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# Interaction in Creative Tasks: Ideation, Representation and Evaluation in Composition

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## ABSTRACT

The design of tools for creative activities affects the creative processes and output of users. In this paper we consider how an understanding of creative interaction can inform the design of support tools in a creative domain, and where creative needs cross domain boundaries. Using observations of musical composers we analyse the theoretical approaches to understanding creativity and their use to HCI. Cycles of ideation and evaluation are suggested as atomic elements of creative interactions, with the representation of ideas a central activity for individual and collaborating composers. A model of collaborative composition was developed, along with an analysis of the representational types used in the domain. This led to the design and evaluation of a prototype *Sonic Sketchpad* for musical idea representation.

## Author Keywords

Creativity, Collaboration, Representation, Music, Composition.

## ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous, H.5.5 Sound and Music Computing

## INTRODUCTION

Creativity is an extremely important aspect of our lives and a feature of many of the tasks we perform when using computers for work or pleasure. In business creativity provides new ideas that create and sustain enterprises. In the arts creativity is central, and the value of artistic work of all kinds is measured in part by the novelty it represents. In science and engineering, breakthroughs are made by the combination of creative ideas and systematic investigation. Creativity is understood as a difficult but vital area of research in various disciplines from psychology to design.

Enabling greater creativity is an attractive goal for HCI researchers, and seems feasible given that tools for most creative endeavours are increasingly computer-based, and

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that the design of these tools can be shown to have an influence over users creative processes and output. By assessing the usefulness of previous creativity research to HCI and attempting to understand the relationships between creators and tools we aim to develop methods to support the design of creative software tools with theoretical knowledge in a usable way.

In designing holistic support for creativity an understanding of both low-level creative processes and high-level goals is required. For completeness this must incorporate the individual, social and collaborative aspects of creative work. Through reference to models of creativity Shneiderman developed a framework to aid high-level understanding of user needs and identify tasks requiring support [23]. Here we produce a complementary approach to appreciate how creative work occurs at the interaction level - how people interact with tools, representations and each other to create. While some aspects of these processes are domain-specific, creativity literature suggests cross-domain similarities. Using wide-ranging theories of creative processes and practical research from various disciplines we consider where and how creative requirements can be universal and analyse the domain-specific needs for the design of tools to support musical composition.

In this paper we develop a focus on the interaction of users with external representations of their ideas in a wider model of creative processes. Significant questions are addressed here such as: What purposes do these externalisations have in individual and collaborative creative contexts? How do users react to constraints imposed on their ability to represent and changes in the relationship between their representations and the actual creative output? How can we use the extended abilities technology gives us to aid the user in realizing, manipulating and evaluating ideas?

Musical composition provides an interesting domain of study where representations take various forms, collaboration is commonplace and tools are ever-present. Abrams et al [1] concluded that the domain provides an excellent vehicle for developing creativity support and exploring ideas that could be applied to other domains. The knowledge gained through an analysis of observations of composers is used to create a model of creative interaction. To stimulate a design focus the study aimed at the development of a tool to aid composers in representing, storing and communicating their ideas.

## Theories of Creativity

What it is that constitutes a creative act is difficult to define with strict boundaries, leading researchers to consider this topic with different conceptions. A variety of structuralist models have been developed, dividing the creative act into distinct stages. A commonly cited version of this is a four-stage model [4] consisting of:

1. Preparation – Identification of a problem and research into it,
2. Incubation – Problem is worked upon only subconsciously,
3. Illumination – Solution is envisaged in a vague form,
4. Verification – Solution is tested, realised and shared.

This type of model presents a useful overview of processes commonly engaged in by a creative individual, but it is one of a number of perspectives.

Other studies of the creative act suggest that divergent and evaluative thinking are the basis for the production of creative ideas [3]. Gabora finds this consistent with the widely held view that there are two distinct forms of thought: An associative mode perceiving metaphoric connections between correlating items in memory, and an analytic mode conducive to understanding cause and effect relationships. The first mode provides us with the ability to associate loosely related concepts and create novel thoughts, the second gives us the necessary focus to evaluate and make use of them [13]. The stages of the structuralist model correspond with this in that 1 and 4 are essentially analytic tasks with 2 and 3 forming the associative aspect.

The analytic mode assesses whether ideas are practical and usable in the problem context, and may also assess whether they are valuable to the wider world. Creativity can be understood as an interaction between an individual and a sociocultural context [9]. Within this model of creativity there exists a culture containing symbolic rules known as a domain and a field of experts that recognise valuable novelty brought to their attention. The individual's understanding of this context is used to judge novel ideas.

While social context is important to individual creativity, collaborative creativity brings a whole new level of complexity to the development of understanding and support. Despite this a holistic understanding of creative processes must be inclusive of both individual and collaborative working practices. Sawyer [22] notes that creative work commonly involves collaboration in some form, ranging from a group working simultaneously at a creative task to a colleague supporting or evaluating an individual's work. Successful creative groups exhibit the phenomenon of *emergence* – through successful interaction their creative output becomes greater than the sum of their individual abilities. The user-centred design of a support system therefore requires an understanding of their methods of interaction.

Creativity can be understood as an aspect of problem solving or alternatively problem solving as one kind of creativity. Creator(s) aim at an outcome they can only partially conceive during the process, and goals may change as progress is made. What is essential is that the outcome is something novel and valuable [20], a suitably loose definition accommodating multiple theoretical perspectives.

