VIRTUAL REALISATION:
Supporting Creative Outcomes in Medicine and Music

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Abstract

In this article, I describe findings on the impact of virtual realisation on professional skills and creativity, based on observational studies and interviews with surgeons and musicians. I also present a vision of computer-supported creativity in terms of a modular set of virtual and augmented-reality environments based around an explicit model of the creative process. I suggest that by combining these two types of study, the potential of virtual realisation technology can be utilised in a way that transcends physical distinctions of time and place, while reinforcing the cognitive distinctions that are essential for the generation of creative outcomes.

1 Introduction: VR and Professional Work

Investment advisors, surgeons, engineers, composers of music, industrial designers, meteorologists, visual artists, geologists, cinematographers, crystallographers, molecular biologists, and many others, are using computer graphics, and sometimes sounds and also tactile displays, to experience information in ways that would have been impossible, or required tremendous imaginative efforts, to realise previously. In this way, new information technologies such as virtual reality and multimedia radically change the nature of professional work and the skills required of professionals in carrying out that work. The adoption of such technology has an enormous impact on several aspects of each profession in which it is utilised; on education and training, on self-perception, on creativity and the generation of new ideas and approaches to problems. This brings fundamental changes to what it means to practise a skilled profession, with consequent changes in the public and self-perception of the professions, in what being a professional is thought to be.

At the Tools for Creativity studio, part of the Interactive Institute (of Sweden), we are currently investigating the impact of proliferating information technology (IT) on professionals such as surgeons, musicians and educators. Two examples will be described in some detail. The first is the use of a dextrous virtual reality environment to plan neurosurgery (see Serra et al., 1999; Waterworth, 2000), and the changes the introduction of this technology has brought to surgeons' ways of working, and what is possible through that work. A short account of the separation of Siamese twins with conjoined brains is used as an illustration. The second example is of a 'synaesthetic medium' (Waterworth, 1997a) used in piano performance education. This permits a performance to be experienced in a new, technologically-enhanced way, compared with other performances of the same piece, and so opens up a multi-modal channel of communication between a teacher and one or more students, or between students. Both of these technologies can be and are used between remote locations, including the home, via the Internet.

Before describing the cases, it is worth clarifying what I mean by the often abused word: creativity.

2 What is Creativity and How Can It Be Supported with Information Technology?

What do I mean by creativity? The term is often used very loosely. Does it differ from originality, innovation, improvisation, generating novelty, or problem solving? And if so, how? I will not try to define all these terms but rather suggest that we can see them all, and others, as referring to ways of achieving novel outcomes or novel ways of achieving desirable outcomes. In the application of professional skills (and probably generally) creativity is best thought of in terms of outcomes. As suggested by Janlert (2002), "the proof of creativity is in the result. Creativity is not identified as a special creative kind of feeling or mood of the person being creative. It is not identified as some spark of inspiration, god-sent or produced by some special creative conditions ….. Creativity is identified as a certain quality of a result produced, relative to the circumstances of the production and the perspective taken". Creativity, as used here, implies novelty in solving a real problem encountered by an individual in a certain situation.

Boden (1995) makes the point that human (and machine) creativity arises from the paradoxical blending of freedom and the application of constraints. Freedom to generate alternative possibilities, unhindered by practical considerations, must be combined with later reflection on how well the possibilities match practical constraints. The stages must be kept separate. Boden's view echoes evolutionary ideas in biology, such as Monod's (1971) characterisation of evolution as the result of chance alternating with necessity in a given environment. More recently, evolutionary ideas on creativity have been extended into the realm of culture and the creation of novel artefacts. Boden (2000) also differentiates between two different kinds of creativity, P-creativity (P for psychological) and H-creativity (H for historical). P-creativity is an idea that is novel to the mind of the individual only while H-creativity is when the idea is novel in the whole of human history (as far as anybody knows). This indicates that P-creativity is more fundamental that H-creativity, and that H-creativity is a special case of P-creativity.

West (2000) provides a useful summary of what is known about creativity and innovation at work. In line with the definition of creativity above, he sees the generation of a new idea as a cognitive process located within an individual. In general, people are at their most creative when alone, free from pressure, and feeling safe and positive. On the other hand, innovation often involves groups, and implementation is best done in teams. Innovation and its implementation often arise as a result of pressure or even threats from outside the group. We can see from this that very different conditions are needed to promote creativity versus the innovative implementation of new ideas.

