Information systems and creativity: an empirical study

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Abstract

Purpose – The purpose of this paper is to report research that sought to understand the requirements of information systems designed to support people engaged in creative intellectual activity. The research aimed to provide empirical evidence based on a case study of a particular arena of creativity, namely electro-acoustic music composition. However, it also sought to identify issues that may apply more widely to other arenas of human creativity.

Design/methodology/approach – The research was based on a related series of three in-depth studies of electro-acoustic music composers at work. These studies entailed the collection of qualitative data from interviews, observations and "think aloud" protocols. These data were analysed inductively to reveal concepts and relationships that formed the basis for a model of interactions between the composers and the information systems with which they were working.

Findings – The paper presents a model of relationships between information system features and use, and the resulting effects in terms of the extent to which creativity was perceived by the composers to have been facilitated and inhibited. In particular, a number of tensions were identified which suggest that conventional "best practice" in the design of data-intensive information systems may be fundamentally at odds with the requirements of such systems to support important aspects of creativity.

Research limitations/implications – The limitations associated with in-depth qualitative research based on small samples is acknowledged, relating in particular to its lack of ability to generalise on the basis of statistical probability. However, such an approach arguably offers the complementary strength of being particularly suited to exploratory research aimed essentially at charting new territory and identifying rich and possibly unanticipated constructs rather than testing hypotheses based on existing theory. The resultant findings, however, must remain tentative and provisional pending further systematic investigation designed to establish the extent to which they are generalisable.

Practical implications – As well as identifying limitations in conventional approaches to designing data-intensive information systems, an alternative architecture is proposed which seeks better to map onto the requirements of creativity support. It is hoped that both the criticisms of conventional approaches and the proposed novel architecture may be of practical use to those engaged in the design of data-intensive creativity support systems.

Originality/value – The research reported here offers a novel perspective on the design of information systems in that it identifies a tension between conventional "best practice" in system design and the requirements of important aspects of creativity support. It has the advantage of being based on the in-depth observation of real composers in action over protracted periods of time. It also proposes a novel system architecture which seeks to avoid reduce such tensions.

Keywords Information systems, Systems software, Music

Paper type Research paper

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1. Introduction

The study reported here sought to explore ways in which information systems might be designed effectively to support creativity. A number of creativity support systems have been developed, yet still the relationship between information systems and creativity – and the question of how systems might be developed effectively to support creativity – are neither straightforward nor well researched. At a more fundamental level, creativity is a driving force in commerce and industry, as well as in the arts. Therefore, this is a significant and important area of research. A particular concern of the current study was to explore ways in which information systems currently impede creativity and hence, ways in which those impedances can be reduced or removed.

This paper reports the findings of a research investigation designed to illuminate the relationship between creativity and computer-based systems – in particular to identify any tensions between the use of such systems and the processes of creativity. In three related case studies, composers were observed and interviewed as they worked with computer-based systems on a number of compositions, and a number of such tensions were identified. These observations and their findings are reported in sections 3-5 of this paper. In order to address these tensions, a novel architecture for system design – which in important ways runs counter to currently accepted "best practice" – is proposed in section 6.

The particular area of creative activity studied was electroacoustic music composition. This was considered an area that is both rich in creativity and to which the use of computer-based support systems is central. Although computer-based support systems for music composition exhibit a number of functions specific to that particular area of activity – for example, the ability to mix sounds – such systems also exhibit a number of key features and design approaches generic to information systems. Indeed, the conclusions drawn from this research are discussed generically in relation to creativity support not restricted to one area.

Our definition of "information systems", in the context of creativity support, is also generic to multiple areas of activity, and relates to software that can enable the storage, description, accessing and processing of data and information. We use the concepts "data" and "information" relatively – that is, "information" represents items of data organised into some higher order structure. Such information may be regarded as data for yet higher order structuring, and so on (Figure 1). Information systems enable the storage of both data and information, and their description via some sort of metadata such that they can be accessed for processing. Such processing may entail their exploration or manipulation including, for example, aggregation, merging, or sequencing into higher order structures.

In the case of music composition software, data may consist of sounds, and higher order structures representing sequences or mixtures of sounds – still higher order

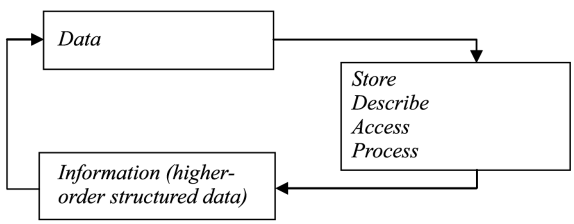


Figure 1.
Generic information system

structures representing musical compositions. In the case of systems designed to support artistic activity the data may, for example, be shapes or colours, higher level structures representing artistic works. In other contexts, data may consist of archaeological artefacts, engineering, design or architectural components, etc.