Scientific creativity differs from artistry on many levels, and creative acts can have very different purposes. Whilst in many creative endeavours the value or usefulness of the idea is at least as important as its novelty, on other occasions the act can be partially or completely autotelic – it is art for art's sake [9]. It is important that designers are not elitist in conceiving where creativity occurs and who benefits from it. Craft proposes that 'little-c creativity' - ordinary people being creative in response to everyday situations - is a required skill in 21<sup>st</sup> century life [7].

## Idea Representation and Creativity

An identified common feature of creative and problem-solving processes in individuals and groups is the use of representations to investigate and better understand ideas and conceptual spaces. These can be seen as useful extensions of the mind of the creative individual [8], external artefacts providing feedback for individual evaluation and facilitating the creation of common ground between collaborators. Oxman identified representation use with reference to visual sketching practises [21]. Schön's reflective practitioner converses with a problem in a 'virtual world', aided by a sketchpad that allows ideas to be realised without real life constraints [24]. Zhang suggests a 'representational-determinism' in problem-solving endeavours, in which the representational forms available determine the information that can be perceived and therefore the mental processes that are activated, leading to new discoveries and solutions being produced [30].

Representation methods are developed by practitioners to suit their needs, and are a product of the inherent properties of the domain. Nakakoji et al advise that in designing tools for the externalisation of ideas, both the reasons for using a specific type of representation and the methods of interaction that make it useful need to be understood [19]. An extended definition of idea representation was used in this study with examples identified of any externalisation, either a physical object or temporal signal, which describes elements of a creative idea. This paper presents idea representation as a key factor in creative interaction. Effective creativity support requires an understanding of representation needs as the methods by which a user interacts with 'tentative structures' - ideas that are produced in response to a creative goal [20]. For this study the aural, temporal nature of music provides an interesting perspective, with representations taking audio, visual, gestural and verbal forms. Referring to studies undertaken in other creative domains we explore universal needs and the domain-specific understanding of representation required when designing creativity support tools.

### Supporting Creativity

Tools of some kind have been essential to most creative domains since their inception: Scientists use laboratories of recording, measuring and processing equipment to explore solutions, a musician cannot play without a suitable instrument, and may use various tools to record, review and communicate ideas whilst creating and editing compositions. The reliance of creative people on such tools gives the designer an important collaborative role in facilitating desired creative outcomes [6].

For professionals and amateurs, new technology continually enables more people to be creative in ways that were never previously possible, with much lower overheads and easier proliferation of their creative output. Networks have also facilitated distanced collaboration and the development of global creative communities [28].

According to the GENEX framework for supporting the generation of creative work developed by Shneiderman [23], users may require tools to aid them in performing the following tasks:

- Collect: Learn from previous works stored in libraries, web etc.
- Relate: Consult with peers and mentors throughout a project
- Create: Explore, compose and evaluate possible solutions
- Donate: Disseminate the results and contribute to libraries

Creative endeavours can require a variety of tools to perform different tasks. Creativity research in HCI has produced interesting examples in a range of disciplines, highlighting the wide possibilities of applying a theoretical understanding of creativity to design. In the domain of musical composition, Abrams et al [1] developed an environment for composing film soundtracks with an emphasis on supporting the composer's observed creative workflow and reducing the tool designer's influence on the user's creative output. Johnston et al [16] created and evaluated tools that produce a visual interpretation of a performer's play, providing inspiration and promoting reflection.

The remainder of this paper describes and discusses the research undertaken. This began with field studies of composing musicians and observations of composers using software tools. Data was then analysed through a process of task analysis, modelling and consideration of the use of representations in the process. A design process and the evaluation of a prototype followed.

### OBSERVATIONS OF COMPOSITION

A variety of techniques considered suitable were used in this study. In analysing such a complex activity, naturalistic contexts are important to obtaining valid results, especially

when attempting to understand collaborative behaviour [14]. Because creative output in this domain is measured in terms of value to individuals (amongst whom there may be a variety of equally valid opinions) quantitative measurement of end products is not useful. Sawyer maintains that it is the study of the process rather than the end product that can enable us to understand creativity [22].

10 composers in two separate groups were involved in the study, resulting in 6 hours of observations of composition processes unsupported by computer software, along with questionnaire responses, semi-structured interviews and discussions with the participants. The observations involved a field study with composers belonging to the Bath University Musical Production Society, members were observed during meetings over a 5 week period and were questioned about their composition methods. Further to this a separate group of 5 musicians were observed in an arranged composition session. The participants in the studies had a range of musical backgrounds, ranging from some who had played instruments and/or composed since childhood to others with only 2 years of musical experience. During the observations 4 participants used guitars, 4 voice, 3 drums / percussion and 2 keyboards. 2 of the participants stated that they personally used computer software in some way in their composition process. No collaborative use of software was mentioned, though the composition processes observed often involved tight collaboration.

Following this an individual and a pair of musicians were observed using 2 software composition tools – Fruity Loops (www.fruityloops.com) and Hyperscore [11] – for a total period of 1½ hours. These tools were chosen from a selection of evaluated software because they were both sufficiently different from each other to provide interesting comparison, and simple enough that the essentials of using them could be taught through a short tutorial. Both involved the use of software instruments rather than the physical instruments participants usually composed with. These observations were conducted to gain some understanding of the relationship between such tools and the composition process, and to evaluate the usability of the tools. The study also provided scope for limited comparisons to be made with the 'unsupported' composition observed previously.

