Shaping minds musically

T Machover

Music is one of the most profound and enjoyable of human activities, yet much about it remains shrouded in mystery. Perhaps it is the combination of centrality and elusiveness that attracts an ever-growing number of psychologists, neuroscientists, neurologists, technologists, and musicians. This paper discusses two distinct but related areas — education and health — where we believe that new tools, concepts, and content can have a significant impact. Since 2001, our approach has been to bring together sophisticated and attractive new music, participatory musical activities that stimulate the creative imagination without requiring years of training, and innovative concepts about pedagogy and healing, to lay the foundations for a new field of 'active music'.

1. Active music and Toy Symphony

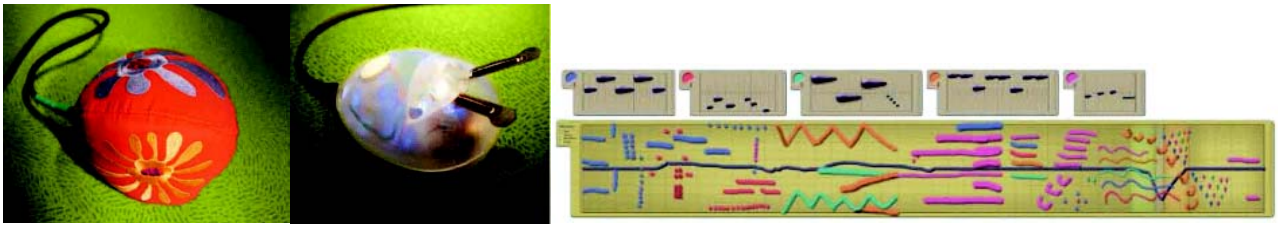
Although most people seem to love music, our culture's involvement with it is increasingly passive, not active. Sounds surround us wherever we are, in elevators, cars, airports, living rooms, within headphones, and without, in our public parks and plazas. Surely having so much music around us is a good thing, and sometimes it is. But often there is just too much to listen to, or to listen to carefully. There is more music than ever in the air, but fewer of us actually play music, sing music, or create our own music. Music rests in the periphery, like background wallpaper, tickling our senses but not engaging our intelligence.

Recent research demonstrates that we get more out of music if we absorb it, touch it, shape it ourselves [1]. This is especially important for children, since they are so well-suited to music-making (with boundless energy, emotional freedom, zeal to communicate, and flexible imagination); they are also often shut out by music's many difficulties. Musical instruments are hard to play and take years to learn. Music notation is hard to read. Musical 'language' is specialised, and the complex rules of harmony, counterpoint, rhythm, structure and form are only metaphorically connected to our common sense and day-to-day knowledge.

What if we could unlock the expressive mysteries of music first, before learning the technical foundations, if we could help young people — and others — fall in love with the joys of music first, subsequently demanding deeper knowledge once they were 'hooked'?

After demonstrating with our Brain Opera project (1996—2000) that the general public is enthusiastic about active music participation, we designed an even more ambitious project to establish a new pedagogy for creative music training, and to develop special tools to embody this pedagogy. The Toy Symphony project (2000—2003) provided an integrated series of activities as an alternative entry for children into music. Rather than develop new tools and technologies in isolation, we imagined Toy Symphony as a programme of on-line and on-site workshops, conceived as collaborations between our Media Lab team and international symphony orchestras. A major public concert was the medium term goal of each Toy Symphony event, while various activities could also be made available on a longer term basis to local children. During the development period, a Media Lab team of musicians, software and hardware designers, and pedagogy experts explored various ways of making musical experience palpable [2]. Initial ideas were based on our experience on what we had learned in the Brain Opera project [3], with an attempt to make easy-to-learn, inexpensive, tactile and fun-to-play instruments. Interface design emphasised skills common to all children — touching, squeezing, tapping, constructing — while intelligent software provided mapping models to balance user control with autonomous behaviour [4].