2. Related work

Creativity and information systems

There exist many first-hand accounts of the process of creativity by scientists, artists, mathematicians, designers and writers. More recently, these have been supplemented by observations by software developers and specific empirical studies to generate a number of models of the processes entailed in creative thinking. As Greene (2002, p. 100) notes:

> Computer tools can facilitate creativity on at least two fairly distinct levels: they can aid in knowledge gathering, knowledge sharing, knowledge integration, and ultimately, idea generation; and they can enable the generation of creative artifacts in a particular domain by providing critical functionality in clear, direct, and useful ways.

Marakas and Elam (1997) consider that two principal approaches have evolved in the study of creativity, namely: origin-oriented and process-oriented. Amabile (1983) stresses the importance of end product, asserting that the result of creativity must exhibit the qualities of novelty and value. Boden (1997) draws a distinction between psychological and historical creativity, the former defining creativity in terms of the processes entailed in creative thinking, the latter requiring some external judgement by others that an end product is truly creative. Boden differentiates historical creativity in terms of "exceptional" (recognised as creative by experts within a particular knowledge community), and "outstanding" (recognised as such outside that community). The importance of taking into consideration end product as well as process is again emphasised by Gotz (1981), who distinguishes creativity from concepts such as "insight", "illumination", and "discovery", by insisting on the importance of concretisation – essentially, the making of something.

Amabile (1983) proposed a five-stage model of the creative process entailing problem presentation, preparation, response generation, response validation and outcome – echoing to some extent Patrick's (1937) very much earlier stages of preparation, incubation, insight/discovery, verification and concretisation. More recent studies have identified types to complement such stages of thinking. Edmonds and Candy (2002), for example, summarise findings, from a number of empirical studies, that creative thought tends to entail: breaking away from conventional expectations; total immersion in the activity; taking a holistic view and finding multiple viewpoints; and parallel consideration of such multiple viewpoints and approaches.

Researchers such as Elam and Mead (1987) and Marakas and Elam (1997) have conducted empirical studies into the effects of software on levels of creativity in problem solving. Shneiderman (2002) observes that a range of techniques have been proposed. Greene (2002), on the basis of her work at the Cognitive HCI department of IBM's T.J. Watson Research Center proposes software characteristics that are capable of facilitating creativity, several of which map onto Shneiderman's activities.

Greene proposes that in order to facilitate creativity software should support activities including: "pain-free" exploration (enabling non-penalised backtracking and u-turns); active discovery learning; collaboration; and support and encouragement for instructive mistakes. Greene (2002, p. 104) notes how, in relation to the use of the Explore Modern Art system:

> . . . it became evident just how useful certain kinds of errors could be if they were instructive mistakes. . . . As they examined a series of trials one could clearly hear them develop a hypothesis. They would then happen on a trial in which the use of that hypothesis would lead them to choose incorrectly. They would then regroup their thoughts and discover new things.

Electroacoustic music and creativity

There are few studies of creativity specifically in electroacoustic composition, particularly from a software perspective. However, there exists a small, but more substantial body of research into conventional (pitch-based) music composition. This has taken four main theoretical perspectives (Collins (2001): stage theory (e.g. Wallas, 1926; Poincare, 1970; Lubart, 1994); emerging-systems theory (e.g. Gardner, 1993; Gruber, 1980); information-processing theory programs (e.g. Newell *et al.*, 1962; Reitman, 1965; Newell and Simon, 1972; Boden, 1994); and Gestalt theory (e.g. Langer, cited in Reimer and Wright, 1992, p. 91). The first three are limited from a software perspective, since they reduce composition to a procedure. Gestalt theories, on the other hand, are more compatible with models of creativity as the discovery of divergent associations through flashes of inspiration (Ford, 1999; Guilford, 1967, de Bono, 1987), since they focus on creativity through re-configuration of the components of a problem. However, most work in the area has focused on perception of music, rather than composition.

Empirical studies, though widely used in audio and music perception research (Sloboda, 1995), have rarely been used to research composition. Empirical studies of conventional pitch-based music composition have used case study data (e.g. Reitman, 1965; Collins, 2001) and controlled experiment (e.g. Bamberger, 1977; Davidson and Welsh, 1988), but do not address issues relating to interaction with computer systems. Also, experimental work has largely failed to address complexities of professional composition, since subjects are typically students, sometimes children, and often musically untrained. Notably, there have been very few studies in naturalistic settings. Few experiments have gone beyond observation of trivial composition exercises using crude and simple sound sources, exceptions being studies in Reitman (1965) and Collins (2001).

Studies specific to electroacoustic music composition are dominated by composers' personal introspections and musicological studies (e.g. Emmerson, 1989; Waters 2000). However, empirical studies of composition from a software perspective have been few and limited. The Tema project (Eaglestone, 1994; Eaglestone *et al.*, 1993) is a rare example, in which the composition of an experimental music/dance piece by Tamas Ungvary was analysed through the composer's detailed diaries, which covered both technical and cognitive detail. This study highlighted and illustrated a number of notions which appear to characterise electroacoustic composition, such as the importance of randomness and serendipity in creative work, and problems relating to process, object and knowledge management. Electroacoustic music composers have also been surveyed to determine their attitude to the software they use (Clowes, 2000), user interfaces (Tracy, 2002) and the composers' views of the composition process itself

(Upton, 2004). However, these have been small-scale studies and highlight the need for a widening of the scope and depth of research in this area, if we are to establish a research base for composition software design.