Individual creativity is inhibited when others question a new idea too closely or too soon, when they make fun of an idea, or when they ignore a new idea. An individual raising a new idea is socially vulnerable and can be easily deterred from following through to the innovation stage. Implementation of innovative ideas, on the other hand, generally requires diversity of knowledge and professional background. But there should also be a high level of social integration within the group. An innovative group that does not inhibit individual creativity will be one where individuals feel safe, with little competition between members.

Dawkins (1976) first proposed the idea of memes, the cultural equivalent of genes, and others have developed the idea further (e.g. Blackmore, 1999; Dennett, 1995). Meme theory applies the genetic operations of copying, duplicating, resequencing, and mutating to ideas, tunes, objects, and other artefactual elements of differing complexity. Evolutionary creativity depends on variation, selection and inheritance (retention). Variation maps onto non-judgmental openness, while selection corresponds to the application of constraints. Retention is what remains after unsuccessful candidates have been eliminated (in standard evolutionary terms, what is retained are genetic features of organisms that survive to have offspring with the same features).

In line with the idea that freedom from normal constraints is important to creativity, Arthur Koestler (1964, reprinted 1990) points to the importance of the suspension of rational thought, and the role of the unconscious in being creative:

> "The moment of truth, the sudden emergence of a new insight, is an act of intuition. Such intuitions give the appearance of miraculous flashes, or short-circuits of reasoning. In fact they may be likened to an immersed chain, or which only the beginning and end are visible above the surface of consciousness. The diver vanishes at one end of the chain and comes up at the other end, guided by invisible links."

Much earlier, Poincaré (1905) had suggested that novel combinations in the unconscious have a role in the creative process. He distinguished four distinct phases, which are generally described as: Preparation, Incubation, Illumination, and Verification (to which a fifth Revision stage is often added). These are described in more detail in Section 5.

Shneiderman (2000) describes work to provide “user interfaces for supporting innovation”, based on a four part process consisting of Collecting (learning from published work in libraries and on the Web), Relating (consulting with peers and mentors), Creating (exploring, composing and evaluating possible solutions), and Donating (disseminating results). This is a very general framework for all kinds of “creative work”, but the focus in on rather mundane activities such as searching for relevant information, composing documents and other intellectual products, consulting with others, and visualising information. There is also a useful review of a few “creativity-enhancing” software tools, such as the Axon Idea Processor for producing “Mind Maps”. But existing software packages most often provide only very limited support for restricted parts of the creative process, or are concerned with general production tasks such as preparing a book manuscript for publication

Other recent authors have suggested that too much rational thought can stifle creativity and even intelligence (Caxton, 1997). De Bono (e.g. 1990) is famous for the idea of “lateral thinking” amongst other techniques that help suspend rational judgments. Part of the idea is to leave time and mental space for novel insights to develop. Another strand in understanding how creative sparks arise is the catalogue of evidence suggesting that this depends more on sensory perception than on conceptual cognition. While conceptual analysis is a necessary part of developing new ideas, original insights may depend more on sensory exploration that on conceptual analysis.

Waterworth (1997a) pointed to the way in which new technologies, by allowing information to be experienced in a variety of vivid media and forms, expand the possibilities for creative inspiration. In other words, experiencing the same underlying information in different representations, and through a variety of sensory channels increases the range of concrete perceptions through which information is experienced. These richer perceptions may then lead to more original concepts. Some people have the natural ability to experience information through several senses at the same time, a phenomenon known as synaesthesia. Synaesthetic individuals appear to be particularly creative (Cytowik, 1989, 1995). Systems that provide experiences of the same material in different modalities have been dubbed “synaesthetic media” (Waterworth, 1997a), and an example is described in Section 4.

The next section presents an unusually unequivocal example of how technology can enhance creativity, using virtual realisation to open up new possibilities in difficult surgical interventions.

3 Separating Conjoined Brains

Surgical operations are rarely as difficult as the separation of two Siamese twins, joined at the head and with inter-mingled brain tissues. Conventionally, a surgeon must interpret large numbers of 2D ‘slices’ of the brain. These slices are radiographs and are of different types – coming from different scanners – according to the type of tissue they are sensitive to. A surgeon then had to form a detailed 3D image in mind – a mental realisation of the anatomical structure – combining large numbers of 2D scans from different scanners, some showing blood vessels, others showing bone structure, and so on.