Based on our initial experiments, a series of special instruments called Music Toys (see Fig 1) were designed that require no special skill but which do reward curiosity, imagination, and expression. The technical magic of these new 'hyper'-instruments eliminates years of practice, and automatically provides much of the specialised knowledge



music shaper
(soft tactile controller)

beatbug
(networked rhythm)

Hyperscore
(graphical environment for composing, exploring)

Fig 1 Music Toys.

needed to pick the right note or chord, or to synchronise and jam with others. With these Music Toys, touch and gesture, whistle and hum, can open up worlds of possibility. With continued exploration and discipline, there is no limit to how far one can develop.

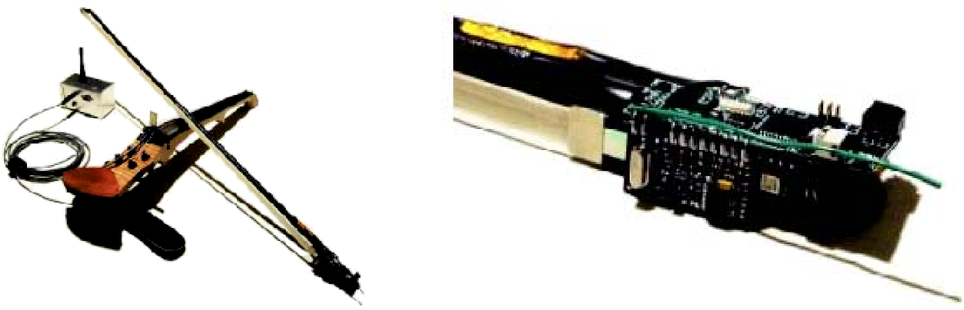
How do children learn music? The short answer is that they learn music by doing music — by interacting with musical material in meaningful ways as composers, performers and listeners. The challenge for music educators is to present children with appropriate objects, activities and situations to stimulate their natural creativity and enable them to grow as musicians. Toy Symphony meets this challenge in novel ways. Beatbugs enable children to explore aspects of rhythm, percussion and group performance, allowing tapped patterns to be retained by the instrument, sent hot-potato-like to fellow players, and modified in rhythmic and timbral complexity using a pair of PDF-sensor bug-like antennae [5]. Music shapers provide the opportunity to control both pitched and unpitched sounds by using expressive gesture and subtle touch — ideal for controlling complex timbres or patterns, and opening the doors for very young people to make music along with the orchestra [6]. Hyperscore, specially designed graphical composition software, gives children the means to create large-scale musical structures in a direct and intuitive way and to immediately hear the results of their work. Hyperscore pieces can then be transcribed semi-automatically into traditional musical notation, allowing children to hear their pieces played by small chamber music groups (like string quintets) or by entire orchestras [7]. We designed one-day and multiple-day workshops based on these activities, and tested them at the Media Lab and in the Boston area in 2001 before attempting our first large-scale public workshops in Berlin in February 2002 [8]. The Music Toys proved to be engaging and easy-to-use, allowing for maximum musical expression without many of the technical and educational difficulties associated with traditional music learning experiences.

Some of the toys are currently being produced commercially, such as Fisher-Price's 'Symphony Painter' (see Fig 2) based on Hyperscore (see section 2), while other designs are under discussion.

In order to reinforce the fact that these Music Toys represented the beginning of an ongoing relationship to music, we also designed extensions of our professional Hyperinstrument technology, providing a model to children — and audiences — of the potential of such tools when mastered by skilled musicians [9].

Fig 2 Fisher-Price's 'Symphony Painter' for Pixter Color, based on Hyperscore.

We developed a real-time signal processing system to analyse the expressive playing of an entire symphony orchestra, and to use this interpretation to let the orchestra directly control and manipulate a complex extension of its sound [10]. We also developed a new version of our Hyperviolin [9] (Fig 3) in association with violinist Joshua Bell, to increase the subtlety



Hyperviolin and Hyperbow

Hyperbow close-up

Fig 3 Hyperviolin.

of audio analysis as well as to add extra Hyperbow instrumentation to the existing speed and position measurements, adding accelerometers, strain gauges, and pressure sensors [11].