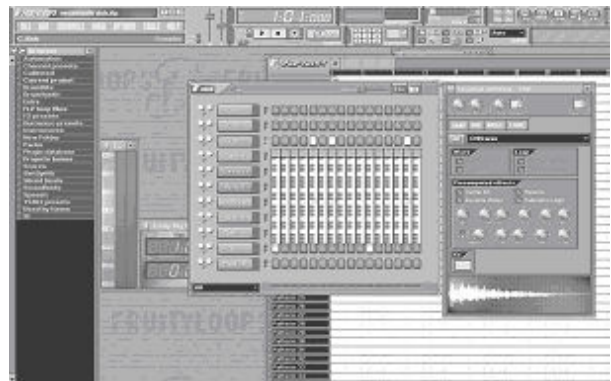
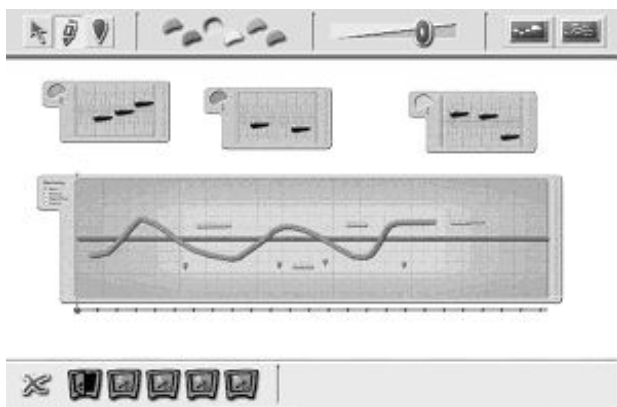


Figure 1. Fruity Loops Screenshot

Fruity Loops is a sequencer package, using a 'playlist' to structure the play of 'patterns' – short phrases made using one or many synthesised instruments. Fruity Loops represents the type of environment most musicians will encounter when using computers to compose.

Comparatively, Hyperscore offers a more graphical method of representation. Different colours represent short 'motives' of several notes, users then draw with the colours on to a separate melody window representing a 2-D graph of time and pitch. The package is simplistic and was designed both as an educational tool and as an exploration of alternatives to standard composition interfaces



**Figure 2. Hyperscore Screenshot**

The same individual and pair used both tools to facilitate comparison. All participants were initially unfamiliar with the tools. In each case a tutorial was given and participants were asked to create a composition they were happy with, with no time limit imposed. After finishing their composition participants were questioned about their experience. The individual took 15 minutes to create a 0.32 minute composition using Hyperscore and 23 minutes to create a 0.41 minute composition with Fruity Loops. The pair took 31 minutes with Hyperscore and 26 minutes with Fruity Loops, producing compositions of 0.38 and 1.03 minutes length respectively.

### Analysis

In analysing the observations our initial aim was to assess the utility of theories of creativity for representing the process in a useful manner for the analysis of support needs.

Evidence from the observations suggests that there are common steps in a creative act, and participants certainly performed and revealed evidence of having performed tasks related to the steps of the structuralist model presented, however no linear path by which a composition is created was observed. Composers appeared individually and collaboratively to focus on the production of ideas and their evaluation with reference to the current state of the composition. A common observation was the communication of an idea, resulting in some form of instrument play, followed by a decision to keep, modify or discard the idea. Compositions were built up with a

succession of 'kept' ideas, which were memorised and/or represented on paper. When questioned participants also mentioned the use of recording as a method of retaining composition ideas.

This behaviour appeared consistently through the observations, and fits the approaches of Gabora and others to understanding creativity as the use of two distinct thought processes. Looking at the use of representation in the process, there is a correlation with Schön's concept of problem solving as reflection-in-action [24]. Understanding the process at this level of granularity – cycles of ideation and evaluation – therefore became the focus of this research.

Task analysis (TA) was used to identify the components of these cycles. One analysis was produced using the unsupported observations, and for comparison another using the observations of composition by the pair using the Fruity Loops tool. As noted by Johnson & Hyde [15] collaborators have dynamic roles and relationships when performing tasks. In these observations, actions could be performed by the entire group, a sub-group or equally by an individual with little or no interaction with others.

### Representational Types and Uses

External representations are the tools of the composer for realising and sharing ideas. Through the analysis of representation use, the following common purposes of idea representation tasks were identified:

- Retention of an idea / the current state of the composition
- Facilitating the evaluation of an idea / how to use it in the composition
- Creating shared understanding of the idea / its possible uses
- Instructing a collaborator how or where to play the idea

Composers were found to use various methods of representation, with each method differing in its affordances, conventions and constraints. A taxonomy of representation types with explanations of use was therefore produced to describe the interactions of composers with idea representations. The following types of idea representation were identified, examples from the observations are included in Table 1.

*Play:* A full performance is the realisation of the composition, but play is also the primary method used to realise and evaluate ideas. It was observed that play of instruments put a cognitive load on the composer that can lead to an inability to evaluate satisfactorily. Observed examples of this include failure to realise structural mistakes during play until pointed out by observers, and the expressed need to review performances or get feedback from observers. It was also observed that participants would repeatedly perform small parts of the composition, evaluating variations on an idea without playing the whole.