In contrast, virtual realisation of medical data allows a radiologist or surgeon to interact with an integrated three-dimensional model that combines data from several different scanners. The model can be rotated, enlarged, viewed from any angle, and selected portions can be rendered completely or partially transparent. Possible surgical interventions can be explored using "virtual surgical instruments" such as a drill, a scalpel, a marker, and a ruler (which can be used to measure *inside* the dimensions inside an anatomical structure). Specialised software tools can be used to help the surgeon identify and highlight particular structures.

What difference does using virtual realisation make to planning and a complex surgical intervention? Benjamin Carson, MD, a neurosurgeon at Johns Hopkins Hospital, Baltimore, USA, puts it like this: ‘It was fantastic. When I put those glasses on and went in to the virtual work station it was like I had them [the twins] right there in front of me.’

In his book *The Big Picture* (Carson, 1999) he writes: *‘I can say it was the next best thing to brain surgery - at least in terms of my preparation and planning for the scheduled operation on the Banda twins. In a Johns Hopkins research lab in Baltimore, Maryland, I could don a special set of 3-D glasses and stare into a small, reflective screen which then projected an image into space so that I could virtually “see” inside the heads of two little Siamese twins who were actually lying in a hospital on another continent* [Carson was in the USA, the twins were in Zambia]. *Using simple hand controls I manipulated a series of virtual tools. A turning fork or spoke could actually move the image in space - rotating the interwoven brains of these two boys to observe them from any and all angles. I could magnify the image in* *order to examine the smallest details, erase outer segments of the brain to see what lay hidden underneath, and even slice through the brain to see what different cross-section would reveal about the inner structure of the brains. This allowed me to isolate even the smallest of blood vessels and follow them along their interior or exterior surface without difficulty or danger of damaging the surrounding tissue. All of which, of course, would be impossible in an actual operating room.'*

Carson continues: *'The chief benefit of all this was knowledge. I could observe and study the inner structure of the twins' brains before we opened them up and began the actual procedure of the operating table. I could note abnormalities ahead of time and spot potential danger areas - which promised to reduce the number of surprises we would encounter in the real operation.'*

The most difficult part of the actual operation was sorting out and separating the *'overlapping, interconnected, and shared blood vessels. It required a tedious and meticulous separation and closing off, cutting through and sometimes reconstructing a massive tangle of veins. Each vein had to be isolated and taken down in the right order - as carefully as if you were defusing a bomb. Make even a small mistake and the resulting blood loss could flood the surgical field and make it impossible to locate and control the problem in time to prevent serious brain damage or death. Being able to see, study, and memorize the vascular anatomy - particularly in the crucial structure around the brainstem, the ventricular system, and the skull base - proved an incredible advantage. I've since tried to explain the benefit this way: a normal human brain is perhaps the single most marvelous and complex piece in the great three-dimensional master puzzle of creation. When you press two such complex organs together, the problems of orientation are compounded almost beyond belief. Finding our way around the abnormal venous structures of craniopagus* [i.e. conjoined by fused skulls] *twins is like being a cab driver dropped into the middle of a foreign city you have never seen to before, where you do not speak the language and cannot even read the road signs - and still being expected to do the job. This time I at least had a detailed road map to study before I got there. In fact, I felt almost as if I had successfully performed the operation.'*

Looking back on the operation, Dr Carson commented in an interview that *'There came a point when looking at their brains it appeared that there was no plane and that we wouldn't be able to get them apart, except that I knew from having done the virtual surgery before, that there was a plane and I remembered where the plane was so I began to tease in that direction and eventually the plane showed itself.'* Dr Carson was able to perform the separation successfully, and both the young twins went on to make a full recovery. This would almost certainly have been impossible without the use of virtual realisation.

The combination of detailed and integrated visualisation with interactive exploration of data lies behind this dramatic increase in the chances of successful outcomes, reflecting the increased creativity of surgeons using virtual realisation tools. Visual information has always been important to medical practitioners and in medical training, using visual aids such as charts, models and visual inspection of patients and cadavers. Of these, only cadavers allow explorative interaction but suffer from the limitations of any physical representation, as well as imperfectly reflecting the reality of a healthy individual. With this kind of tool (see Figure 1) the surgeon has the possibility to choose between different views of the data on a spectrum from specific details to views that contain all data that has been collected (an holistic view).

