A Qualitative Analysis of Composers at Work

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Abstract

This paper presents an empirical study of electroacoustic music composers at work, using qualitative research methods. The study is based on experiments in which composers were commissioned to work on pieces using their own familiar software and hardware environments. Rich data was collected through multi-angle observations, interviews and artifacts produced. The paper presents the motivation for this research and reviews related work. Methodology and experimental design are then outlined, followed by a summary and discussion of preliminary results. These identify 'sensitizing concepts' of our problem space and provide the basis for the second phase of our ongoing research. We conclude by relating the results to requirements for enhanced composition systems which might better support creativity.

1 Introduction

This paper presents a study of an elusive aspect of computer music, how composers interact with computer-based composition systems when they are being creative. We describe experiments in which we have observed composers at work in natural settings and analyse the results, using qualitative research methods (Eaglestone et al 2001b). This research has been conducted within the context of an ongoing study of how composition software can be enhanced so as to create a more fertile environment within which creativity can occur (Eaglestone et al, 2001b)

The first two sections briefly review motivation for this research and related work. The remainder presents part of our empirical study. Methodology and experimental design are discussed, followed by a summary and discussion of preliminary results. We conclude by relating the results to requirements for enhanced composition systems which might better support creativity.

2 Motivation

Electroacoustic music composition software aims to make available to composers, services by which they can create compositions, i.e., to retrieve, manipulate and combine musical artefacts, and environments within which those services can be used creatively. Research has focused on composition services, as is evident in ICMC proceedings, which provide a showcase for new audio-related techniques and composition software.

However, research into software environments for composition has been largely neglected. Instead developers have applied current wisdom on good software engineering. Accordingly, evolution of composition software has largely paralleled evolution of paradigms in software technology. Early systems, e.g., csound (Moore, 1990) and cmusic (Vercose, 1985), supported asynchronous use and resembled assembler programming languages, whereas subsequent systems introduced higher-level abstractions, and later object-orientation. Similarly, synchronous systems with graphical interfaces have superseded asynchronous text-based ones.

There are exceptions to the above, where software diverges radically from conventional software engineering wisdom. For example, Thonk (http://www.hitsquad.com/smm/programs/Thonk/) generates sounds from audio files using granular synthesis, and boasts that users have "no control whatsoever" over the process. Thus, this tool can generate unanticipated material to solve "writers blocks without them having to think at all". However, such tools are the exception, and for the main part, composition software has followed a more conservative approach.

Our research suggests inherent tension between accepted software engineering and requirements of creative composers (Clowes, 2000; Eaglestone et al, 2001a, Eaglestone et al, 2001b, Eaglestone & Ford, 2002). This can be explained in terms of models which characterise creativity as "divergent" thinking (Guilford, 1967) in which associations are made at a high level of abstraction between apparently

dissimilar concepts. The extent to which an idea may be thought of as "creative" is time- and context-dependent, since a creative idea can rapidly become a cliché through acceptance and repetition. Instances of creativity are often thought to occur as a sudden perception or realisation, occurring when the person is not intensely focused on the particular problem. As Gregory (1987:171) has noted:

"…our brains are at their most efficient when allowed to switch from phases of intense concentration to ones in which we exert no conscious control at all."

De Bono (1987) has described the first stage of thinking as the *perception stage* - how we look at the world, and the concepts and perceptions that we form; and the second stage as the *processing stage* - what we do with the perceptions. Logic can only be used in the second stage since it requires concepts and perceptions to work upon.

Given this explanation of creative thought, one could reason that computers are irrelevant to creativity, and particularly to De Bono's perception stage (De Bono, 1987), since they are better at convergent processing tasks whereby ideas of a creative thinker are elaborated and refined. However, computers have become an integral part of composers' working environments, which begs the question, is current composition software a help or hindrance to creative aspects of the composition process, and how can it be improved to provide more fertile environments? This is the question that our research, described in the remainder of this paper, addresses.