Representation Type	Example: Unsupported Composition	Example: Software Tools Composition
Play	Play of Instruments in all sessions	Pattern, Playlist etc. is played (by computer)
Play Gesture	Tapping of feet / clicking of fingers to define tempo before play starts (BUMPS)	N/A
Vocalisation	“dee duh dee duh dee duh de” ( <i>Participant mimics guitar</i> ) (2nd Group).	“After that ‘ding’, put in a ‘ding’” ( <i>sung with higher pitch</i> ) (Hyperscore)
Verbal Communication	(Discussing lyrics) “Probably ( <i>emphasise</i> ) the one about the colours and the light shining through, its the most personal of the three lines” (BUMPS).	“That sounds awful, its the ‘raindrops’ ( <i>a symbol used to represent notes played for short periods</i> ) that are making it wrong” (Hyperscore)
Artefact Gesture	Pointing at sections of a visual representation when negotiating how to play a piece. (BUMPS)	Pointing at drawn lines and saying “Those two sound good, but then these others don’t work” (Hyperscore)
Recording	Referred to by two participants as a common way of retaining compositions.	Pattern or Playlist is played and / or saved.
Visual Representation	Written description of chords and words (BUMPS).	The use of both tools involved interaction with a visual representation of the composition.

**Table 1: Representation Types and Examples**

Evidently participants focus on the composition at different levels of granularity with reference to the idea being evaluated. In the software tool observations instrument play was replaced by computer play, and assessment of the two TAs showed comparable use of this for evaluation.

*Play Gesture:* Gestures were used to communicate parts of the composition where play made verbal communication inappropriate. This type of gesture was not observed in the software tool observations so is considered to be a method for coordinating instrument play.

*Artefact Gesture:* Discussions were also observed that used gestures aimed at representation artefacts to represent new ideas. The creation of shared understanding of an idea was the perceived reason for these actions, which occurred in both types of observed collaborative composition.

*Verbal Communication:* Verbal representations of ideas and evaluative opinions were commonly observed, often full of adjective use and reference to musical rules or the work of other composers. As reflected in the model (Figure 1), discussions of ideas occurred before play to generate necessary shared understanding and reflected opinions and further ideas after play, aiding the negotiation of a decision on the next move to make.

*Visual Representation:* Sketches of compositions were observed being created, manipulated and reviewed to provide an externalisation and record of the composition. The interaction method of both software tools involved manipulating visual representations. Despite music being a non-visual art, the universal utility of visual representation is evident through its common use in this as in other domains. Representations commonly form instructions for the play of a composition in a sequential manner, but it is evident that composers have differing methods, and adapt representations to suit the instruments and people involved.

*Recording:* A recording retains the composition in an almost natural form and participants stated that they used software tools, dictaphones and other recording devices for evaluation and to make a record of raw ideas for later review and revision.

*Vocalisation:* The voice was used to communicate musical ideas as an alternative to performance. Unlike singing – which is considered a form of play – vocalisation was observed as use of voice to communicate ideas that would normally be played using another instrument by mimicking instrument output. Use was most apparent where the vocalising participant had no access to the instrument / software tool and attempted to communicate an idea to the controller of the tool. Verbal descriptions of tempo (“1,2,3,4”) were also considered as a form of vocalisation.

#### **Model of Representation Use in a Composition Process**

To understand the process in its natural form, the TA of unsupported composition was used to develop a model of an ideation / evaluation cycle and the use of representations within this. Figure 1 represents a collaboration between two composers and uses the following definitions:

*Collaborator:* A person working with others with the explicit goal of composing, contributing to the process by ideating, representing and / or evaluating.

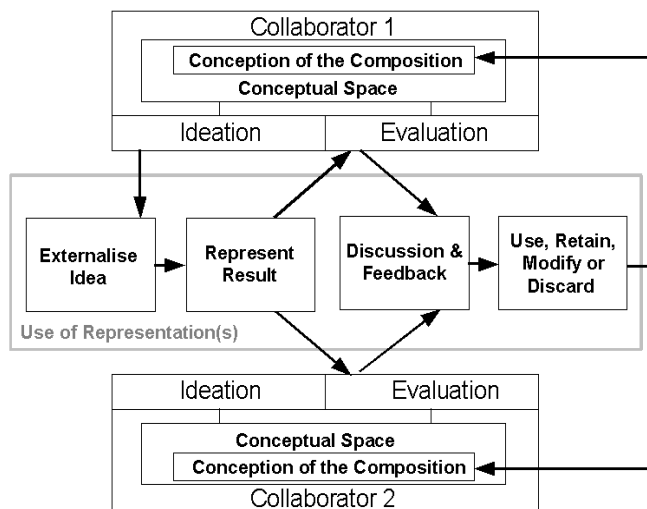
*Composition:* The intended product outcome, beginning empty but added to and modified over time.

*Representation:* Embodiment of an idea, elements of the composition or a combination of the two.

*Conceptual Space:* Mental construction of problem space supporting ideation and evaluation. This is the individual’s understanding of the composition, applicable constraints, the domain and the field [5,9].

*Ideation:* The generation of new thoughts that lead to externalised ideas.

