challenges and while remaining engaging over long time scales. This is obviously true of most conventional musical instruments, but it can also be true of traditional games and toys.

Stretch!

One of the aims of *Stretch!* (see Figure 5) was to create an interface with fewer constraints, one that presented a less prescribed way to interact with the system. An exciting aspect of the evolution of traditional musical instruments is the way in which musicians appropriate their instruments and use them in a manner never envisaged by their original creators. *Stretch!*, which was developed in collaboration with Mark McCabe, gives the player an explorative environment with hands-on control of various aspects of sound.

Process

The idea for the interface was to use sheet latex rubber stretched across a frame so that it could be physically pushed or pulled in a number of different ways to control different parameters of the sound. The sensor technology is the same type of

slider variable resistor as in the Bullroarer, with one mounted on each corner of the frame. The moving slider element of each of the variable resistors is attached to an anchor in the middle of the stretched latex sheet by a length of string. The force into the middle is balanced by an elastic band providing an opposite force outwards. Mapping each of the valves of the four potentiometers to different synthesis parameters, this interface can independently control four different aspects of the sound.

The first sound patch for *Stretch!*, *BassLine*, involved using the interface to change the sound quality of a looped sequence of notes programmed in the computer. The four axes were used to control four parameters of an analog synthesizer: filter frequency, filter resonance, attack, and decay. The results were interesting, and the interaction was an unusual way to manipulate the synthesizer. However, *BassLine* did not offer the primary control of the sound for which we had hoped. *Stretch!* works in an unusual way: when the latex sheet is pushed in at the center, several of the axes are changed simultaneously, making it quite difficult to independently control one axis at a time. This creates a stimulating, explorative interface but makes it difficult to give it a set of mappings that can be clearly understood by the user.

As I was struggling at this point to understand how the relationship between the four axes worked, I built a second sound patch, *Tone*, that

concentrates on working with timbral elements of a single note. When pressed in lightly, the object plays a tone which bends up in pitch the further it is pushed. The individual axes are mapped to some fundamental timbral parameters, such as the filter frequency and resonance as in *BassLine*, but also the sound output from the synthesizer oscillators. One axis controls the mix between a square wave and a sawtooth wave, and the other controls the pulse width of the square wave.

The interface became an instrument: sound was created only when the interface was being played, and it let the player create broad sweeps of pitch and timbre, similar to a Theremin but with the physicality and tactility of the latex sheet. This certainly helped clarify some of the workings of the interface. The mapping of the pitch bend felt particularly satisfying. Once pushed in, the greater subtlety of the individual axes becomes more apparent, and the mappings gradually reveal themselves. Another version of this kind of sound patch, *Noise*, used white noise as the sound source instead of a harmonic waveform.

Conclusions

The unusual nature of the Stretch! interface offers the player a very large space that demands exploration. The mapping of the sound parameters to the physical push and pull of the latex surface allows the interface to respond to big gestures while also offering the resolution to handle very subtle movement. However, Stretch! is a very different kind of interface from the two previous projects. It works very well as a way to explore the nuances of sound creation but seems less successful as a way to manipulate elements of music. Interestingly, this perhaps makes it closer to traditional musical instruments, which are simply objects from which sounds can be made; they contain no inherent musical content, depending instead on the musician to provide all aspects of the musical performance. Not using elements of musical content in the sound design makes the interface less immediately engaging for the non-musician but offers a less constrained set of possibilities that appeals to trained musicians.

When I think of heaven . . .

The final project of the series was a finished installation that was shown at the Royal College of Art Degree Show in 1997 (see Figure 6). The show provided an opportunity to employ a number of different strands from the previous projects within a single piece of work. To this end, I concentrated on creating an interface that would let a number of people play with sound and music together but in a physical, unusual, yet playful way.

The piece was built to be fitted as a section of wall within the gallery. The basis for the piece was the Stretch! interface. Four of these were mounted in a square formation. In addition, two smaller circular cutouts were used to create percussion pads. To make the piece big enough to be accessible by a few people simultaneously, the Stretch! panels were scaled up, with the whole wall section measuring 12 × 8 ft (3.6 × 2.4 m). The section was built using four separate medium-density fiberboard (MDF) panels containing the circular cutouts. These panels were then covered in 2-m wide, 1.4-mm thick latex sheeting. The material used was clear, but when mounted on the boards produced a yellow honey-like color. Its semi-translucency also allowed me to use lights behind the boards to enhance the circular spaces and hence the areas of interaction.