We constructed a concert programme to integrate all of these activities, providing a concrete, motivational goal for young participants, and a tangible result for audiences (see Fig 4). Each concert began with an overture that I composed, *Sparkler*, to provide a glimpse of what a future, technologically enhanced orchestra might sound like. The piece is a set of complex variations based on music important to me as a child (Beethoven and The Beatles), kaleidoscopically altered and transformed by the electronically enhanced orchestra. This piece was followed by two works for music shapers and orchestra — *Nature Suite* commissioned from the young French composer Jean-Pascal Beintus, and *Gestures*, a collaborative composition by Hugo Solis and Natasha Sinha. This latter piece — for seven orchestra members playing acoustic instruments and six children playing shapers — was especially notable for bringing together an MIT graduate student (Solis) and a 12-year old budding composer (Sinha) who worked as a team on every aspect of the piece, from brainstorming, to research, to prototyping, to composing, to production, to performance. As Solis has written of this groundbreaking experiment: '[I] tried to limit myself to being a guide for Natasha's own exploration. Suggesting, proposing, showing possibilities and options, discussing and arguing, comparing situations and giving examples, listening to previous works and teaching the principles that give substance to the digital technologies were the foundations on which the piece was built' [6].

The next piece on the programme was *Nerve* by Media Lab PhD student Gili Weinberg, for six children and two orchestra musicians playing beatbugs. This intricate, interconnected, kinetic work provided a context for the players to listen carefully to each other, responding rapidly as the seven minutes of music gained in complexity. Although the beatbugs were easy to play and learn, performing the music on stage required an intensive study period to perfect, and participating children acquired new skills of concentration, expression, communication, and dexterity. *Nerve* also turned out to be a crowd-pleaser, as audiences easily appreciated the demonstration of these skills (Fig 5).

2. Hyperscore — creativity for everyone

Many children have been excluded from active participation in music because of its technical and theoretical difficulty, and this has been especially problematic with composing one's own original music. Although most preschools in the world invite children to explore the visual world by developing free-form projects derived from basic materials such as cutting,

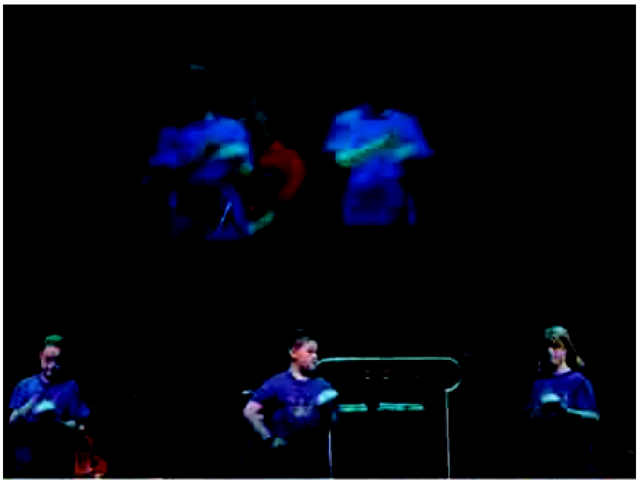


Fig 5 Performing *Nerve* on beatbugs in Glasgow.

pasting, colouring, touching, etc, the same has generally not been available for creating music. Hyperscore, developed especially for Toy Symphony [7], changes this by combining an intuitive visual interface — allowing anyone to imagine the details and overall shape of a composition, with intelligent algorithms, providing theoretical 'training wheels' for harmony, simultaneity, and continuity.

The development of this composing environment revealed several surprises (as ambitious research projects often do). At first, our goal had been to create a physical infrastructure for playing with musical material.

Originally called the 'Big Thing,' we imagined a kind of cross between Lego and Dr Seuss, with musical elements being represented by soft, squeezable, brightly coloured objects into which 'musical material' could be 'poured', and which could be plugged together to create meaning and continuity; our goal was to make a large (over seven feet tall!) building system that 'would look like it sounded' during constructivist play [12] (Fig 6). But after a year of designing versions of this physical composing environment, we came to believe that its physical instantiation was restrictive rather than liberating, partly because of the tangibility of musical abstractions, and partly because of the complexity and expense of building a toy that was both flexibly soft and combinatorially robust.

The decision was made to abandon this physical 'Big Thing', and instead to develop a more imaginative composing environment based on Paul Klee's description of his own fantastical art work as always 'taking a line for a walk' [13].

Once the Hyperscore software system was developed, it opened up a new category of activity for children participating in Toy Symphony — besides performing on stage with

Fig 4 Children performing on music shapers in New York.