3 Related Work

Research into creative composition processes is sparse and focuses mainly on conventional (pitch-based) composition from musicological and educational perspectives. Four theoretical perspectives have been taken in this work (extensively reviewed in (Collins, 2001)): stage theory; emerging-systems theory; information-processing theory and Gestalt theory. In the first three cases, composition is reduced to a procedure, which, though useful in understanding in retrospect how specific compositions were created, cannot form a basis for composition software. It is clearly inappropriate for generic composition systems to constrain composers by imposing generic working methods and procedures. Gestalt theories provide a more promising basis, since the focus is on organizational aspects of problem components, and creativity through re-configuration of those components. This is compatible with the model of creativity as divergent associations through flashes of inspiration, discussed in the previous section. However, with the exception of Collins (2001), work in the area has focused on perception of music, rather than composition.

Empirical studies potentially provide insights into composition. However, though widely used in audio and music perception research, they are rarely used in studies of the composition processes (Sloboda, 1995). The exceptions either analyse case study data through observation or "near to the event" documentation of professional composers at work (Reitman, 1965; Eaglestone et al 1993, Collins 2001), or collection of data through controlled experiment. However, the latter have involved only trivial exercises, typically performed by students or children, often musically untrained (e.g., Bamberger, 1977; Davidson & Welsh, 1988). Specific limitations of empirical studies are a lack of "time-based" analysis, or studies in naturalistic settings (Collins, 2001).

The nature of creativity in electroacousic music composition is largely unresearched, though there exist a number of reflective and introspective papers on requirements of individuals, often with proposals for future research directions. For example, Emmerson (1989) elaborates a simple model of composition and uses it to motivate a manifesto for future research, centred on the idea that the electroacoustic music community should establish experimental analysis as a partner to experimental composition. Two rare empirical studies are the Tema project (Eaglestone, 1994; Eaglestone et al, 1993) and Clowes' (2000) survey of composers' attitudes to the software they use. The former applied software engineering methods to analyse the composition of the Tema electro-acoustic ballet music (1986), composed by Tamas Ungvary and choreographed by Peter Raijka. Data for this study was Ungvary's comprehensive diary of the composition period. Though a result of this study was an object-oriented model that provided a framework for a particular composition style, with hindsight, the researchers now believe that the main value was the qualitative research through study of electroacoustic composition in a naturalistic setting. Clowes (2000) surveyed composers' attitudes to software they use, using qualitative and quantitative methods, including questionnaires, interviews and the mining of Internet discussion group archives.

Results of these two studies largely support the above model of creativity and suggest software features that may better match aspirations of composers (Eaglestone et al 2001a). However, they represent only a modest start to investigations in this area. There is a clear need for further research to establish a base for such developments.

In summary, creativity in composition, electroacoustic in particular, is largely under researched, particularly from the perspective of composition software. Analysis of composition

according to Gestalt principles warrants further investigation. It is also important to study composition in naturalistic settings. A variety of methods have been used in the research reviewed, which poses the following questions: which have the greatest efficacy, in which situations should they be used, and how can they be best used in combinations to achieve triangulation? These observations motivated our research presented in the remainder of this paper.

4 Methodology and experimental design

Our choice of research methodology to establish a research base for composition software support for creativity was problematic (Eaglestone et al, 2001b). As Laske observes,

"the kind of musical knowledge that, if implemented, would improve computer music tools is often not public or even shared among experts, but personal, idiosyncratic knowledge…the elicitation of personal knowledge and of action knowledge still awaits a methodology…" (cited by Polfreman, 1999:31).

We concluded that both qualitative and quantitative approaches are appropriate. However, there is a need for a preliminary phase of study that is predominantly qualitative, so as first to establish basic parameters of the research area and research "tools". Further, we identify an immediate need for qualitative studies of professional and expert composers at work. We then envisage a second phase, in which both qualitative and quantitative methods will be used in tandem. Research-based invention of software devices to improve support for creativity are therefore a future aspiration, at which stage engineering methodology will also become appropriate.