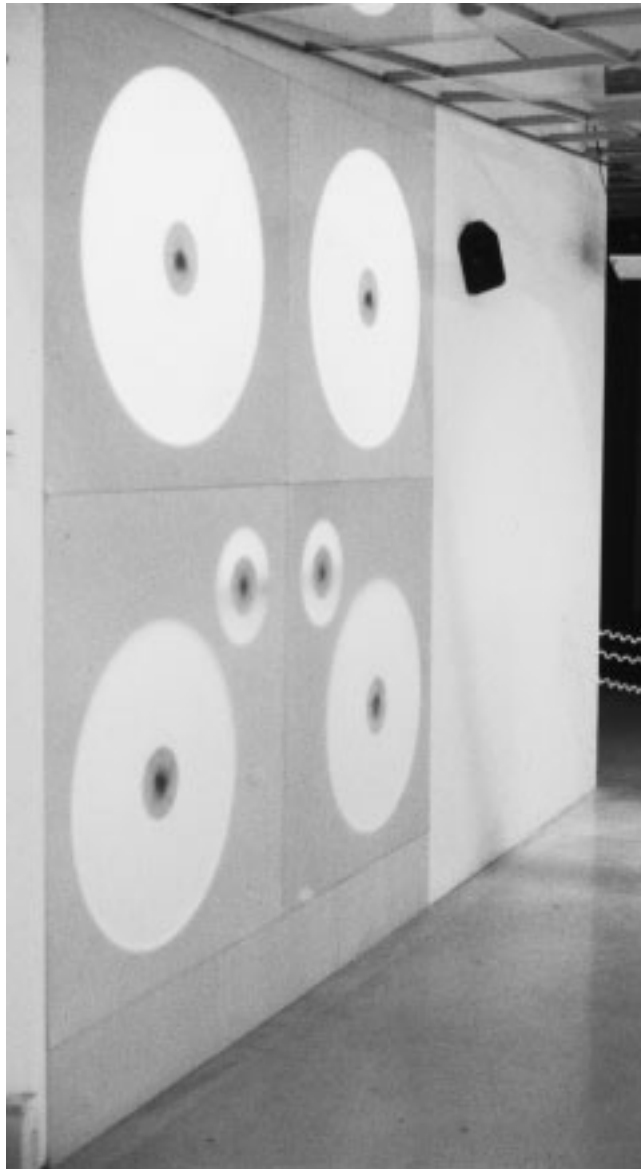
Technically, the piece used a system similar to all the previous projects, with interface sensors that are read by a Basic Stamp 2 microcontroller and the values sent to a Macintosh computer running Max. The Max patch takes the raw sensor values and generates musical information, delivering MIDI commands to a set of sound modules and effects boxes whose audio signals are sent to a conventional mixer and then to stereo speakers.

Sound Design

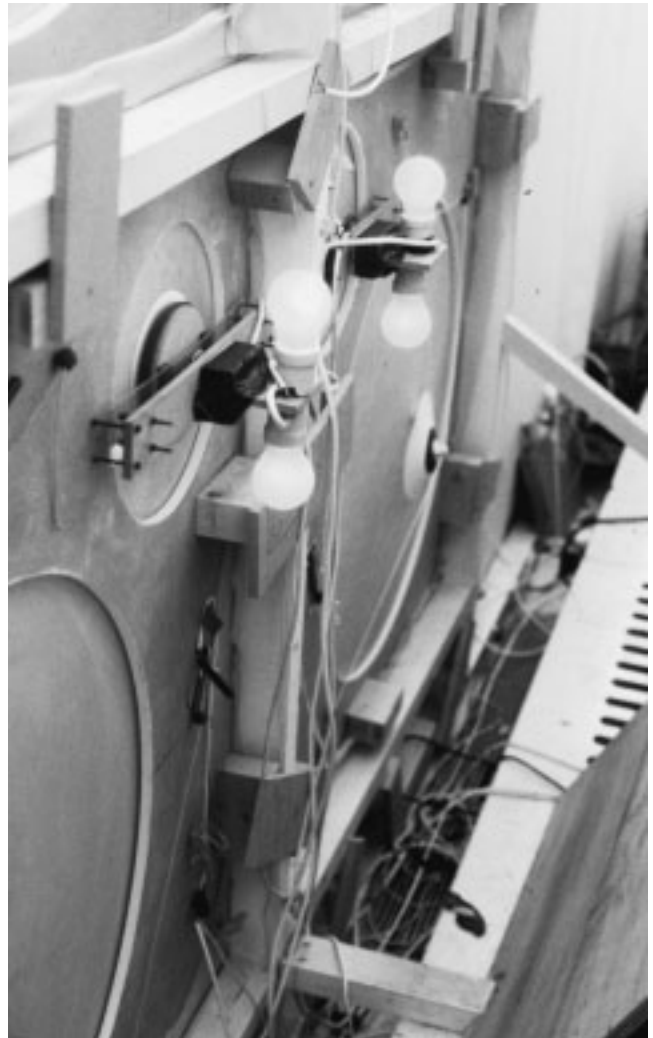
The sound design for the piece proved to be complex. Using the four Stretch! panels and the two percussion pads, I wanted the interface to be immediately responsive to players while letting them create something musically coherent and listen-

Figure 6. When I think of heaven . . . in the RCA gallery space: front view (a); detail behind the wall (b); and audience members during the show (c).