Fig 6 Conceptual sketch for the Big Thing.

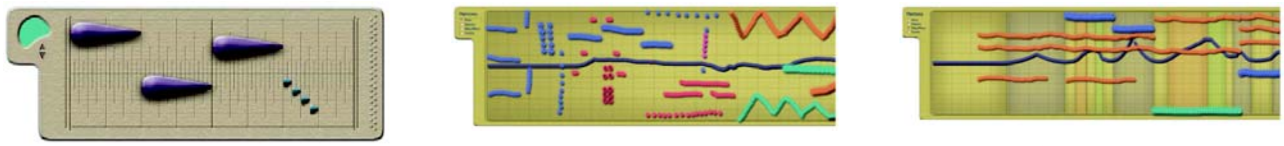
professional musicians, kids could now compose their own music for professional orchestras to perform. In each Toy Symphony city, composing workshops were held using our Hyperscore software, and the best pieces in each city were included on our programmes, performed by acoustic orchestra. Since Hyperscore is easily disseminated — downloadable to most PCs from the Toy Symphony website [14], we were able to train local mentors in its use and to initiate composing workshops well in advance of each public concert. In general, we hosted a public open house to demonstrate Hyperscore several months before the planned concert. This was followed by multiple workshops in each locale, organised in different ways (i.e. through schools, after-school programmes, museums, an orchestra or festival facility, etc) in each place depending on a variety of factors. The target age for children in our Hyperscore workshops was 7—12, and we especially sought out children who had little or no previous musical training and might especially benefit from such an unusual activity.

Hyperscore was designed to be particularly effective with novice musicians, and we had two major concerns at the outset of the experiment. Firstly, there was the fear that novices — and especially children — would not know how to begin a composition when faced with a blank screen; secondly, there was the suspicion that the more powerful and intelligent the tool, the more each piece would ‘sound like the software’ rather than like the user (imitating frequently heard music — like Top 10 AM Radio — rather than being individualistic). Both of these fears turned out to be unfounded. Children rejected the melody databases provided with early versions of Hyperscore, and invariably asked to make their own basic material from scratch. And we were pleasantly surprised time and again that no two Hyperscore compositions sounded alike, and that a relatively large percentage of children’s pieces were both bracingly original and of surprisingly superior quality.

Our Hyperscore workshops developed to encourage discovery rather than imitation. We started workshops by discussing what makes interesting motives, and then let each child begin constructing original ones (Fig 7). This led to exploration of equilibrium and interest in motives, and then to the construction of several contrasting and complementary motives. Even with something as simple as a motive, melodic contour and rhythmic definition can vary greatly, and therefore individual styles always surfaced after one or two mentoring sessions.

At this point children were ready to start combining and prolonging motives by assigning different colours to each of them and drawing with them in the sketch window. Here the power of Hyperscore became quickly apparent. Since drawing was with fragments of music rather than with individual notes, these lines and colours on the screen were viewed as powerful abstractions rather than literal representations of the music. For this reason, children were almost never attracted to draw pretty pictures and to listen afterwards; even the youngest and most inexperienced users quickly adapted to the use of Hyperscore as a formal representation system, imagining and manipulating sounds through the use of these intuitive symbols. From this perspective, it became easy to use Hyperscore to discuss with children many fundamental aspects of music such as form, contrast, directionality, intent, dramatisation, and content, issues usually reserved for graduate level composition classes. Children were able to compose one to three minute compositions, and to strengthen and perfect these — for maximum impact — over the course of a one-week workshop (Fig 8). Our workshop team was constantly surprised by the freshness of the pieces produced. And when they were performed by symphony orchestras, smiles were universally seen on player’s faces, something not often seen in the course of a typical symphony season.