*Evaluation:* An analytical thought process used to understand the value of ideas developed internally or communicated by others.



**Figure 3. Model of Representation Use in a Composition Process**

#### *Explanation*

Figure 3 represents a cycle started by the externalisation of a new idea by Collaborator 1. This is the result of internal ideation and evaluation processes, informed by his/her understanding of the current state of the composition. The implementation of this idea is represented in some way(s), for example through play, vocalisation and/or the manipulation of an artefact representing the composition. The positioning of the idea within the wider context of the composition often forms part of a representation.

The collaborators develop individual understandings of the idea, and to some degree common ground. But the representations also function as an evaluative tool for both collaborators. A period of discussion follows, where the individual evaluations of both collaborators can be externalised through further representation. Verbal communication is commonly used to negotiate the resulting action, with artefact gestures allowing the representation of where the idea could fit in to the composition. A decision must be reached either to use the idea in the composition, retain the idea external to the composition for possible later use, modify the idea (thus invoking another cycle) or discard it completely. The resulting action may involve the creation / modification of a visual representation or the production of a recording of the changed composition. Both individual's conceptions of the composition are updated.

#### *Analysis of the Model*

The model describes the composition process in terms of the interaction of composers with idea representations. Relating this to the GENEX framework, this model focuses on the 'create' task. As the name suggests this is where the

intentional creative activity occurs, with the other tasks being necessary supportive elements to facilitate this creative function.

Adapting the model to other configurations provides material for comparison of needs in differing situations. When an individual works alone on a composition task the element of discussion is removed, leaving feedback from representations as the only method of evaluation. This simplifies representational needs, allowing the individual to focus on their ideas without needing to create shared understanding, however at some point external evaluation may be required [9]. Adding further collaborators to the model, the number of inputs and outputs to the discussion / feedback element increase. Questions arise about the tools required and communicative processes used to deal with this: How can each collaborator have an equal ability to create, manipulate and view representations? How can numerous evaluative contributions be represented to and understood by each individual? This issue raised by the model relates to the 'Production Blocking' concept found by Diehl and Strobe to explain the poor performance of brainstorming groups [10].

#### *Analysis of Composition Using Software Tools*

Comparison of the two TAs confirmed ideation and evaluation as essential components in both cases. Sub-tasks had common purposes in inspiring, representing, evaluating and in collaboration, negotiating the use of ideas. The most obvious difference between the two processes was that the software used a complete representation of the composition that the computer played whereas the composers in the unsupported observations used multiple partial representations of the composition. With reference to the model their internal conceptions of the composition were to some degree redundant, replaced by a concrete representation built in to the software. Musical performance typically involves interpreting representations of a composition [26], leaving room for improvisations that may develop into further new ideas. By replacing human performance, the software tested may remove a mechanism for developing novelty, however it does allow evaluation without the identified cognitive load of instrument play.

Zhang's concept of representational-determinism was demonstrated. For example the pair of users complained that the Hyperscore representation did not specify the note that was being played, making it difficult to use scales or develop chord sounds. It was also observed that users adapted the available representation system to their own working methods. When using Hyperscore participants maintained a section of the representation space to store ideas they were not currently using, but wished to retain for later reuse.

Whilst the timing data does not form conclusive data, it is worth noting that no relationship was found between time taken and length of composition produced, and that the group used both tools for longer periods than the individual.

The software tools are designed to enable users to build compositions from the repetition of phrases of limited size. Whilst it can be perceived that most music contains repeated phrases building concepts such as this in to the software restricts user's freedom and this may constrain novelty. Using Fruity Loops the pair were frustrated to find that tempo changes were global - the tempo of individual elements of the piece could not be changed. Such constraints allowed participants to compose quickly and simplified the combination of phrases, but restricted the ideas that could be represented and realised in a form of 'constraint-determinism'. The saying "You must learn the rules in order to break them" could be the basis of a principle for design of creativity support – 'You must allow users to make use of constraints, but also ignore them'.

### DESIGN OF A COMPOSITION SUPPORT TOOL

Li found composers to require both tools that expand working memory and storage space, and tools for the making of music [18]. We have assessed that these defined needs have different requirements, the first relating to the representation of ideas whilst the second, realisation of a creative product. Many composition environments provide both of these capabilities, combining the ability to input audio from an external instrument, generate music using the computer as an instrument, and represent a composition. Whilst this is in keeping with Shneiderman's requirement of an integrated environment for creative endeavours [23], maintaining the same design for both tasks unnecessarily constrains the representation of raw ideas.

Given that composition has been observed to be a non-linear process, with composers modifying elements of a composition or adding completely new ideas at late stages, the production of two separate environments however integrated appears a flawed response. An attractive solution is to give users control over a flexible space for composition, able to impose or remove constraints at will, making use of them as an aid to understanding practicalities rather than having to work around them when developing ideas. This also allows composers to design a space suited to their own working method and current project.

The aim was therefore to produce a tool enabling composers to represent, record and share ideas, whilst keeping the environment flexible and open-ended. Using representation types as the building blocks of a composition, a system enabling users to represent these in a free form space was prototyped. The adaptation of these forms for use as input methods to a composition tool provides an interesting design problem considered here.