(a)



(b)



able. To satisfy the first requirement of immediate response, each interactive part of the interface creates a sound upon any nominal interaction. The two lower Stretch! panels play a tone that bends up in pitch as one's hand pushes into the wall. When hit, the percussion pads play two types of sounds simultaneously. The first is a vocal utterance taken

from a recorded voice but cut very short to give it a strong, percussive, occasionally guttural sound whose organic quality departs from the synthetic feeling of the sound modules. The second sound is a short pitched sound, whose pitch is selected by the lower Stretch! panels. These pitched sounds are stored in the computer as a sequence of notes; they

(c)



play back as a repeating loop that slowly fades away.

The upper right Stretch! panel controls the reverberation of the entire piece. When the panel is pushed in, the overall sound becomes immersed in the wash of a big cathedral-like reverberation. The more one pushes into the wall, the more profound the effect becomes.

The upper left Stretch! panel again uses sampled voices. A piece of found speech that utters “when I think of heaven . . .” was sliced into a series of separate samples. As the Stretch! panel is pushed, the samples play back such that if one pushes into the panel at a certain speed the original sample is played back perfectly; if the panel is pressed only part way in and held, a small single slice of the original sample is heard, creating a rudimentary granular synthesis effect.

Whereas the previous projects had all been built as a series of prototypes, “When I think of heaven . . .” was finished in form, concentrating on the final physical aesthetic. The installation felt minimal, but it was striking in its simplicity. Although it was presented as a flat wall, the lighting

behind the cut-out Stretch! panels gave the piece visual depth and alluded to something behind the wall. The natural latex sheeting used to cover the panels imbued the whole piece with a shiny honey-colored hue in combination with the tactile qualities of the rubber. The efforts to work toward more complex mappings in the sound design seemed to have been worthwhile, judging by the positive responses from many people who interacted with the installation. To me, the piece still felt interesting to play after two weeks of tending it during the show.

Overall Conclusions

A Rich Space

The most immediate conclusion from this work is that the primary area of development—creating simple collaborative objects for those who feel musically inexperienced—is very rich. First-time users respond enthusiastically, willingly placing themselves in performance-like situations. Unlike musi-

cians, who often approach new musical interfaces as musical instruments that demand to be mastered, naïve users respond better to the playful qualities of the objects. New interfaces that have no clear rules of usage greatly lower the user's risk of appearing incompetent.

A Collaborative Approach

The second conclusion is that the most interesting direction of the work was in creating environments that allowed a number of players to collaborate in playing music. As with multi-user computer games, the interaction between the players becomes at least as important as the interaction between player and machine. The technology recedes as the primary focus, becoming a catalyst for social interaction. With the *Disco3* sound patch for the Bullroarer, the sound manipulation is very basic, mostly turning tracks of sound on and off. However, this did not preclude players from having fun, particularly in a group in front of other people.

The Wonderful World of Mapping

Sound design for interactive music systems is still in its infancy. However, even with simple musical interfaces that offer only a single axis of control, possibilities exist to create very rich musical or sonic interactions. The key lies in how the sound changes along the control axis. The obvious first step is to map a single sound parameter across one axis of the controller, such as using the Bullroarer's single axis of movement to control the pitch of a single tone. This will work but is unlikely to be very interesting.

Instead, if not only pitch but also timbral features are altered as the Bullroarer is spun faster, suddenly the sound and hence the interface becomes much more engaging. By giving the sound interaction these complexities, we can craft musical interfaces that offer the kind of sonic depth traditional musical instruments have always had. These multiple mappings—what changes what and by how much and with what kind of response (linear, exponential, etc.)—will give new interfaces the richness they require to feel satisfying.

Future Possibilities

This work suggests a number of possibilities for creating physical environments in which people can actively explore the nature of sound and music together. Such environments do not need to be technically complex. In creating collaborative toys that are straightforward to use, the best approach seems to have been to begin with simple ideas and then add complexity until the experience becomes sufficiently engaging. It is important, however, to avoid the traditional route of adding more technology, and instead to look for alternatives that may well be easier to realize. This complexity can be designed in different ways: one can create more toys, allowing more people to play together, or one can make the sound output richer by building more layers of sound. In many respects, software offers the perfect place for complexity to lie. Visible only to the author of the system, and with infinite possibilities, it can become the crafted core of the experience. Interactive music software environments like Max/MSP and SuperCollider offer so many possibilities for creating exciting sound worlds that can incorporate and manipulate musical content in wholly novel ways. As Cage wrote in 1939, we "must explore the materials of music. What we can't do ourselves will be done by machines and electrical instruments which we will invent" (Kostelanetz 1970).

Acknowledgments

I would like to thank Mark McCabe, who was a major collaborator on most of this work. Thanks also to Gillian Crampton Smith, Bill Gaver, Nina Pope, and the staff and students of the Computer Related Design Department of the Royal College of Art, London, for support and critical feedback. I am also grateful to Bob Adams, John Eichenseer, Geoff Smith, Lukas Girling, Tim Perkis, and many others at Interval Research Corporation for giving me an excellent opportunity to start working in this field and for continuing to offer an ideal environment in which to discuss it.

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