A naturalistic and holistic approach was taken to the research on both theoretical and pragmatic grounds. At a theoretical level, arguably (see Ford, 1999 for a review) a mapping can be made between (a) a relatively holistic approach to perception and information processing and (b) creativity or divergent thought. At a practical level, this approach is particularly appropriate to the investigation of problems and phenomena which are not clearly understood and do not benefit from a large body of existing theory. Arguably what is required most urgently in this field is what Olaisen (1991: 254) has termed sensitising (as opposed to more definitive) concepts. These are somewhat tentative and speculative concepts that:

"... offer a general sense of what is relevant and will allow us to approach flexibility in a shifting, empirical world to 'feel out' and 'pick one's way' in an unknown terrain."

Research aimed at discovering sensitising concepts is particularly appropriate for discovering "what we don't know that we don't know" as opposed to "what we know that we don't know", the latter arguably benefiting more from the relatively analytic and atomistic research more characteristic of the physical sciences.

The study sought to investigate the phenomenon of creativity as a complex holistic interaction of factors - including the "natural ecology" of the phenomenon as it takes place within a broader relatively naturalistic context. Multiple perspectives of the phenomenon under investigation were sought.

The research design of the first phase of our investigation evolves around in-depth case studies of only a few composers. Our approach follows the naturalistic paradigm, described by Lincoln and Guba (1985), which stresses existence of multiple constructed realities and the need to remain true to context.

A central aspect of this naturalistic paradigm is the triangulation of different data gathering methods. According to Erlandson et al (1993), triangulation leads to credibility of the naturalistic inquiry, and hence increases the truth value of the study. The term credibility replaces the notion of "internal validity" in a more conventional inquiry.

An equally important feature of the naturalistic mode of inquiry is the absence of a clearly defined hypothesis before the data collection begins. Consequently there is no predefined goal how to analyse the data, but data collection and data analysis are an interactive process, and in an ideal situation, theory will emerge from the data alone.

In our preliminary study we are observing composers from multiple perspectives, since a single view, e.g., computer interactions only, can give misleading clues. Also, we are taking care to use data collection methods adapted to the needs of the composer, since data collected in an unnatural or uncomfortable setting may be meaningless. We have taken care in the choice of subjects, since we believe that the relationship between researcher and subject is of great importance and determines the openness of composers, both conscious and subconscious, to the observer.

Collection of data through observation of composers is problematic. It is not possible to see into the minds of composers, as we would wish, and so inferences must be made from that which is observable. We therefore attempted to capture as complete a picture as possible through a range of techniques, i.e., verbal protocol techniques, real-time computer data, video recording and unstructured and semi-structured interviews.

Based on results of previous research and personal experience of the researchers involved, we

tried to benefit from the notion that electroacoustic composers often regard externally imposed limitations as welcomed challenges around which to design their compositional strategies (e.g., in (Eaglestone et al 2001a)). Our brief for the composers was therefore to compose a piece of electroacoustic music in a single day, using their own familiar set-ups. We saw that as a fairly natural and acceptable imposition which would allow us to be present with the composers during the entire composition process.

With the rationale to make the process of verbalisation as unobtrusive and natural as possible, in the first data collection exercise, two composers working together on a single composition were observed. However the composers request to work on separate computers during the first, and longest stage of the composition process, their obvious reluctance and difficulties to increase the verbal exchange during this first stage, and the shortage of time, strongly implied a rethinking of the methodological approach. In the reflective interview, one of the composers made clear that he would feel a lot more comfortable to talk concurrently about what he is doing while working on his own. The next observations therefore involved only one composer working within a protracted period of time. The observation of composers in this more loosely defined setting also revealed difficulties in capturing the process of a particular composition, because the composers' work was much less linearly than expected, i.e. it was common for composers to work on different pieces simultaneously. The intent to capture a particular composition in a procedural fashion was therefore sacrificed for the notion of observing composers as they would normally work. This new approach was viewed by the composers in a more positive light and the verbalisation during the composition process was far more prolific.