### Requirements

The research undertaken highlighted a number of requirements for a usable composition support tool, the consistency of these requirements was also considered with reference to creativity research in other domains:

1.) Composers need tools for representation of ideas as well as realisation. Idea representation tools aid the capture of raw ideas, provide a flexible medium for manipulation and support communication and negotiation with collaborators.

2.) Given the centrality of ideation / evaluation cycles to the process, effort must be made to reduce the costs of idea capture, modification and removal to a minimum. One aspect of evaluation – and by extension further ideation – is the comparison of ideas. Terry & Mynatt [27] noted the importance of undo/redo functionality to creative problem solving, and conceived a multi-state model that supports comparison and design iteration using a single file. Sedivy & Johnson's use of voice input to a sketching tool, reducing the time required to access functionality offers an example of support for this requirement [25], however there is a need to assess the introduced disruption and effect on users.

3.) It was observed that play of ideas creates a cognitive load that makes evaluation difficult for the player(s). The ability to review ideas without this load was considered to be useful by participants. Ideation and evaluation should also be possible whilst review of recordings occurs, and at different levels of granularity. Schon's distinction between reflection-in-action (reflection during externalisation) and reflection-on-action (review of representations) [24] parallels the composer's evaluation during play and the observed utility of making recordings available for review.

4.) Visual representation plays an important role in composition. Users should be free to apply textual and graphical descriptions to any part of the representation in order to aid personal and shared understanding of the creation. Additionally it was observed that users require methods for identifying individual elements, or related groups of elements. The main identified use of this is for communication between collaborators, however the ability to identify elements by various characteristics is expected to aid individual processability [30]. Colours [11] or spatial relationships [2] provide differentiation methods to support this and their utility is explored in our work. Research by Nakakoji et. al. [19,29] suggests that 2D representation spaces allow users in the early stages of various design tasks to make inferences about elements of their work and consider alternative structures without commitment or the task of explaining relationships explicitly.

5.) Composition rarely occurs entirely in one location for several reasons: Inspiration is unpredictable and illumination has been found to often occur outside of time spent actually thinking about the problem. Additionally new ideas coming within collaborative meetings need to be recorded, and an individual's previous ideas need to be presented and used as shared artefacts. Portability is therefore required of support tools. Fischer et al suggest an "and" not a "versus" relationship between individual and group creativity [12], and a kind of co-existence was observed: Group composition sessions focused on ideas that collaborators had produced and individually evaluated as useful, producing emergent compositions utilising the



abilities of the entire group. Enabling the communication of ideas between distanced collaborators is therefore potentially useful, but should respect individual space. There is a need to support the methods of interaction used when co-located to maintain interactional synchronicity [22], by supporting the use of the representation forms identified, a groupware system would go some way to overcoming barriers of time and space.

### Prototype

To explore and validate these requirements a prototype tool was produced and evaluated. This tested methods of supporting the requirements and acted as a focal point for discussion. The prototype focused on supporting composers using standard instruments rather than software to actually create music, this allowed evaluation to focus on representation use rather than requiring participants to learn a new instrument. The design requirements were realised in the following ways:

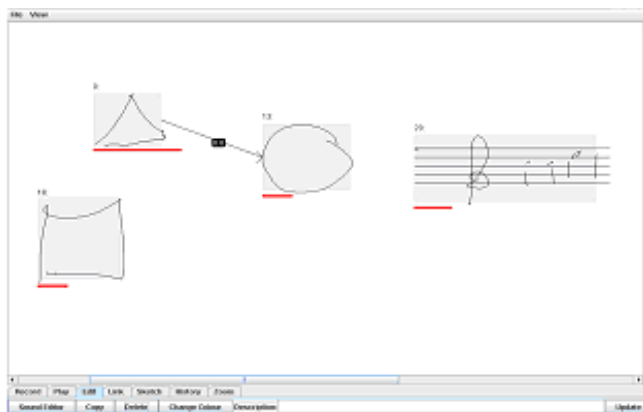


Figure 4. Sonic Sketchpad

#### Minimal Idea Input Costs

In an effort to reduce the cost of inputting an idea, a foot pedal provides a method to control recording or alternatively a single mouse click. Minimal system dialog was used in the recording process, descriptions could be added later or left blank at the user's discretion.

#### Free Representation Space

Whilst the majority of existing composition tools are aimed at realising pre-existing ideas [1], Sonic Sketchpad aims to support the representation and evaluation of partial composition ideas by avoiding constraints on representation style where possible. Users create recordings that are added to a free-form 2D space, these can then be reviewed, combined and manipulated. Notes or diagrams can be added anywhere in the space using a stylus.

#### Icon Sketching

When an idea is recorded, the user is given the opportunity to create a visual sketch using the stylus along with providing a text description. The sketch then forms an icon for the recording which can be positioned anywhere in the representation space. A user may for example choose to

sketch notation, a picture or a description of the content. The pictures with grey backgrounds in figure 4 are examples of these sketched icons. Since composers have been found to use both visual and audio representations of their ideas the aim is to link these representations in a suitable manner and create a connection between sketched information and a recording even if it is repositioned or re-used.

### History Review

The prototype offers a slider mechanism as a visual timeline allowing users to view all the previous states of the representation space. This information is saved as part of the composition file and so can be reviewed or made available to collaborators.