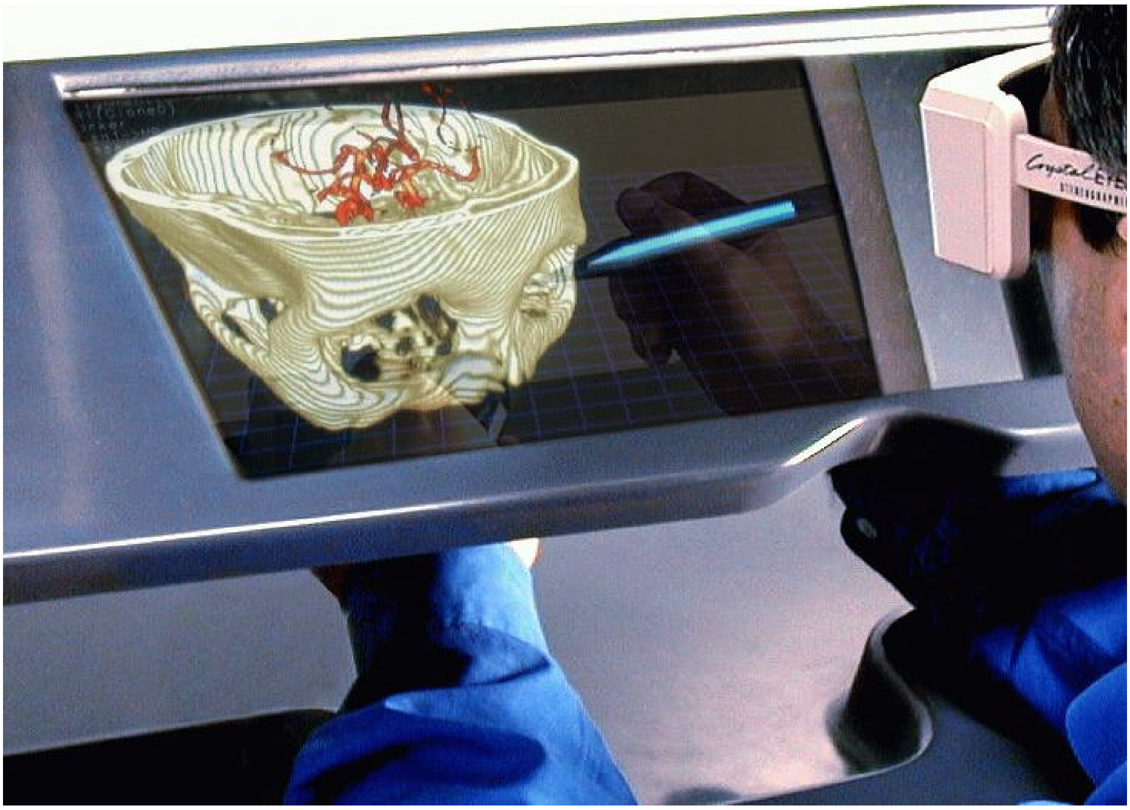

Figure 1 – The Dextroscope™ system used by Carson ©Volume Interactions 2003

In brain surgery, the scope of possible visualisations of accurate patient-specific information has, until the advent of VR techniques in the last decade, been limited to two-dimensional images from various types of scanner. Major decisions about a surgical intervention had to be made on the basis of this information, with no opportunity for direct visual inspection of the patient's brain. A surgeon would mentally realise the three-dimensional structure involved and, on the basis of this, drill down through the skull and into the brain to the target area. Virtual realisation means that a surgeon can inspect and interact with a three-dimensional rendering of the patient's brain, formed from a combination of data from the various scanners available. Each scanner reflects different types of material – typically, blood vessels, bone, and soft tissue – which can be visually represented as in nature, or differently to bring out a particular density of material, as required.

At this stage in the state of the art, there is a strong emphasis on visualisation. But this is coupled with manual interaction with the displayed data. A growing trend is to incorporate other modalities, such as touch and hearing, in the virtual realisation. Using force feedback devices allows the surgeon to feel the resistance of represented materials, by pushing a probe into the virtual realisation. Different sounds are also used to reflect tissue densities, and while this is much less natural than the use of vision or force feedback, people seem to be readily able to interpret and use this switched-modality information. In fact, modality-shifting is one of the great strengths of virtual realisation, since it enhances the likelihood of novel insights and creative outcomes.