The data generated was extremely rich and in particular the multi source computer data posed difficulties in terms of manageability and synchronization. In particular it was difficult to examine data with the intent of reconstructing the composition process in a procedural way. Instead, we chose to analyse data in a non-linear way by coding different sections of all data types produced and placing them into different categories. We then established relationships between the different categories that formed the basis for our attempt to derive models of the compositional process. Thus, we applied the spirit of a qualitative grounded theory approach, as expounded by Ellis (1993):

"The model derived should organize the features or the data in a coherent form that relates both to the perceptions and concepts of those studied and to the viewpoint that the researcher is developing. In that sense, although the concepts are derived from the data, they are not simply a restatement of the data. In developing the model with its attendant categories, properties, and relations, the researcher embodies the perceptions and activities of those studied in the model but in a way that allows them to be understood in other terms."

Accordingly, rather than attempting a procedural or comprehensive model of creativity in timbre-based computer composition, the following analysis identifies sensitizing concepts which more clearly establish parameters of the problem. Further we concentrate on those emerging aspects that have not yet been looked at in previous studies in favour of more obvious and previously discussed aspects of creativity, such as the role of serendipity. However where appropriate we discuss findings of this study with reference to previous studies in the electroacoustic area.

5 Preliminary Results and Discussion

In order to analyse creativity in the context of electroacoustic music it is essential to understand it not as simply another strand of classical music. Electroacoustic music is not merely concerned with its 'musical' outcome, but often equally important is the development of new tools or at least new ways of using the tools available. Hence creativity in electroacoustic music can not be determined by purely taking into consideration work with the sound material, but also must consider other artifacts, such as home-made software, that has been created to produce those sound pieces. It seems that electroacoustic music is not so much judged, within its community, by what it sounds like, but by what made it sound. In some ways electroacoustic composition can therefore be better understood in terms of research rather than artistic design.

However, it would be too simplistic to generalise the above notion since composers are very different in their approaches.

With regards to the dichotomy between creating music for the music's sake and creating music as a showcase for new tools and techniques we have identified three classes into which composers can be loosely grouped.

Our first group comprises composers for whom creation of computer related tools (i.e. software, hardware interfaces) is a natural accompaniment to composition and is inseparable from the process of composing. Composers in this category also consider it normal to adapt their way of thinking to the way the computer is structured in order to mediate their ideas to the computer, even if this means that "there is a constant battle going on."

One composer succinctly characterised the problem which this group faces, as follows:

"…when the computer becomes an interest in itself, in terms of certain programming aspects, … the computer takes over as an interest in its own right, over and above sounds…"

The second group are instinctively more concerned with engaging with the sounds themselves, i.e. composing with the tools made available to them, but seem to feel the need to deal with aspects of tool creation, i.e. computer programming etc., because of "peer pressure". The importance of the structure of the social interactions surrounding computer use has already been highlighted by Ungvary when he discusses parameters of human computer interaction (Ungvary & Kieslinger, 1998).

There appears to be a strong notion within the (academic) composing community that the quality of a musical outcome is directly related to the complexity and idiosyncrasy of the processes involved in creating those sound pieces. The question remains whether originality of processing necessarily results in a high quality and originality of the sound material produced.

The third group of composers are similar to the second one, with regards to their natural preoccupation with sounds rather than with the tools. However, unlike the second group they do not worry about technical sophistication involved in the production of their audio pieces and hence are able to better focus on the sounds themselves.

"I don't care about it [self-written software tools] …, all that stuff is bullshit, …, it's just tools and you've just got to use whatever you feel comfortable with."

This does not mean that they are not interested or do not critically engage with the tools they use, but will rather try to push the tools they know to new boundaries to create original sound events.

"I think probably more than anything I have tried to find interesting, say, audio events from mal-appropriation of existing programs and so on, and I tend to more take an existing piece of software, just an average, ordinary piece of audio software, and try to enhance any idiosyncrasies."

It has been suggested in a previous study (Clowes, 2000) that composers do not feel the need for a single audio application – the "holy grail" of audio software- that would facilitate them with all the processing and arranging power they could wish for and make the existence of multiple applications redundant. This study has found further support for this. We have found that the use of multiple audio applications during the compositional process is not only a phenomenon that composers have learned to live with, but also has an important positive impact on their compositional process and appears to support their creative behaviour.