3. Aims and research questions

The study reported here aimed to develop a model of the interactions between creative activity and software support systems, and to identify features of these interactions that might inform the design of more effective systems.

The specific research questions addressed were:

RQ1. In using software to assist in the composition process, can tensions be perceived to exist between software usage and the creative process?

RQ2. To what extent can knowledge of any such tensions inform the design of novel software better to support creativity?

4. Research design

Methodological issues

Here, we outline a number of issues which affected our choice of methodological approach, which is described in the following section. Researching "creativity" poses a number of problems for researchers:

- Creativity may be defined in a variety of ways, depending on which of its various aspects is focused upon.
- There is a degree of consensus that creativity is often not susceptible to planning and expectation, but rather is by nature to a large degree spontaneous and unplanned.
- The very essence of divergent thinking is difference – thus creativity may be displayed in very different (and by definition unpredictable) ways by different individuals engaged in creative thinking in different arenas of activity.
- Creativity is still not well understood in terms of empirical evidence.
- The phenomena on which this study focused, namely: how composers interact with computer-based composition systems when they are being creative, is not amenable to the formal modeling approaches of computer science, since, as Laske (cited by Polfreman, 1999, p. 31) observed: "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 . . . "

These considerations, and the lack of previous work, mean that there is arguably a need for preliminary study to identify sensitising concepts, which according to Olaisen (1991, p. 254): " . . . 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" in order to establish some basic parameters of the research area.

Methodological approach

The issues described above were instrumental in the framing of our methodological approach. Specifically, they led to the following decisions:

- To work with a sample of people who, it seems reasonable to assume, are generally agreed to be "creative" (namely, music composers), and observe what they do when engaged in creative activity, and what they say about their creativity. This was considered likely to prove more appropriate and practical than attempting to obtain judgements of the end products of the activity in terms of levels of creativity, or to measure the subjects' levels of creative ability using, for example, psychometric tests.
- To explore one area of activity in depth, as opposed to engaging in a less intensive exploration across a range of diverse areas.
- To adopt a naturalistic, qualitative approach to data collection, and an inductive approach to data analysis (Denzin and Lincoln, 1994). Although entailing a relatively small sample of people compared to, say, a statistical survey-based study, it was considered more appropriate to adopt this approach in an area that is as yet little understood, in order to identify key concepts and themes that are unlikely to be anticipated by the researchers. Such an approach is arguably particularly well suited to the task of investigating "sensitising" concepts in a preliminary mapping of the territory.

Sampling

A theoretical sampling approach, advocated by many writers on qualitative research (e.g. Mason, 2002; Silverman, 1997), was adopted. This enabled the researchers to develop the sample from each of the three observations (described below) to the next, in order to reflect emerging analytic themes. An important consideration within the sampling strategy was that we wished to maximise the variation within the sample across a range of dimensions. Variety-based theoretical sampling was considered appropriate for an exploratory "mapping of the territory" in order to avoid unintentionally restricting any findings in relation to tensions in the interaction between users and software which might be specific to a particular group of composers. In relation to sample size, it was decided to obtain as rich as possible data from intensive and prolonged engagement with a small sample:

- In the first observation, two professional freelance composers (1 methodologically-oriented academic, and 1 intuitive-oriented non-academic) working collaboratively.
- The second observation entailed a research student who was studying for a PhD in electroacoustic music composition. He had over 12 years experience in composing electronic music, with eight years experience of composing timbre focused pieces.
- The third observation entailed a well renowned and prize-winning electroacoustic composer.

The tasks: environment, type, duration and equipment used

This section specifies the type, duration and location of the different compositional tasks, as well as the computer systems used by the composers to perform them. Again in order to maximise variety, each of the three observations entailed a different compositional task:

(1) In the first observation, two composers working together on a single commissioned composition over an entire working day were observed. The compositional boundaries for the composers were set by a time restriction of one day. Also we asked the composers to use a collection of roughly 80 sound files provided by the researchers. This observation took place in a large studio space at Middlesex University, because both composers were familiar with and fond of that space. Also it provided all facilities needed for our experimental set-up, including two computers with a video output ports. The first of the composers worked mainly with *SoundEdit 16* (by Macromedia) and *MAX/Msp* (by Cycling 74). The second worked mainly with *Supercollider* (command line based software (now freeware) available at www.audiosynth.com) and *Soundhack* (by Tom Erbe). When they worked together they used *Logic Audio* (by emagic).

(2) The second observation stretched over five three-hour sessions during which a PhD student in electroacoustic music worked on a commissioned piece in his familiar environment at home, using his own equipment and sound files. The composer elected to work mostly with *Logic Audio*, *SoundEdit 16* and *MAX/Msp*.