4 Playing piano with feeling

As with the practice of brain surgery, the important part of learning to play the piano is about performing physical actions in a highly-skilled way. Going beyond reading the notes to making quality music involves the acquisition of an intimate complex of physical and mental skills, and how a good teacher imparts those skills to a good student remains an art form. Virtual realisation can, however, facilitate communication between teacher and student during this learning process. It can also serve as a “synaesthetic medium” (Waterworth, 1997a) by which listening skills are enhanced through the use of dynamic graphical displays. Beyond establishing whether or not a performer gets the notes right, it is possible to use MIDI technology (Loy, 1989) to record several aspects of a performance, including dynamics, tempo, articulation, and synchronization. If these records are then displayed in a suitable representation, it will be easier for a piano teacher to communicate to a student the distinction between the art of playing piano and the technique of playing the correct notes.

What happens when an advanced piano student comes to his teacher? Usually, the student has been asked to prepare performances of one or more compositions. It is already taken for granted that the student is familiar with interpreting the notation of these compositions, so what happens next? Assuming that the student has been practicing these works, the lesson will most likely begin with his playing one of them, probably in its entirety, for the teacher. The teacher listens to this performance and takes note of specific aspects that need to be pointed out to the student. Some of these may involve mistakes in "decoding" the notation; but, as the student becomes more experienced in notation literacy, the teacher becomes more concerned with the subtleties of interpretation—the transition from just reading the notes and playing them according to the score to making good music. In other words, how can the student move on to become a creative musical performer? A related question is how can the teacher support the student's learning process in the best way, and in which form should this support be expressed?

This transition can rarely be expressed easily in words. Communication depends more on the ability of the teacher to demonstrate to the student how this subtle quality of interpretation involves more than playing the notes exactly as they are written. Such demonstration requires cultivation of the student's ability to perceive that such a difference does exist, and it also involves the teacher's ability to perceive what the student is or is not doing by way of appropriate interpretation. This is a very subtle process which has been examined considerably by Donald Schön (e.g. 1987) as a problem of educating talent in designing. Schön analysed several case studies of master classes in musical performance, which he interprets as dealing with "designing performance." One of the lessons to be drawn from the studies reported by Schön is that the role of the teacher is just as important (if not more so) as that of the "information being acquired" by the student. This is because one of the most critical difficulties is whether or not the student has really grasped what the teacher is trying to say (and in whether or not the teacher can establish whether or not the student has grasped it). This cannot be established through words. Just because a student knows how to say the right thing does not mean he will actually do it when he brings his fingers to the keyboard.

This is not a problem of "knowledge acquisition" which would fit comfortably into the paradigm of expert systems (Clancey, 1989). Rather, it is a problem that depends critically on the ability of the teacher to exercise judgment; and, in music education, that judgment must be grounded in the skill of listening. The teacher can only assess the success of her communication with the student when she hears how the student is performing. However, if that student has not been successful, what and how should the teacher be communicating to him? As with exploring the structure of a brain, these are ultimately perceptual problems. The teacher hears certain features of the performance that indicate that the student is not playing as the teacher intended. The student must learn not only to play like his teacher but also to listen that way - to perceive the significant distinctions on which a skilled performance is based.

Several piano teachers were interviewed about the observations they tend to make during a student performance, and the skills they are trying to impart. The assumption was that these observations would reflect what teachers wanted the student to actually hear. What we discovered was that the question of what students should be listening for could be restructured as a collection of related questions:

i) **How are the dynamics being interpreted?**

This is one of the best examples of how interpretation must be more than simply "decoding" the notation. In the work of many composers, such as Wolfgang Amadeus Mozart, dynamic markings are few, if they are present at all, while they are far more abundant in compositions by, for example, Franz Liszt. However, even when they figure heavily in the notation, a precise rendering of all dynamic markings is not necessarily a satisfying interpretation; or, put another way, dynamic markings at best indicate how a performance could sound, which need not also be a specification for how it should be executed.

(ii) **What are the onset times of the notes?**

Absolutely precise interpretation is rarely desirable in performance. We all know the experience of tapping the foot to a "beat" defined by these onset times; but we are probably not aware of subtle variations in the rate at which the foot is tapped. Indeed, variation from a uniform tempo is as important as variation from uniform dynamics, often for the same reason—as an indication of "inflection" which sets off phrasing (Desain and Honing, 1992).