After performing several of these original Hyperscore pieces on each Toy Symphony concert, the programme ended with a piece of mine — *Toy Symphony: Lullaby* and *Chorale* — which brought together all of the different resources of the project, including beatbugs and shapers, and added a children’s chorus plus a virtuosic Hyperviolin soloist. My intent was to create a piece that would dramatise the coming together of such disparate and improbable collaborators. The piece begins in stillness and builds to a rousing finale. *Lullaby* is a slow movement, which features the expressive power of the new Hyperviolin. A set of variations brings the Hyperviolin through a landscape of calming melody, juxtaposed fragments, layered sound masses, pulsating spectra, and back to the original melody, gently transformed. The Hyperviolinist uses bow speed and pressure, changes in sonority and



motive window sketch window harmony line and chord changes

Fig 7 Different stages of Hyperscore composition.

Fig 8 The author with children from a Hyperscore workshop in New York.

articulation, and general phrasing to expand, mutate, and colourise its own playing. The chorus begins with whispers, then changes into delicate percussion and finally into singing, all the while enhanced and modified by specially designed hyperinstrument software. The orchestra provides a gentle and discrete accompaniment, as if helping the violin to rock the children to sleep. *Chorale* opens with a theme sung by the chorus, growing and building in surprising ways. The Hyperviolin morphs its sound as it soars melodically, and the children add beatbug and shaper accompaniment to pulsate, scintillate, and accumulate. The core melody is taken up by the bass instruments, while violin and kids pull and tug at each other, with Music Toys 'bouncing' the violin sound around, and the violin pulling the kids' voices zigzag-like, as a magnet attracts iron filings. Violin and children reach a moment of repose, and then build with the orchestra to a culminating statement of the work's themes, recapping melodies heard in fragment in the opening *Sparkler*. As *Toy Symphony* closes, Hyperviolin, Hyperorchestra, and hyper kids have reached a common musical ground of free expression and open communication.

Between February 2002 and May 2003, *Toy Symphony* was performed in Berlin, Dublin, Glasgow, Boston and New York, with intensive workshops taking place in each city. We learned new things in each venue that allowed us to refine our workshop techniques, find new ways to involve the general public, sharpen the impact of some of our Music Toys (which led us, for instance, to commission the Solis/Sinha music shaper piece in mid-tour, to best exploit that instrument's capabilities), and discover the potential of some of our tools. Hyperscore turned out to be particularly powerful, awakening considerable enthusiasm in children who used it, and attracting many adults to start using it as well. In unlocking such a door to musical creativity, my attention was drawn to the powerful effect that composing seemed to have on a wide range of participants:

- the exploration of deep feelings without the need to describe them (to others or to oneself),
- the precise context of solving hard problems in a well-defined space (i.e. finish a piece!),
- the observation of the impact of proportions, simultaneities and groups,
- the simple but liberating sense of being able to make something personal and original that can be shared with others.

3. Music for mind and body

Hyperscore worked so well with children that we began to wonder whether the software could produce equally powerful results with a wider population. We began to wonder whether creating one's own personal music might be an especially motivating, inspiring, and even transformative experience from people who are traditionally shut out from such activities, like seniors or those with various physical or mental disabilities. With this in mind, between November 2003 and May 2004, we experimented with different models for Hyperscore use, trying workshops for families, film industry professionals, and adults in Japan, Costa Rica, and throughout the United States.

So we have begun a study of how music affects human behaviour, and how active involvement in music-making — facilitated by new interface and interaction technologies, and potentially supported by new classification schemes for mapping music to brain function — can exert a powerful influence on behaviour modification and neurological function. It is increasingly known from clinical case studies that music can affect, in very specific ways, human neurological, psychological, and physical functioning in areas such as processing language, expressing emotion, memory, and physiological and motor responses [15]. Music seems to bind to our memories in a uniquely complex way (such that Alzheimer's patients often remember — and respond to — favorite music when they have lost recall of all else). Music is increasingly used to restore speech to aphasic patients, who seem able to sing familiar songs with full lyrics even when they cannot speak. Music seems able to help stroke victims relearn physical movements, both because of music's tendency to synchronise mental functions as well as its deep and complex interconnections with our motor memory system. And specific musical activity has been shown to have the potential to provide a valuable multi-sensory environment for a variety of learning disabilities, such as dyslexia [16]. However, the required musical, neurological, and behavioural skills are seldom combined in a unified research context, with the result that the necessary underlying theories, and the potentially transformative digital sound/music which would be grounded in such theories, have not been able to flourish.