On occasions, for example, when a particular sound was needed, the composer would quit the arrangement program she was working in and open up a more specialised application for the creation and transformation of sounds. This quite logical and problem focused action would then often lead her astray from the original intentions, because the new sounds inspired her to wander off in a completely different direction and not return to the original arrangement for quite some time.

The switching of applications could be viewed as a hindrance for the composition process, as indeed it will often prevent the composer from focusing on the original problem (creation of new sound for a particular section in the arrangement). This view would certainly hold true if we assumed that electroacoustic composition was subject to any demands on (cost/time) efficiency. However, those criteria will enter a composer's mind only in rare circumstances whereas usually their top premise will be to create interesting, new sounds – at whatever 'cost'. Viewed from that perspective, the switching of applications is a stimulus for creativity because it frees composers from getting stuck on a particular problem. Instead the diversion catalyses the expansion of ideas and possibilities.

Our observations have shown that paradoxically the visual senses do play a major role in what is often referred to as acousmatic composition. On a very basic, perceptual level this even applies to the mere look of the hardware as well as software interfaces. One composer even tried to explain his adverse attitude towards command line based programs for esthetic reasons!

"I think very visually when I think about sounds. Maybe that's why I don't like text based programs, because they look so awful."

The same composer positively commented on the unusual look and feel of Metasynth (http://www.metasynth.com). In this software environment the normal desktop environment is completely hidden by a black canvass and the software application takes over completely – leaving the composer with only the waveform representation of the sound sample and various sound editing tools. The composer observed that this masking "helps me to concentrate on the task I am doing."

At a procedural level we observed that even when it comes to editing sounds (cutting and pasting) or when placing sounds into the time-lined arrangement environments composers are often led more by visual cues than by auditory ones.

"[…] sometimes when I edit, you know, obviously I can recognize where certain audio events are visually, and I cut according to that. I don't even listen."

Despite the fact that the visual representation of sound is generally regarded as an advantage by composers we got a strong impression by looking at the computer data that the visual score representation has the potential to negatively influence the compositional process. This is because it can give misleading information about sonic material and can

also distract from the listening process. For instance, if there are many score events in a given section the composer might be misled by the event density to feel that the section is "busy" enough or "too busy", even if the sonic material is actually quite "thin", and vice versa.

To some extend the negative, or at least distracting, impact of visual representation of sound (events) is supported by the fact that composers would frequently request to listen to composition in a totally acousmatic situation, i.e. from minidisk over a hifi system.

The impact of vision on auditory perception is a known phenomenon in experimental psychology. For example, in the McGurk effect (McGurk and MacDonald, 1976), the movement of a speaker's face and lips has a large influence on the perception of speech. Similarly, visual stimuli influence the auditory localisation of sounds in space (Wallach, 1940). Clearly, what we hear is influenced by what we see - and composers may elect to work from a purely visual representation of sound, or to disregard visual cues in order to achieve a "pure" listening experience.

A further preconception was that the *semantic gap* between conceptualisation (in the mind) and relalisation (in the software) would be a major impediment to creativity. However, this was found to have positive connotations and reinforced a theme that emerged throughout this study and was very prominent in previous studies (Clowes, 2000): Software limitations can be turned to advantage.

The availability of easy-to-use, heavily destructive (real-time) processing tools as well as the easiness to assemble a huge number of sounds over a short period of time seems to create a situation where composers are not aware anymore of the processes involved in their sound manipulation. This can lead to over-processing and over clustering of sounds and consequently results in sound pieces which do not refer to any common, shared experience but the experience within the composing community. Thus the accessibility of electroacoustic music to a non-expert audience is effectively denied. Maybe there should be some form of feedback from the computer regarding the amount of processing that is involved in certain operations so the composer has an objective basis on which to assess how much she is actually doing. The problem of over-processing is widely acknowledged by members of the composing community. One composer commented that he "likes the gap in command line based application, because in very user-friendly applications like ProTools he feels he often does too much."