(iii) **How are the notes articulated?**

Articulation is basically the percentage of the time until the next note onset during which the current note sounds. Notes which are notated as staccato tend to sound for only about 50% of the time between successive onsets, while the sound of a slurred note tends to endure right up to, or even beyond, the onset of its successor. Articulation tends to define the character of a phrase, just as dynamics and duration contribute to its shape; so observation of a student's articulation technique is very important. The detailed ways in which these questions are answered determines whether the performance is experienced as lifeless, mechanical, boring or moving, expressive, creative.

pianoFORTE (Smoliar et al., 1995) is a virtual realisation system which addresses these three questions by performing computations on MIDI representations of performances. Answers to each of the questions are then communicated through graphic displays. None of these answers implies correctness: the system produces a visual description, not an assessment (see Figure 2). A faithful reproduction of the score that the student is playing provides the infrastructure for all displays. A session will typically begin by recording a student performance; but, because all performances may be easily stored as computer files, it may also begin with the teacher retrieving either a past student performance or a demonstration performance by one of possibly several teachers. The recorded performance allows the teacher to demonstrate specific elements of interpretative technique to the student, and the teacher interacts with the computerised score to select those particular portions of the recording which best illustrate the points to be made. Computations on performance data may be applied to any of these recordings, so the teacher communicates with the student by supplementing the act of listening to selected passages with that of viewing graphic annotations of the score describing how the music was performed, whilst also listening to the performance.

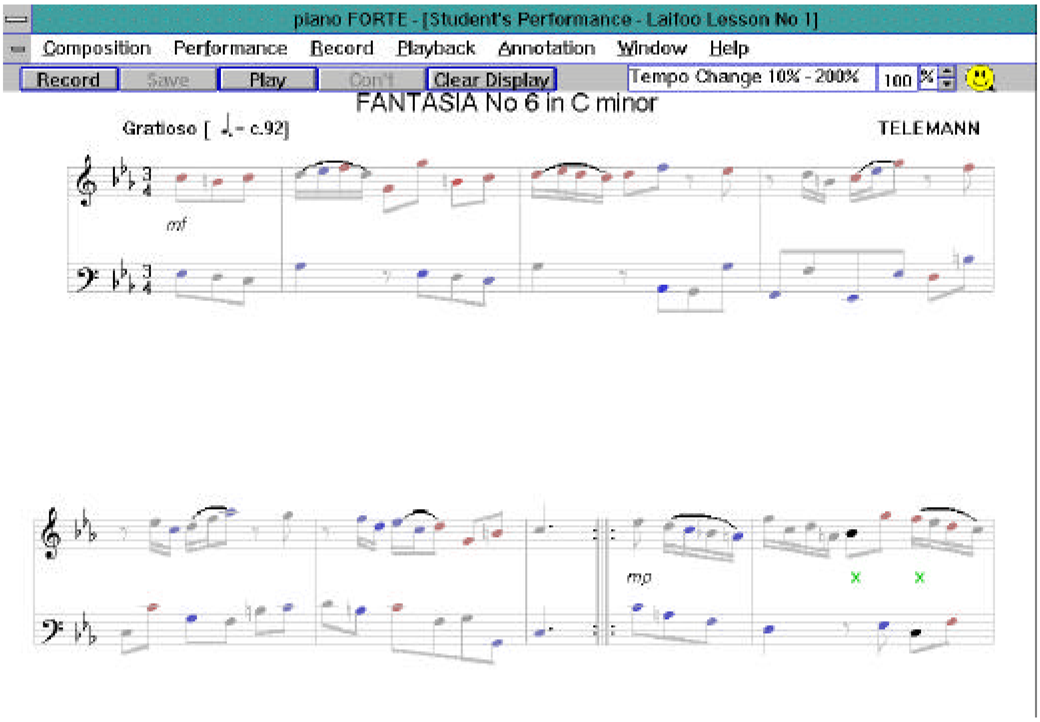

Figure 2 – Using colour to convey performance dynamics in pianoFORTE

This new approach to communicating about piano performances demands a new kind of skill from the teachers, who are generally not used to the idea that viewing a performance can be a valuable supplement to listening to it. The very perception of music changes through the use of these displays; ultimately, their primary function is to cultivate listening skills. Indeed, we have observed that even expert teachers have been able to hear things they had not previously noticed in a performance after examining the displays. Nevertheless, the displays should not be seen as a replacement for listening but as a tool for increasing awareness of what is being heard. With sufficient exposure and practice, the attentive student can eventually learn to hear those features which are first presented to him visually; so, even without the aid of computer displays, he will then be better equipped to discuss problems of performance with his teacher