(3) The third observation consisted of a single three-hour composition session during which a well renowned and prize-winning electroacoustic composer was asked to simply continue his composition of a piece in progress. The composer mainly worked in his own home studio and with his own setup of *ProTools* (by digidesign) and a locally developed command-line based software.

Data collection

In order to achieve a degree of triangulation whereby a phenomenon may be viewed from different perspectives, a variety of data collection methods were used. The selection of such methods developed from one observation to the next. Data collection methods adopted in the second experiment were selected in the light of, and in order to overcome problems and limitations experienced in, the first observation. This process was repeated in the design of the third experiment. The methods used in each observation – and the rationale for introducing changes from one experiment to the next – are described below.

(1) In the first observation of two composers working together on a single composition, think-aloud protocols were used. In addition to the use of verbal protocols, the composition scenario was videotaped. We introduced a permanent capturing of the composition process by simply connecting a video recorder to the video output port of the computer. At the end of the one-day composition scenario we also conducted an unstructured, reflective interview where topics and incidents that have arisen during the task were reflected on. Further, we made use of semi-structured interviews, which took place on a separate meeting before and after the one-day observation. These interviews provided background information about the composers and covered more general composition related areas, such as the relationship between

composer and computer, and attitudes to computer music composition. In particular we tried to shed light on those lengthy periods of time that are difficult to monitor, where composers gain inspiration for compositions. It became apparent during the composition task and the reflective interview, that the time restriction of one day was initially an exciting challenge for the composers, but insufficient to bring the compositional process to a satisfying, and more importantly, naturalistic result. The composers' reluctance and the difficulty encountered in attempting to increase the verbal exchange during this first stage of the composition process, along with their expressed slight discomfort working with researcher-provided sound files, strongly implied the need for alternative approaches to data collection in the next observation. 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.

(2) In the second observation (a single composer working over a five-hour session), the methodology used was basically the same, but refined to address the problems described above. Specifically, the differences were that the observation focused on one composer, over a longer period of time, using no prescribed materials. To avoid the poor verbalisation results of the first observation, we emphasised to the composer the unconditional importance of this process. In order to maximize the verbalisation, the observing researcher constantly encouraged the composer to talk about and reflect on what he was doing. This form of intense and inquisitive observation was viewed by the composer in a surprisingly positive light and he assured us that instead of it being an intrusion he actually enjoyed this process of reflective and analytic working. Because of the multitude of short interviews during the observations in the second observation we felt there was no need to conduct separate interviews with the composer.

Our experiences from the second observation formed the basis of our third design entailing a prize-winning electroacoustic composer. At the beginning of the session we asked the composer to briefly contextualise verbally the piece he was working on. In the remainder of the session we simply followed the compositional progress and asked questions in an intuitive and spontaneous manner whenever an interesting issue arose out of the context of the composition process. As in observation two, where appropriate we would then try to go into more depth of some of the issues, even if that meant that the compositional process was interrupted. Table I summarises the main features of the three observations.

Data analysis

The data set consisted of the observer's written notes, tape recordings of the interviews and "think aloud" protocols, and videotapes.

An inductive approach was taken to the analysis of the data. Although grounded theory (Glaser and Strauss, 1967; Scott, 1996; Strauss and Corbin, 1994) was not used in its entirety for this project, elements relating to data analysis, namely open and axial coding procedures were applied. In open coding, raw data are interpreted in terms of higher order concepts that the researchers consider them to represent. These concepts

	Observation 1	Observation 2	Observation 3
Sample	2 professional freelance composers working collaboratively, 1 academic; 1 non-academic 1 methodologically-oriented; 1 intuitive-oriented	1 music PhD student	1 distinguished professional composer
Task	Collaborative composition Commissioned	Commissioned work	Simply continued working on an ongoing piece
Materials	Had to use 80 researcher-supplied sound files	Own materials	Own materials
Duration	1 day	5 three-hour sessions	1 three-hour session
Environment	Observational conditions	Own home environment, but computer supplied by researchers with own software and sound files imported	Own studio (home) and own setup
Data	Think-aloud during composition Videotaping Pre- and post-composition interviews	"Interrogative observation" encouraging think-aloud and reflection during composition	Pre-session verbal scene-setting by composer "Interrogative observation" encouraging think-aloud and reflection during composition

Table I.
Summary of the three observations

are labelled and categorised. Axial coding entails relating the concepts in terms of, for example, cause and effect in an attempt to understand the relationship between them.

The data generated were extremely rich. 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 a model of the interaction between the composers and the software they were using. 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.

Reliability, validity and generalisation

Issues of validity, neutrality and reliability were addressed to the extent that:

- Sampling was designed to maximise variation, with the intention of avoiding developing a model on an uncharacteristically narrow range of composers.

- The model developed (and presented in the Results section) accounts for all the data – i.e. it does not selectively ignore any counter-evidence in the data relating to the themes identified.
- The data resulted from relatively prolonged engagement across the three lengthy observations reported.
- Both observations and analysis were conducted by the same researcher.