#### Sequencer Functionality without Representation Constraints

Sonic Sketchpad allows users to combine the play of recordings simultaneously or sequentially to build longer compositions. Playback can also be looped. This functionality aids the review and modification of a composition without instrument play, and allows the development of a composition from multiple phrases. Such functionality exists in the software tested, but in the prototype users remain free to use recordings of any length, and position linked recordings anywhere within the space. To allow users to edit recordings access to an external audio editor was provided through Sonic Sketchpad.

#### Use Flexibility / Portability

The system was designed with a variety of use scenarios in mind. These included individual use, asynchronous and synchronous collaboration. Although distanced synchronous collaboration was not supported in the prototype it is envisaged that the tool could be extended to act as a shared workspace by adding further functionality to support synchronous use of each of the representation types. Sonic Sketchpad would then become a shared workspace.

The prototype was coded in Java for portability, and evaluated using a portable tablet PC, giving the option of pen input and allowing the user flexibility in positioning the system in his/her workspace.

### Prototype Evaluation:

In evaluating the prototype the aims were to observe how composers made use of the tool and the functionality highlighted previously, how the introduction of this tool affected the creative process and - using the prototype as a discussion point - how users considered this kind of tool could be useful to them.

Two composers, neither of whom were involved in the original observations, evaluated the prototype informally in individual and collaborative composition sessions. Participant 1 played an electric piano and participant 2 an acoustic guitar. The participants had 16 and 12 years of musical experience respectively.

As in the original observations of software tool use, a tutorial was given, no time limit was imposed and participants were asked to compose something they were happy with.

An initial individual evaluation was performed with participant 1, lasting 49 minutes. This highlighted a problem with the visibility of feedback to pedal input, in response to this the system was redesigned so that the whole representation space - around 80% of the screen - turned red, providing an obvious sign that a recording was being made. Additionally the removal of unwanted silence at the beginning and end of recordings was found to be a commonly performed task and a distraction from evaluating combinations of recordings, functionality was added to semi-automate this process. After this redesign participants 1 and 2 both used the tool in individual sessions for 35 and 38 minutes respectively followed by a collaborative session for 36 minutes. The composers had not collaborated with each other before, so musical common ground had to be found.

Most of the issues raised by participants in the evaluation were focused on reducing input costs and automating processes where possible. Both participants praised the utility of the pedal as a method to start recording. In collaboration the introduction of the pedal also provided a means by which both users had some control over the system, as participant 2 sat in front of the keyboard and participant 1 had the pedal at his feet. Participant 1 also felt that the highly visible feedback for recording introduced after the initial evaluation was useful as they did not have to attend to the screen and could concentrate on their instruments. The participants both felt that the main frustration in using the software was in synchronizing recordings correctly, a process that involved the use of the editor to correct timing issues and distracted from the evaluation of combinations of ideas. Participants felt this activity would be made easier if they could be given some kind of visual information on timing in the representation space.

Use of the icon sketching functionality was limited in this evaluation. Figure 4 shows three examples of the shapes produced by participant 1 as icons and a single case where incomplete notation was sketched. When questioned about this functionality participant 1 stated that he was “not a visual person” and felt little need to sketch notation when a recording had been made. However he also stated that he found the ability to “hold” recording icons and move them around the space helpful, suggesting that the direct manipulation of visual-spatial representations of relationships between elements of a composition aided his creative process.

The participants explained their collaborative creative process simply as making recordings and trying to link them. Clearly defined ideation and evaluation stages were observed involving different methods of using the tool. During an ideation stage the participants attended to their

instruments and represented ideas to each other using verbal communication, gesture and play. After making a recording, participants then moved to evaluate it. They attended to the screen, combined and played recordings and negotiated a next move. This involved further verbal communication and gestures towards the on screen representation.

## DISCUSSION

The observations performed repeatedly found that compositions are created through cycles of ideation and evaluation, and that this is reflected in the interaction of user(s) with composition support tools. The evaluation of Sonic Sketchpad suggested that lowering idea capture costs and automating or simplifying tasks that distract from evaluation would improve the usability of the tool. The nature of these issues supports our assertion that the design of effective creativity support requires an understanding of interaction methods as well as high-level user needs.

The unsupported composer has the ability to represent ideas with the freedom to develop and manipulate the representation types used. When using software tools, the composer’s ability to represent is constrained by the design of the representation environment (e.g. Hyperscore not displaying note information), and the need for the computer to understand the user’s input (hence the inflexible representation style required of users in both software tools tested). Whilst both of these tools provide avenues for creative expression, the representation methods required frustrated users in externalising their ideas as intended.

An investigation of the types of idea representation found in composition gave us an understanding of how composers expect to interact with tools and each other. Representation methods are utilised where appropriate and are developed by practitioners to suit their needs. Creating tools that connect the expressive abilities of the representation methods found ‘naturally’ in a domain to a capacity for rapid idea realisation and evaluation is an important goal for designers. An example of this inspired by our study is to allow users to enter a melody or set a tempo through a vocalisation.

Whilst some details of the creative process found here are specific to musical composition, a review of creativity research reveals the wider importance of representation and the ideation / evaluation cycle to the creative process. Understanding representational needs within these cycles combines a cross-domain framework for designing creativity support tools with room for necessary domain-specific understanding. This could provide a platform to develop and share requirements for creative interaction design between domains with a valid common language. Analysing musical composition with this focus provided insight into the design of support for this domain, and simultaneously raised design issues with cross-domain significance.