The goal should be to develop a comprehensive set of musical, neurological, and behavioural tools and techniques to investigate whether (and, if so, under what conditions) musical activities are associated with enhancements and improvements in memory, concentration, pain management, anxiety, stress, and creative imagination. We are focusing especially on technologies that enable people, at any level of physical or mental ability or disability, to express themselves musically.

In addition, we seek to make use of ways by which the brain recognises patterns in the environment, since we believe that listening to music is, in essence, an exercise in pattern recognition. Musical and sonic sequences comprise repeated tonal patterns that can vary across repetitions. Somehow, our brain is able to spot the underlying pattern, despite its variability, and can thereby discern the organising structure of the musical sequence. Without the perception of such structure, a sequence is likely to be relegated to the status of 'noise'. In other words, our brains are wired for music in the broadest sense, constantly seeking out rhythms in sensory inputs, be they in the order of seconds, or days and years. The question of how the brain learns to detect repeated patterns is one of the great unsolved mysteries of neuroscience. The answer would have implications for many fundamental issues ranging from music appreciation, to learning, to navigation and survival in the real world.

One eventual, and very ambitious, goal of this research is to develop a comprehensive understanding of how the brain discovers regularities in the world — a challenge that is justly considered a 'holy grail' problem in neuroscience. Music may provide a beautiful way of approaching this grand challenge. Studies have shown that motivation in particular, the lack of which is a core condition of many learning problems, can be enhanced by changes in background stimulus [17], and that music is a particularly effective stimulus. The brain integrates sensory information in ways that exceed the physical content of stimuli; this is the essence of cognition, as opposed to sensation, and is exemplified by the identification and processing of complex sensory stimuli such as music. While every sensory system engages the brain in this way, the most spectacular examples are in audition and vision. Discovering the principles by which the brain processes complex stimuli is a central goal in neuroscience. Using new knowledge uncovered in our own research, to begin to define which kinds of music influence people in what specific ways, and studying how specific activities which we develop can enhance general learning, is our fundamental goal. We are approaching this by creating contexts through which the subject can participate actively in a musical experience, positioned in between passive listening and sustained musical study. It has recently been shown that passive listening does not induce significant changes in behaviour or brain function, whereas sustained musical training has several limitations, including availability of the subject's time and the tendency to emphasise physical over mental activities [18]. However, engagement in music and response to musical stimuli can cause significant changes in both behaviour and brain activity [19]. We are using both affective measurement techniques and immersive musical environments designed for non-expert subjects in order to create precisely such 'active listening' experiences which we believe are crucial for both the research and teaching aspects of the present study.

4. Tewksbury — an unusual musical celebration

In order to launch our study in this area, we established a collaboration with Tewksbury State Hospital, twenty miles northwest of Boston, from January to May 2004. The goal was to test the effectiveness of patient manipulation of musical structures, as well as to investigate the use of individual musical composition for improving cognitive and physical conditions in a wide variety of contexts. The clinical sessions consisted of using Hyperscore to encourage and assist patients to compose music for musical instrument digital interface (MIDI) instrumentation, and eventually for string orchestra. As a result of this constrained and structured work with patients of various levels of physical and cognitive deficit, a large group of patients was able to compose powerful and convincing music, with little or no prior experience with computers or composition. This new music was presented at an internal Tewksbury concert and 'CD Release Party', as well as at a public gala concert to celebrate Tewksbury's 150th anniversary, featuring the Lowell Philharmonic Orchestra. This was the first time that Hyperscore had been used in a clinical context for patients with severe mental and physical disabilities.

response to musical stimuli can cause significant changes in both behaviour and brain activity

The Hyperscore sessions were held once per week, for two separate groups (Fig 9). The first group consisted of approximately ten patients from the residential mental health unit of the hospital. Most of the mental health unit patients had prior serious suicide attempts and diagnoses ranging from eating disorders, to bipolar depressive disorder and schizophrenia. Several had significant periods of homelessness before coming to Tewksbury. The second group consisted of approximately ten patients from the physical health unit. Many of the physical health unit patients had been long-term residents at the hospital, with a wide range of functional limitations stemming from diseases such as spina bifida, severe cerebral palsy, Parkinson's and Huntington's Disease, Alzheimer's Disease. Each session was an hour long, beginning with a five to ten minute introduction. This introduction served to teach fundamental aspects of the program's functionality, or basic concepts of music

Fig 9 Images from the Tewksbury workshops.

compositions and organisation. Then patients were encouraged to compose on their own. Along with student mentors from MIT and Berklee College of Music (music therapy department), we provided intermittent assistance with program functionality while giving suggestions as part of the composition process. Several of the sessions were concluded with five or ten minute opportunities for the patients to reflect on their work and the experience, and/or to play their in-process compositions for each other, followed by discussion.