There was evidence in all observations that a lot of the creative process is happening away from the computer, e.g. between computer based composition sessions and during field recordings. Also, a very short interruption from working on the computer can act as a huge inspiration for the compositional process, similar to the catalytic effect of switching between computer processes previously discussed.. A good illustration of this, captured on video, occurred when one composer got out of his computer chair to pick up a metal tube nearby, recorded the sound of the hit tube into the computer and then continued to work on the computer. Even though the time spent away from the computer was less than 5 minutes, it became evident from the procedural protocol of the observation that in the following 15 minutes the composer went on to create the most "significant" (in his own judgment) sound structure of the whole 7 hour composition day.

In more substantial breaks composers reflected on their compositional process and made plans for the proceeding sessions. Some composers made lists on paper about tasks they intended to perform at the computer. Generally the composers followed those lists not very closely and a more immediate feed-in of compositional strategies and tasks from the physical paper note into the digital domain might be beneficial.

One composer printed out lists of all the sound files he had used and would possibly use in a particular piece and said that he regularly spends a day just listening to his pool of sounds in order to make notes about what is contained within the sound files and also to highlight relationships between different sounds. He would do this under the premise of "which sounds might go well together" and delete files that he thought were useless. The fact that the process of writing down qualities of and relationships between different sounds happened to a large degree on paper highlights the insufficiency of composition environments to allow for the possibility of expressing relationships between data and tools in a free associational manner.

The inappropriateness of existing GUI-based software tools to express those relationships was highlighted by the preference of one composer to group sounds logically in a custom made command line based application rather than having to engage with sounds on a visual interface where they would appear away from each other.

"…with an object orientated approach you can structure sounds hierarchically into groups. Or at least I could perceive a means of doing this, I have started rudimentary experiments with this, but even though that you have got these separate objects perhaps in Logic which belong to the same group of sounds in the way that you perceive the whole sound texture, they may actually be implemented on separate tracks – even a number of visual spaces away from each other – whereas they are actually acting [sonically] in combination, whereas in SuperCollider you could physically group them – or not physically – but

you could group them logically together in a group so that they stayed as one unit."

A further illustration of the mismatch of cognitive styles and available interfaces was provided by another composer. He made a metaphorical comparison between composing and building a house - "First you have to lay down the foundation, then build the walls and roof, then decorate the walls and put furniture in the rooms until you come down to the very fine details." This begs the question, if a composer perceives his work in such a way, is it then appropriate to reflect the same metaphor in the software environment, rather than having a standard track based arrangement environment? In conversation with the composer, he indicated that he has already considered one possible way of partly achieving this. He suggested putting the first two tracks of the arrangement environment, which usually contain the sonic equivalent of the house's foundation, at the bottom of the arrangement window. The compositional representation within the computer domain would then better fit with his mental image of the composition.

Further, the above accounts about expressing relationships between individual sound files and the desire to group sounds logically together as well as the holistic, image based analogy between composing and building a house, support our suggestion that parts of the compositional process can be explained by analogy with Gestalt concepts. Particularly relevant in this context is Gestalt theory's concern with the importance of relationships between individual elements of a system as well as the principle of 'grouping by similarity'.

Generally, approximate real-time manipulation with an intuitive graphical user interface was preferred over less accurate non real-time manipulation. However, on occasions, accurate non real-time applications were also valued highly. The real-time use of *hyperdraw* whilst listening back to the developing composition, seemed particularly popular with the composers. In *hyperdraw* mode, which is available in most professional sequencing applications, one can place different envelopes, e.g. amplitude envelope, over an entire audio or auxiliary track. This development of the whole as a kind of envelope placed over the individual elements is again very much in line with Gestalt concepts (Reybrouck, 1997).

In contrast to our previous studies (Eaglestone, 1994, Clowes 2000) strong evidence emerged that spatio/visual processing could serve as an aid to creativity. One composer expressed the need to enhance the translation of body movements he would perform while engaging with the computer into more representational computer data.