However, it is acknowledged that validity, reliability and neutrality would have been increased with the use of a larger sample, and measures such as "member checking" of interpretations and the model with the observation participants, and inter-rater reliability checking entailing the use of a number of independent coders also to engage in the open and axial coding of data. However, limitations in the time and funds available to the investigation, the volume of the data obtained, and the fact that the participants had given prolonged time to the project meant that it was not feasible for such additional quality procedures to be conducted.

It is also important to note that the methodological approach was not designed to provide statistically generalisable evidence. The research was exploratory, and sought to map the territory in an area that neither is particularly well understood nor has been the subject of extensive empirical research. The resultant model therefore represents a tentative mapping of the possible rather than the probable. Its function is to suggest concepts and themes worthy of further systematic investigation. Such further investigation could explore the extent to which aspects of the model are observable in a larger sample of creative users, across a wider range of creative activity, and address issues of the generalisability of the model.

5. Results

The following sections report the main themes to emerge from the data obtained in the three observations. These themes address the first of our research question, namely: "In using software to assist in the composition process, what if any tensions can be perceived to exist between software usage and the creative process?"

Use of multiple audio applications

All composers involved within the observations elected to work with multiple applications. This phenomenon was also noted in the motivating survey (Clowes, 2000) and is explained by one of the subjects:

> Operational limitations are important because with the right collection of operationally limited stuff you can envisage a job that needs doing and do it. It is a modular way of operating
>
> . . . in electroacoustic composition one is not limited to a single instrument – what I can't accomplish using NoteWorthy I can often do using CoolEdit . . . .

The observations supported the view that this is not only a phenomenon that composers have learned to live with. It also has an important positive impact on their compositional process and appears to support their creative behaviour. In particular, two aspects seem to have an impact on creativity: the switching between applications and the generation of new and unexpected musical ideas.

Generation of serendipitous\unexpected novel sounds and ideas

Much of the activity observed can be characterized as a "voyage of discovery", in which musical sounds were sought through experimentation with available software, rather than systematic realisation of preconceived musical ideas. In this respect, the use of multiple software applications catalysed creativity by offering a variety in the generation of new and sometimes unexpected sounds. One subject expressed this desire for inspiration through "accident" in a more general sense:

> . . . being an intuitive composer I have often found that my best results have happened while playing with software that I did not fully understand, adding a random element of mystery to the outcome.

However, there was clearly a dichotomy between realizing the sought for sound, and discovery of unanticipated possibilities. Clowes (2000) throws light upon this tension between the underlying principle that compositions are essentially conceived in the mind and realised in audio signals, and the influence on the composer of specific software. The former purist view was expressed by subjects in the following quotes:

> . . . relating to a computer during the compositional . . . phases of music creation is anathema and inevitably destroys my muse;

Whereas, the latter pragmatic acknowledgement of the real situation was expressed as:

> The overall *modus operandi* of music software and its idiosyncratic ways of executing tasks cannot fail to have an influence on the composer. It is important to have an awareness of such influences . . . to maintain any sense of compositional freedom.

However, analysis of computational data in our observation of composers suggests that, in practice, the composition was often a progression from the pragmatics towards the idealistic position, since reliance on serendipity decreased with the continuation of a particular piece and was replaced with more intentional and purposeful actions towards its completion.

Frequent switching between applications

Use of multiple software tools necessitated frequent switching between applications. 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. The new sounds would often inspire a completely different direction, not returning to the original arrangement for some time. This switching of applications could be viewed as a hindrance for the composition process, as it often prevents composers from focusing on the original problem. However, in practice the diversion seemed to catalyses the expansion of ideas and possibilities, acting as a stimulus for creativity by freeing composers from getting stuck on a particular problem.

"Time away" leading to creativity

There was evidence in all observations that much 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 five 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 seven-hour composition day.

In more substantial breaks composers reflected on their compositional process and planned the proceeding sessions. Some 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.

Mismatch between systems and cognitive processes

The mismatch between the composers' cognitive process and the available interfaces was also evident in our observations. These are discussed under the following "limitations of software" sections.

Limitations of software: need for visual representations

Paradoxically our observations show that visual senses play a major role in what is often referred to as acousmatic composition. On a basic perceptual level this even applies to the look of hardware as well as software interfaces. One composer even tried to explain his adverse attitude towards command line based programs for aesthetic 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* (www.metasynth.com). In this software environment the normal desktop environment is completely hidden by a black canvas 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-aligned arrangement environments composers were 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.

To some extent a distracting impact of visual representation of sounds was also present. This was indicated by the behaviour of the composers, who would frequently request to listen to their composition in a totally acousmatic situation, i.e. from minidisk over a hi-fi system. The impact of vision on auditory perception is a known phenomenon in experimental psychology. For example, in the McGurk effect (McGurk and McDonald, 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.

Limitations of software: need for free associations

The fact that the qualities of and relationships between sounds were often recorded 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. This is a facet of a more general problem, i.e. the inappropriateness of existing GUI-based software tools to express free associations between data and tools. This 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-oriented 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 importance of personally meaningful associations 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.

In conversation with the composer, he indicated that he has already considered one possible way of partly achieving this by 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. 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?