As a result of this pilot programme we were fortunate enough to observe exciting and far-reaching evidence of patient change over the baseline of their typical functioning as residents of the hospital. On the mental health unit, the patient representative commented that there was a significant decrease in purging behaviour for one patient, and less self-damaging behaviour for another, due to the consideration that the patients would be barred from participation in the Hyperscore group if any such behaviours were exhibited. Then, staff members from the unit reported that the patients with schizophrenia were focused for a longer duration of time on a single task than is typically displayed on the unit or in other activities. Furthermore, one patient with schizophrenia reported that he heard fewer voices while working with his Hyperscore composition. In a general measure, patients were assessed as maintaining a maximal level of group interaction and participation compared to significantly lower levels for most other activities.

On the physical health unit, patients were able to develop unique strategies to interface with the Hyperscore program to overcome their physical and cognitive limitations.

For instance, one patient with cerebral palsy was able to control the Hyperscore program through an infra-red sensor, a receiver running a mouse control program, and a serial connection to the computer. Another patient, with a severe visual impairment, was able to use a magnifying program to manage the visual component of the computer interface. Also, a patient with blindness was able to communicate her musical ideas physically — through tapping — or by vocalising, as a series of musical relationships that were very manageable within the Hyperscore program.

Each weekly session was followed by a group meeting involving myself and the Hyperscore team, hospital administrators, hospital neurologists and psychiatrists, and arts therapy staff. Benchmarks were observed and compared for each patient, and both specific and general progress was assessed. We were not able to incorporate brain imaging comparisons into the current work, but will do so in any subsequent work.

The session work at Tewksbury Hospital was a unique opportunity that provided a novel platform for communication on a level that was previously not available due to the disabilities exhibited by the patient population. In some ways, an inability to communicate can be considered as part of the primary diagnosis for each patient that we were able to work with. On the mental health unit, the patients were debilitated as part of isolating factors of their mental illnesses. On the physical health unit, there is a clear line drawn as to the level of communication that is implied for a patient with little or no control of muscle movement in their bodies, save for eye and tongue control, and this is but one example. In general, the patients have communicative and expressive needs that are ameliorated by more than the simple presence of therapists or mentors utilising music as a tool. Adaptive and creative technologies are quite literally providing the opportunity for patients to have a voice.

In addition, composing and shaping personal music was seen to have distinct and significant advantages. Composing a short piece of music is usually very difficult, yet most barriers are eliminated with the use of Hyperscore. Guiding patients to create satisfying, complete compositions of one to three minutes duration sets a goal with realistic chances of completion, leading to a sense of accomplishment and satisfaction that most of these patients seldom experience.

Music composition also allows patients to explore personal feelings, thoughts and memories without ever needing to make them explicit — either to themselves or to others. In turn, this 'emotional protection' seemed to increase patients' willingness and desire to share works-in-progress with their peers, establishing a warm and open environment unlike any that had previously been observed at the hospital. In addition, it was noticeable that each patient pursued a very personal form of expression, and that none of the pieces created resembled each other.

The public concert (Fig 10) of four compositions created during the Tewksbury workshops was a remarkable success. Two pieces were chosen from each of the workshops (mental and physical divisions), and then semi-automatically transcribed from electronic MIDI version to full notated score and parts for string orchestra.

Fig 10 Hyperscore concert at Tewksbury Hospital.