User trials have revealed significant enthusiasm from the students and a ready acquisition of the necessary skills from the teachers. Students also acquire the skill of reading these displays on their own, as the graphics become a vehicle for communication with the teacher. There is thus the possibility that *pianoFORTE* can also serve as a tool for self-study. However, there is a danger of attaching too much importance to this role, since *pianoFORTE* has been designed to display the what of a performance, rather than the why. *pianoFORTE* does not detract from the role of the teacher but is designed to facilitate that role.

While many treatises have been written about the art of playing the piano (Lhevine, 1972, being one of the leading classics in the literature), the nature of piano pedagogy remains highly intuitive. Ultimately the problem is one of communicating "knowing how" (as opposed to "knowing that") knowledge (Ryle, 1984), while much of our theoretical knowledge of education tends to concern the communication of "knowing that" knowledge. *pianoFORTE* uses graphic displays as a means of facilitating the communication of "knowing how," knowledge, taking advantage of the fact that a MIDI interface can be used to provide data concerning both what and when specific actions are taken. Because these actions are limited to the scope of moving keys and pedals, one may easily represent the "how" of piano performances (by both students and teachers) in terms of these data. It is the representation of performance in such terms which serves as a basis for teacher-student communication. Activities based on the recall of fleeting perceptions are realized as concrete data structures that may be analyzed and examined in detail.

However, it is also important to observe that this new approach to communication will demand a new kind of skill from the teachers, who are not currently used to the idea that, for purposes of a critique, "viewing" a performance can be a valuable supplement to listening to it. It is not unusual for VR to lead to an increased emphasis on the visual. But what is more unusual, and perhaps important here, is the shift of modality (or, more accurately, the addition of an extra modality). The very perception of music may change through the use of these displays, and this seems likely to be an increasingly frequent effect of virtual realisation. Any digital medium can be transformed into another – from vision to sound, from sound to vision, from vision to touch, from touch to sound, and so on. But, ultimately, the primary function of *pianoFORTE* is to cultivate listening skills. With sufficient exposure and practice, the attentive student should eventually learn to *hear* those features which are first presented *visually*; so, even without the aid of computer displays, that student will then be better equipped to discuss problems of performance with any teacher, even one who has not had experience with the *pianoFORTE* system.

One of the biggest dangers of computer music as a technology is that it detracts from the behavioural aspects of music as an art form. Music is neither the notes on a printed page nor the motor skills required for the proper technical execution of those notes. Rather, it is a far more elaborate complex of behaviour in which the making of sounds is tightly coupled with their perception (Smoliar, 1994). Whether one is composing music, performing it, or just improvising, listening is still the paramount skill. The ultimate goal of this example of virtual realisation is to make us all better listeners. This skill is equally important whether we make our music at a piano keyboard or at a computer workstation.

5 Virtual Realisation: replacing cognitive space

The two examples of virtual realisation presented above, clearly represent cases where information technology can enhance quality of outcomes, and perhaps creativity. But a major problem with many current uses of information technology is quite the opposite - that they reduce the ‘cognitive space’ in which people feel they can be creative. A large part of the reason for this is the progressive loss of the distinction between work and elsewhere – especially the home. When we are always contactable by e-mail, mobile phones, and SMS, it seems likely that our creative capacities will be compromised. This is because time spent out of the workplace –

and, traditionally, away from the technology and communications found in the workplace – is actually vital to creativity. Home workers may organise things to have periods of inaccessibility at home, times when they do not look at e-mail or accept incoming phone calls. This is almost never the case in a professional work environment.

Technologies of virtual realisation, such as those mentioned above, also have the capacity to reinstate necessary distinctions as a by-product of the characteristic way in which they support the 'concretisation' of information. They can provide a range of types of virtual environment that support not only communication, conceptual work, and rich sensory experiences, but also play, exploration, introspection, relaxation and even meditation. Our current approach is based on a three-dimensional model of experience, comprised of *locus, focus* and *sensus* (Waterworth and Waterworth, 2001a).