Summary of results

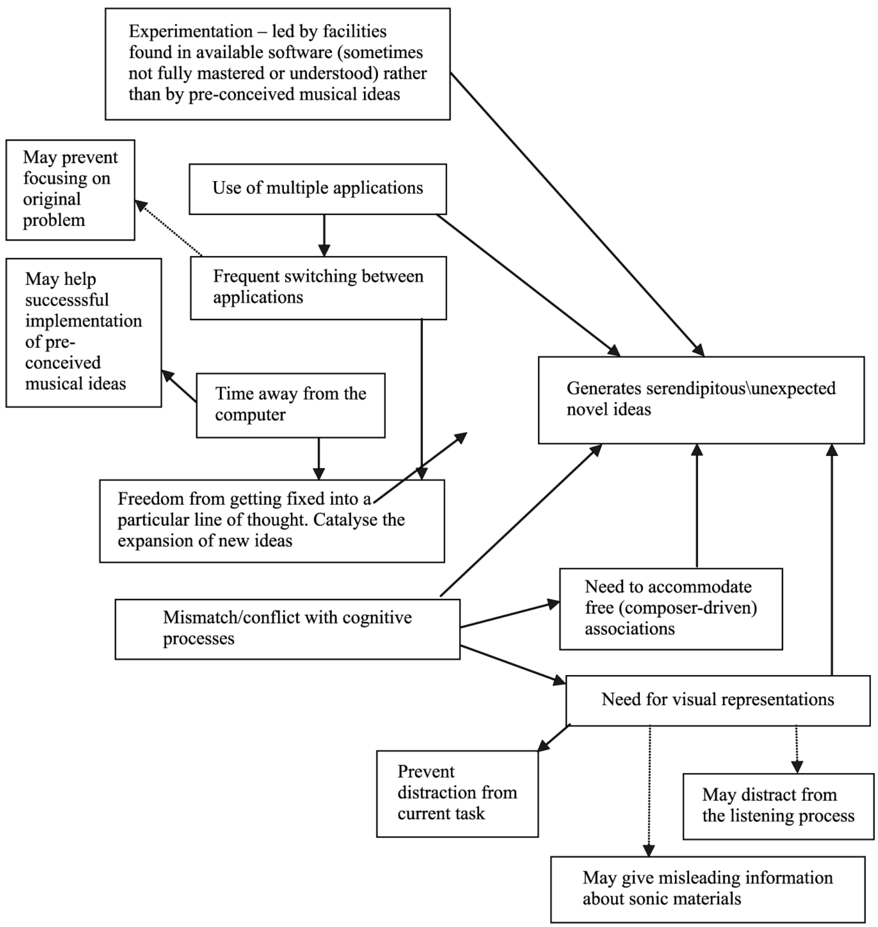
A theme that runs through much of the data was the "voyage of discovery" nature of the creativity being observed. Creative stimuli were provided by working with and switching between multiple software applications. There was also evidence of computer systems that stimulate and challenge, rather than reflect, users' perceptions as a catalyst for creativity. We also identified frustration with software interfaces which impeded the composer in making free associations between audio material. Thus, a further requirement is for interfaces which allow the creative user to override semantics and assumptions built into the high-level interfaces they use. This will enable users to reconfigure the problem and solutions from basic components, i.e. a Gestalt approach (Reybrouck, 1997). Finally, time away from the computer seemed to have importance, because of limitations of current software systems, but possibly also because it makes possible aspects of creativity in which the computer has no role.

The concepts and themes presented above are shown in diagrammatic form in Figure 2.

As noted in the section, this model is exploratory and tentative and is designed essentially to suggest concepts and themes worthy of further systematic investigation.

6. Implications of the results from a database perspective

With the caveat relating to the tentative nature of the model presented above and the need for further systematic study, it would appear to have potentially important implications for the design of information systems to support creative activity. This



Note: Broken arrows indicate negative effects, solid arrows positive effects

Figure 2.
Categories and relationships within the composition process

discussion addresses the second of our research questions, namely: "To what extent can knowledge of any such tensions inform the design of novel software better to support creativity?"

This section discusses implications of the preceding analysis, with respect to the requirements of software environments for composers. We take a database system perspective, since this a common approach for design systems, apparent in much computer music software and information systems for supporting creative activity in a wide range of areas. First we reiterate "textbook" basics of database systems and then re-examine these basics in the light of some of our findings.

Classic database design

The conventional database system architecture (Figure 3) comprises a logical model used to describe the logical structure of the data, an internal model, which defines how that logical model is implemented, and external models which support application- or user-specific views of the logical model. Users access data via the external models, thus, shielding them from complexities of logical structures that are irrelevant to them and complexities of how the logical structures are implemented, such as file structure and access method. This shielding is referred to as data independence and allows the sharing of data on the basis of its natural structure, rather than how it is stored. The ability to utilize the logical model to produce a natural representation of information as data is core to the database approach. Thus, a fundamental tenet is that a well-designed database system mirrors users' perceptions of the problem space, allowing them to address the problem in hand without complexities and distractions of implementation details.