The pieces were beautiful, attractive and moving by any standard, but were especially moving since few people had thought these patients capable of any sustained activity, let alone of this emotional and intellectual level. All four pieces were also extremely different, one from the other:

- *Peter's Country* (by Peter, suffering from severe depression) was lyrical, contrapuntal, and made careful use of Hyperscore's 'harmony' feature,

- *Heartbeats under the Staircase* (by Marlene, formerly homeless, with acute manic-depression) was all in pizzicato, atonal, spooky, and complex,
- *Dancing in the Rain, Hurry Home* (by Joannie, who is blind and has a variety of other physical disabilities) is a mini-concerto featuring piano, building up syncopated rhythms and turning from twisted and minor to major and exalted,
- *Our Musically* (by Dan, a young man with severe cerebral palsy, unable to use limbs or to speak) brought the house down with its pulsating positive rhythms and sonorous quartile harmonies.

Needless to say, the experience for these patients of having their music performed by an excellent orchestra in a public venue, and listened to by family, friends, caretakers, and peers, was overpowering. One thing that surprised all of us was the observation that all patients took great pride and satisfaction in hearing the beauty and success of each other's work, both in the workshop setting and in the final concert. The hall was packed for this event and the applause was thunderous; but a good part of the appreciation was showered from one patient to another. The sense of achievement gained from creating music seems to be contagious, and to provide many social and community benefits besides the purely individual, health-oriented ones.

5. Future Directions

Based on the insight gained from this pilot programme, there are several implications for future research that could lead to enormous impact concerning how we integrate the arts — and especially music — into health care and education. First of all, the use of Hyperscore and similar technologies as treatment modalities within the clinical setting should be measured for statistical significance as a method for achieving change over a baseline of functioning for patients with specific deficits. For instance, the hospital administration, staff, and group facilitators agreed that there were improvements in many different areas for a number of patients. If this could be shown over larger populations, with effective controls for the study, then clinical work could be drafted and reimbursed to integrate treatment modalities with technologies that integrate music into health care.

Secondly, along these lines, research that correlates patient deficits to specific interfacing strategies with technologies such as Hyperscore may elucidate novel pathways for cognition and perception related to the creation of music. Only through reproducing this work, with more custom-tailored technologies, can we begin to understand the differences in how patients with certain conditions tend to interface to overcome their pathological distinction. Hypothetically, a trend could emerge within a unique pathology, by which we could better understand cognition and the creative process as a whole.

Thirdly, to effectively resolve the outcomes of this project and similar work, controls must be put in place to whittle out extraneous factors that could potentially skew the outcome. For instance, as researchers we must determine to what extent the interface is responsible for observed changes in patient functioning, rather than the interaction between the patient and the mentor or facilitator.

Lastly, and most importantly, all of the aforementioned implications for future development imply new theories, technologies and interfaces. Hyperscore was designed for a different purpose than this use in clinical environments with patients exhibiting pervasive disabilities. While exceptional and surprising results were achieved with the current version of Hyperscore in this pilot programme, more radical adaptations of Hyperscore — and the development of next-generation systems — could allow us to gather more information, and would provide even greater insight into the clinical use of music, and the development of a theoretical basis for describing the effect of music on human behaviour, brain function, and mental and physical health.

it is possible to develop tools that allow anyone to engage in valuable musical experiences

More generally, a tool like Hyperscore can benefit from improved ability to manipulate musical details ('looking under the hood' of the graphic interface), while also providing even more powerful features to graphically shape qualitative aspects of a music composition, such as tension/release, complexity/simplicity, intensity/calm. We are currently working on such extensions to Hyperscore, as well as planning next generation systems.

Our experience at Tewksbury has reinforced our opinion that active participation in music-making is more powerfully transformative than passive music listening, and that creating one's own personal music — given appropriate tools, context, and guidance — and being able to share it with friends, family, caregivers, mentors, and the general public, should be encouraged and enabled in every way that we can, and in a wide variety of contexts.

The projects discussed above suggest that it is possible to develop tools that allow anyone to engage in valuable musical experiences, and that what might be gained extends far beyond increased knowledge of music. Such active involvement in music may turn out to be one of the most powerful contexts we have for stretching our minds, for understanding ourselves, and for reaching out to others.

And this last aspect of music may be the most important of all. In inventing ways for all to participate, we may have restored music to its most essential and important function — the ability to maintain the infinite counterpoint of individual difference while providing the harmony, literally, that binds us together.

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