## REFERENCES

1. Abrams, S., Bellofatto, R., Fuhrer, R., Oppenheim, D., Wright, J., Boulanger, R., Leonard, N., Mash, D., Rendish, M., Smith, J., QSketcher: An Environment for Composing Music for Film. *Creativity & Cognition* 2002. ACM Press (2002).
2. Amitani, S. & Hori, K., Supporting Musical Composition by Externalising the Composer's Mental Space. *Creativity & Cognition* 2002, ACM Press (2002).
3. Baer, J., Evaluative Thinking, Creativity, and Task Specificity, In M. A. Runco (Ed.), *Critical Creative Processes*. Hampton Press, USA. (2003), 129-151.
4. Boden, M. A., *The Creative Mind: Myths and Mechanisms*. Abacus, UK, 1993.
5. Boden, M. A., What is Creativity?, In M. A. Boden (Ed.) *Dimensions of Creativity*. MIT Press (1994).
6. Candy, L., & Edmonds, E., Collaborative Creativity, *Communications of the ACM, Vol. 45, Issue 10*, ACM Press (2002)
7. Craft, A., Little c Creativity, In A. Craft, B. Jeffrey & M. Leibling (Eds.), *Creativity in Education*. Continuum, UK. (2001) 45-61.
8. Clark, A. & Chalmers, D. J., The Extended Mind. *Analysis* 58 (1998) 7-19.
9. Csikszentmihalyi, M., *Creativity: Flow and the Psychology of Discovery and Invention*. Harper Collins. 1996.
10. Diehl, M. & Strobe, W., Productivity Loss in Brainstorming Groups: Towards the Solution of a Riddle. *Journal of Personality and Social Psychology* 53 (1987) 497-509.
11. Farbood, M. M., Pasztor, E. & Jennings, K., Hyperscore: A Graphical Sketchpad for Novice Composers. *IEEE Emerging Technologies Jan/Feb 2004*. 50-54.
12. Fischer, G., Giaccardi, E., Eden, H., Sugimoto, M., Ye, Y., Beyond Binary Choices: Integrating Individual and Social Creativity. In *Int. J. Human-Computer Studies* 63 (2005) 482-512.
13. Gabora, L., Cognitive Mechanisms Underlying the Creative Process. *Creativity & Cognition* 2002. ACM Press (2002).
14. Grudin, J., Groupware and Social Dynamics: Eight Challenges for Developers. *Communications of the ACM*. Vol. 37, Issue 1.
15. Johnson, H. & Hyde, J., Towards Modelling Individual and Collaborative Construction of Jigsaws Using Task Knowledge Structures (TKS). *TOCHI Vol. 10, No. 4* pp 339-387. ACM Press (2003).
16. Johnston, A. Amitani, S. and Edmonds, E., (2005). Amplifying Reflective Thinking in Musical Performance. *Creativity & Cognition* 2005. ACM Press (2005).
17. Li, T., Who or What is Making the Music: Music Creation in a Machine Age. *Creativity & Cognition* 3, ACM Press (1999).
18. Nakakoji, K. & Yamamoto, Y., Toward a Taxonomy of Interaction Design Techniques for Externalising in Creative Work. In *Proc. HCII 2003*.
19. Nakakoji, K., Yamamoto, Y., Takada, S. & Reeves, B. N., Two-Dimensional Spatial Positioning as a Means for Reflection in Design, In *Proc. DIS 2000*, ACM Press (2000).
20. Necka, E., Creative Interaction: A Conceptual Schema for the Process of Producing Ideas and Judging the Outcomes. In M. A. Runco (Ed.), *Critical Creative Processes*. Hampton Press, USA. (2003), 115-127.
21. Oxman, R., Design by Re-Representation: A Model of Visual Reasoning in Design, *Design Studies* 18, 4 (1997), 329-347.
22. Sawyer, R. K., *Group Creativity: Music, Theatre, Collaboration*. Lawrence Erlbaum, NJ, USA, 2003.
23. Shneiderman, B., *Leonardo's Laptop: Human Needs and the New Computing Technologies*. MIT Press, MA, USA, 2003.
24. Schön, D. A., *Educating the Reflective Practitioner*. Josey-Bass Publishers, CA, USA. 1987.
25. Sedivy, J., Johnson, H., Supporting Creative Work Tasks: The Potential of Multimodal Tools to Support Sketching. *Creativity & Cognition* 1999, ACM Press (1999).
26. Shaffer, L. H. & McAngus Todd, N. P., The Interpretive Component in Musical Performance. In Aiello, R & Sloboda, J. A eds., *Musical Perceptions*, Oxford University Press (1994), 258-270.
27. Terry, M. & Mynatt, E. D., Recognizing Creative Needs in User Interface Design. *Creativity & Cognition* 2002. ACM Press (2002).
28. Thomas, S., The Tools of Online Community: The First Five Years of the trAce Online Writing Centre. *Creativity & Cognition* 2005. ACM Press (2005).
29. Yamamoto, Y. & Nakakoji, K., Iteration design of tools for fostering creativity in the early stages of information design, *Int. J. Human-Computer Studies* 63 (2005) 513-535.
30. Zhang, J., 1997. The Nature of External Representations in Problem Solving. *Cognitive Science Vol. 21* (2), 179-217.