In considering the applicability of the above approach to support creativity, we must address a fundamental difference between users requiring creativity support and users of conventional database systems. The database approach creates working environments with logical structures, constraints and processes that reflect accepted perceptions of the semantics of the problem space and thus impose constraints of "good practice". Therefore, it is well suited to prescribed tasks in which principles and methods are well understood. By contrast, in our observations we observed users who were creative, individualistic and idiosyncratic, and who chose to work with multiple

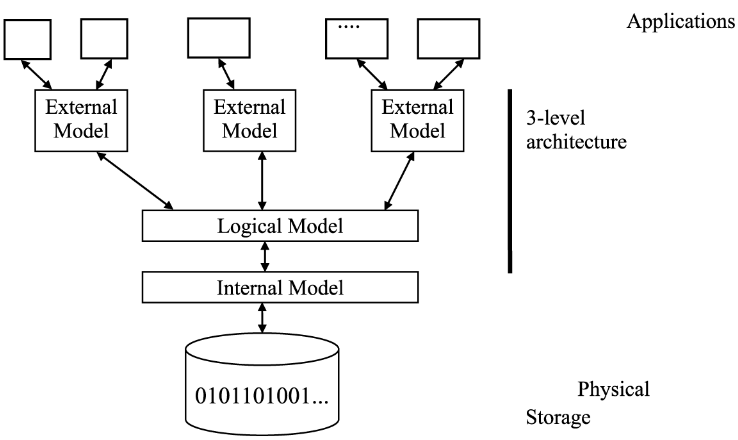


Figure 3.
The3-level database architecture

software tools at all levels of abstraction and which stimulate and challenge, rather than reflect, their perceptions.

The "semantic gap"

In doing so, those users were contradicting the widely-held notion that the semantic gap between conceptualization (in the mind) and realization (in software) may be a major impediment to effective support. The common wisdom in computer science is that this gap should be minimised, such that computer systems allow users to work with models that reflect their perception of the problem at hand. However, as reported above, a wide semantic gap can have positive connotations and can catalyse creativity by challenging a composer's perceptions.

The experimental and creative nature of the activities in which these users were engaged meant that they were constantly seeking new forms of expression. Thus, the notion of constraining them to work within the bounds of "good practice" is inappropriate. Also, the importance of randomness, serendipity and capitalising upon the byproducts of mistakes set creative users apart. This difference causes us to question, for creative applications, the validity of the above tenets relating to reducing the semantic gap, and hence of the conventional architecture.

Aggregation rather than integration

The apparent preference of our users for working with multiple and diverse software applications and their positive impact on creativity conflicts with the Figure 3 architecture, since the latter assumes a single database. We must therefore consider more generalized architectures, such as those of multidatabase systems (Bukhres and Elmagarmid, 1996, Sheth and Larson, 1990). Multidatabases provide access to multiple distributed autonomous database systems, and thus may be adapted to host multiple applications each with their own architecture and data stores. However, the creative use of multiple applications conflicts with the aims of a multidatabase architecture. A multidatabase system provides integrated access to its component databases, usually by mapping globally accessible parts of their logical models into semantically rich global models (e.g. as in the architecture of Sheth and Larson (1990)). The global model is then used to present relevant distributed data to each user as a virtual database. In contrast, creativity support systems can profitably expose users to diversity and idiosyncrasies in the services, representations and interfaces of the hosted applications. Thus, a creativity support system should aggregate rather than integrate.

Transaction management

Also, the frequent switching between the multiple applications discussed in the preceding section suggests that new approaches to transaction management are desirable. The software should allow creative users to multitask their activities, and manage the resulting multiple incomplete concurrent transactions. However, though support for concurrent transactions is standard for multi-user systems, they are less well supported for individual users. Within this context, conventional requirements for transaction correctness, i.e. the ACID (atomicity, consistency, independence and durability) test, may not be valid, since these are concerned with completeness and semantic isolation of transactions such that they do not interfere with each other, whereas, in seeking an artistically valid result the interaction and interference between activities may be of value. An extreme example is where failure can provide unexpected results that have artistic value. As the composer Tamas Ungvary observed, "Errors will often produce the most artistically interesting results!" (Ungvary, personal communication, 1992). In such cases, not only is the error of value, but it may also be useful to repeat it.

Finally, in considering the artistic importance of multiple applications, we note that creativity support systems must be open with respect to the services they support. Users should be able to import new and unfamiliar software tools, and possibly modify existing tools and create new ones. Again, this contrasts with conventional database systems in which services are predefined and/or defined and maintained by the administrator rather than by individual users. Note also, that where creative users see development of new tools as part of the creative process, the tools themselves are design objects.