Locus captures the extent to which the observer is focused on the real world or a virtual model. *Focus* describes the nature of the user's attention, specifically whether they are attending to currently present stimuli (from the real or virtual world) – in which case they will experience a feeling of *presence* – or are attending to information which is not currently present in the real or virtual environment. The former can be characterised as perceptual (or concrete) processing, the latter as conceptual (or abstract) processing. I refer to this latter, reflective state of mind as *absence*. Finally, the *sensus* dimension refers to the level of attentional arousal of the observer, and ranges from awake and alert to totally unconscious. Refer to Waterworth and Waterworth (2000, 2001a) for more details of the model and its application. The three dimensions of the model describe a design space for what I call "Creative Spaces" – virtual realisation environments specifically developed to support creativity.

The *Creative Spaces* we are developing correspond to one or more of the stages of a hypothesised cyclical process, which carries the individual through changes along the three dimensions of experience outlined above. The suggested process consists of five stages: sensory stimulation, inactivity, conceptual exploration, recollection/reflection and selection. In more detail, the process is as follows:

1. Sensory stimulation (varying modal form for the same content). Here the idea of modality shifting in so-called *synaesthetic media* (Waterworth, 1997a) is applicable – emphasising perception rather than conception, thus inducing a strong sense of presence and emotional engagement. The two examples given earlier fall into this category

2. Inactivity (or HCI; but in this case, it is human-computer *inactivity)*. Here the participant is encouraged, with technological assistance, *not* to focus consciously on the issues or problems under consideration. This can be done in various ways, but all involve the inducement of a calm, free-floating sense of low-level awareness. Seclusion in a personal creative space, safely open to emotions, will often support this phase (see Waterworth and Waterworth, 2001b).

3. Conceptual exploration (ideas in action, manipulating memetic elements). Here the strong emphasis on pure perception of 1., and the relative

unconsciousness of 2., give way to more conceptual activities, such as the synthesis and evaluation of new combinations of memetic elements. The participant alternates between mild presence and mild absence as he or she explores information models in a detached way (see Waterworth, 1997b).

4. Recollection and Reflection (assessment of results against goals). Conceptual faculties are now fully engaged in a more analytic stage of the process. The participant is highly conscious but no longer feels present in the current (real and/or virtual) environment. Rather, he or she is fully engaged with concepts generated during the creative process. However, earlier phases may need to be re-experienced, through the replaying of earlier situations. This will tend temporarily to recreate the conditions of those particular phases.

5. Selection, and deletion of unwanted materials. In this stage the participant is engaged in critiquing and editing the results of earlier stages, and so feels strong absence, but is reconnected to the real world through reflecting on the feasibility of the ideas generated earlier in the process. The result of this phase may be to re-enter the process at an earlier phase.

The stages of the process match standard views of creativity (which are mostly derived from Poincaré, 1905) quite closely, but each component utilises computer-based informational techniques such as virtual reality (VR), augmented reality (AR), multimodal and cross-modal information presentation, and memetic manipulation (by computer and/or by the participant).

The transition from stage 1 to stage 5, as can be seen from the descriptions above, is a move from passive, conscious being, in a state of mental presence, to more active, conscious doing, in a state of relative mental absence (see Waterworth and Waterworth, 2000 for more details). Although the process is described in linear form, it is actually cyclical. The final stage will often lead to a realisation of the need to re-enter the process to develop insights further or just to start all over again. It will also often be the case that participants feel the need to enter or leave the process at a particular stage. This flexibility is facilitated by a modular approach: people should use the components they feel they need in light of their creative needs.

The potential to use technology to help develop professional skills, and to carry out professional work in creative ways, has never been greater. Although some existing skills (such as mental realisation) will be diminished, greater possibilities are opened up. But technological trends towards mobility and networked information systems mean that this trend is no longer limited to the traditional workplace. More and more, professionals carry out parts of their work from home, and this is part of a larger tendency for the distinction between work and leisure, workplace and home, to diminish. However, what is known about how creative ideas arise indicates a strong need for distinctions of location and mindset of the kind that are now disappearing.

This is the paradox of new technology: it provides tools that can, if used appropriately, enhance creativity in the exercise of professional skills; but it also often removes distinctions between environments and ways of working that are themselves necessary for creative work. To solve problems creatively people need, first, a problem they are intensely interested in solving. They need to attack the problem with all the technical resources at their disposal. But if the needed solution is truly novel, the approaches they have used before will be unlikely to succeed. This is when they need to step back, forget the constraints imposed by previous ways of working, and allow the cognitive space needed for creativity to open up.

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