"An interesting thing I noticed as well, I developed new body movements as a consequence of using it (the computer), because, … I am constantly using the mouse and I make cuts, and this kind of arm movement to the point where I damaged my shoulder and back, yeah (laughs), so I move my arm from left to right quite rapidly. It would be a case of maybe enhancing this."

A need for more direct, tactile means of seeking and manipulating sounds in composition and performance was expressed by the desire for malleable interfaces that would allow for a sculptural shaping of sounds. There seems to be a general desire to physically touch the sounds which implies the need for force feedback interfaces.

The need for physically engaging with the tools composers are working with feeds our overall impression that all composers had to cope with the distance between physical and virtual domains. This contrasts with areas of computer science in which this is considered an asset. For example, a principal of databases theory is *data independence*, whereby users are shielded from physical implementations.

In the overall context of this paper we feel it is necessary to point out that there was absolutely no indication that composers need more and new signal processing techniques. However, there are several pointers that indicate high demand for increased knowledge exchange and a "know-how" data base. It was evident that the composers would have profited from collaboration with a wide community. On several occasions composers encountered a clearly defined problem which could have been helped with by a query a knowledge base or to others who may have addressed the same problem.

6 Conclusions and Implications

In this paper we have identified a need for research towards a base for improving composition software. Also, we have argued that preliminary qualitative research is necessary to establish the sensitising parameters for this area. The main contribution is the presentation and discussion of results from such a study, in which composers have been observed in natural settings, working on commissions.

The discussion of results in the previous section implies limitations of current composition software, and suggests requirements for overcoming those.

Our classification of composers is into those who seek innovation in the use of computer-generated sounds within music (group 3); and those who also seek innovation in sound generation tools (groups 1 and 2). This split is similar to that in computer science, between those who research advanced applications within existing theoretical models and paradigms, and those who seek new ones. Software environment requirements for using existing tools

and for generating new tools differ. Accordingly, we should not be seeking a generic software environment for all persuasions of composers. This complements the requirement for diversity of composition tools that we have already noted.

The observed "voyage of discovery" nature of composition, whereby refinement of an artifact (convergent thought) may lead to new inspiration (divergent thought) and unanticipated compositional activity, has software implications. Consequently, composers may multitask their activities, thus creating multiple incomplete concurrent transactions. Support for concurrent transactions is standard for multi-user systems, but not for single user systems. Also, the conventional requirements for transaction correctness, i.e., the ACID (atomicity, consistency, independence and durability) test, does not hold, since these are concerned with semantic isolation of transactions, such that they do not interfere with each other.

An interface issue is the importance and impact, both positive and negative, of visualization of sounds. This relates both to individual composition tools, and also to the environments within which they are used, since the latter must also represent compositions and their components such that the use of tools can be focused and integrated. Our observations suggest the need for further research into this HCI aspect, specifically focusing on visualization of compositions at both the macro and micro levels, so as to better communicate properties and quality of the audio content.

The observed importance of "time away" from the computer system during composition has two possible interpretations. Either, it represents limitations of software being used, where the composer has to find some alternative form of support, or aspects which are essentially human and for which the computer has no role. We believe further analysis will reveal instances of both, each having significance for future composition systems. However, one clear implication from our observations is that some integral untyped workspace within which composers may make notes and freely sketch associations between musical artifacts may be valuable.

We have also identified tension between those associations that are important to composers and those that are visible on GUIs. Again, this suggests that it would be useful to have a space to represent what is perceptually important, in addition to representations concerned with "engineering" the composition.

Note that, both of the previous two speculations are consistent with the notion of creativity as a process of divergent thought, whereby associations are made at a very high level of abstraction.

Finally, our experiments reveal a clear requirement for interfaces that put composers in touch with the physical nature of sounds, and with the wider community. In systems terms, this suggests: (i) the need for interfaces that provide low-level possibly tactile feedback relating to waveforms and sound quality, to complement the symbolic representations; and (ii) the need for a repository component within which a composer can accumulate personal know-how together with access to the community's know-how, through the Web.

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