External models

We now consider those results that relate to the notion of an external model within the Figure 3 architecture. This represents, for users and applications, relevant data in a form that is meaningful to them. This facility is well suited to convergent thought whereby ideas are refined and elaborated, since the external model predetermines and constrains the scope and structure of the information accessible to users. Conversely, the potential for randomness and serendipity as catalysts to creativity and also the ability to freely make associations between artifacts are restricted. Thus, it can be argued that access to data via an external model will inhibit the "voyage of discovery" mode of creativity that we observed. In general, any pre-defined external model potentially conflicts with a creative user's cognitive processes. The observed importance of "time away" from computer systems during composition can be interpreted as evidence of this tension. Two possible explanations for time away are, to find alternative, possibly less formal, forms of design facility not provided in the system being used, and to engage in aspects of creativity 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 creativity support systems.

Free associations

However, since time away often results in "pen and paper" lists and sketched diagrams, this suggests it would be beneficial for software to provide capabilities for informal writing and sketching, to represent both data and metadata. This is in line with Puckett's proposal (Puckette, 2002) that composition systems should provide facilities for describing compositions at an abstract level, with the same expressive possibilities as a pen and paper musical score. Further, the advantage of providing this facility within the system is that the user can then selectively assign formal semantics to parts of the sketched artifacts by delimiting and mapping them to objects and types defined within the system.

The observed apparent tension between those associations that are important to creative users and those that can be expressed in the GUIs of the systems currently used also supports the notion of a workspace that can be dynamically defined by the user as creative activity evolves. This workspace should allow arbitrary associations between artifacts, thus making it possible to represent what is perceptually important, in addition to representations concerned with engineering products currently supported by GUIs.

Micro and macro views

Here we consider one of the many issues relating to the user interface. Our observations suggest the need for further research into HCI aspects, specifically focusing on holistic approaches to visual representations of information, including both macro and micro levels of detail, so as to better communicate properties and quality of the artifacts in use. At the micro level, composers of electroacoustic music, for example, are concerned with audio waveforms and their characteristics and statistical properties that relate to the listeners' perceptions of the sound. At the macro level, composers are concerned with ways sounds are combined, i.e. musical structures. In music and more generally, useful micro and macro information could be automatically inferred from artifacts using known techniques. It might be beneficial for a user-defined external model, as described above, to be complemented by metadata inferred by the system itself.

"Access all areas" interface

Also, an architectural implication is that, rather than accessing the database in the conventional manner, i.e. via the restricted and personalized view provided by an external model, users require access to data processing functionality at each level of abstraction – to take a music example – ranging from perceptual representations to waveforms and signal processing algorithms. This suggests the interface should be "side on" to the architecture, ranging over all the levels of abstraction.

Towards a novel architecture

The architecture in Figure 4 addresses the above notions in a very literal manner, by adapting and reconfiguring components of the Figure 3 architecture. As in a multidatabase architecture, the system hosts many systems. Accordingly, the system-specific models represent the services, structure and constraints of the various tools hosted by the composition system. The physical models represent how the data (e.g. sound files) are physically stored. The neutral artifact model is the aggregation mechanism and replaces a global logical model, since it provides a directory of the artifacts created using the hosted tools. Also, instead of application-specific external models, the system includes user-defined external models. These are created without predefined contents, constraints and semantics to better supportive the observed creative behaviour, since this will allow users freely and dynamically to create their own external models to describe the structure and semantics relating to a creative product as it takes shape, e.g. using a drawing tool to sketch and annotate ideas. The semantics is then defined by mapping the symbolic representations to artifacts in the "neutral model". Finally note that the interface is "side on" such that users can access artifacts at all levels of abstraction. This architecture has been implemented in relation to electroacoustic music composition (Dahan et al., 2003), and a prototype composition system, named *Sketcher*, can be down loaded from www.dcs.shef.ac.uk/ ~ guy/mistres/

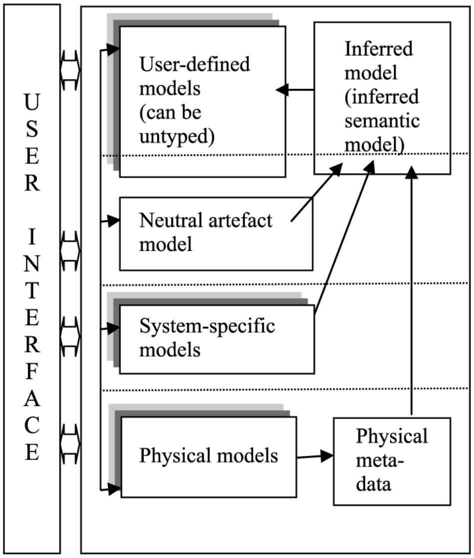


Figure 4. Outline architecture for a novel creativity support system based on the research presented here

Conclusions

The naturalistic study of electroacoustic composers at work presented here represents a preliminary attempt to understand the relationship between creative users and the computer systems designed to support their work. Though the study is limited in scope, the richness of the data collected has provided insights into tensions that can occur in such situations. These reinforce much of the generic understanding of creativity reviewed in the related work section, but also suggest that the causes stem from what would normally be considered "good software design", thus providing criteria for improved systems. We hope that the tentative model presented here will motivate further research to test and elaborate our findings. In particular, it would be interesting to establish if our findings have generality across other areas of creativity.

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