Understanding Productive, Structural and Longitudinal Interactions in the Design of Tools for Creative Activities

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ABSTRACT
A deeper understanding of the interactions between people and artefacts that characterise creative activities could be valuable in designing the next generation of creativity support. This paper presents three perspectives on creative interaction that have emerged from four years of empirical and design research. We argue that creative interaction can be usefully viewed in terms of *Productive Interaction* – focused engagement on the development of a creative outcome, *Structural Interaction* – the development of the structures in which production occurs, and *Longitudinal Interaction* – the long-term development of resources and relationships that increase creative potential. An analysis of each perspective is described, along with the development of an exemplary prototype. The use of the perspectives as a basis for design is considered, including the influence of contextual factors on instances of creative activities.

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Creativity, Creative Process, Interaction Design.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI)

General Terms
Design, Human Factors

INTRODUCTION
The interactions between people and external artefacts are central to creativity [23], and a better understanding of these could be valuable in designing effective interactive support tools for creative activities. The purpose of the research presented in this paper is to build an understanding of the generic interaction processes that occur between humans and the tools in creative activities, and to consider how contextual factors can affect these processes.

Creativity is commonly defined as a process resulting in outcomes that hold some form of both novelty and value [6]. Interaction in this context is the interplay between human processes and external artefacts, leading to these outcomes. It links the mental world of novel ideas and the physical world to which idea representations and creative outcomes are externalised and evaluated. Interactive systems exist in this context, and therefore design can be informed by an understanding of creative interaction.

Along with a review of relevant research and existing tools, the findings reported here have emerged from four years of empirical and design research, applying a range of methods to explore the area. These include observational studies of musical composition and filmmaking, a questionnaire study of practitioners from a range of domains, participatory design sessions, and three prototype design and evaluation studies. The design of each prototype has focused on exploring one of the perspectives described here, and also highlights connections between the perspectives.

Our research has considered the interactions between practitioners and tools, and between practitioners themselves. We often focus on artistic domains as a test bed where creative thought is consistently and explicitly aimed for. However, creativity occurs across a wide range of human activities, with different purposes, and in varied contexts. Rather than bound our work to a subset of these situations, we explore how the generic processes that define creative interactions are influenced by contextual factors.

UNDERSTANDING CREATIVE INTERACTION
This section introduces existing research and systems that provide a relevant background to interaction in creative activities. We use this to explain the development of the perspectives, and how it highlights important issues in the design of tools for creative activities.

Computer technologies pervade creative domains in a variety of roles, and designers intuitively develop systems that support creativity. To add to this there is a growing collection of research exploring the relationships between computers and creativity. Reviewing a collection of research on this topic, Lubart defines four roles for the computer in creative activities, each based on a human metaphor for the computer's role. These are as a *Nanny* – providing support, as a *Pen Pal* – a device to communicate with or through, as a *Coach* – helping users to be more creative, and finally as a *Colleague* – a partner in the creative process [15]. Shneiderman categorised existing models of creativity as *Inspirationalist* – considering how ideas occur, *Structuralist* - – focused on systematic exploration of conceptual spaces, and *Situationalist* – taking social and environmental context as paramount [26]. Both these sets of classifications can aid

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design thinking and have influenced our work – the contribution of which is to define useful abstractions of creative interaction, for the task of designing interactive systems to support creativity, based on empirical and design research.

Perspectives on Creative Interaction

Creativity by definition involves the production of an outcome, so the interaction that occurs when engaged in this production is an obvious starting point for understanding the phenomenon. Schön's analysis of creative problem solving in professional practice describes a process of reflection in and on action, involving the external representation and evaluation of ideas [23]. Cziksentmiyalhi and Sawyer developed an understanding of creativity focusing on how an individual or group *flows* as they produce creative outcomes effectively [7, 22].

This '*Productive Interaction'* could be defined as the generation, externalisation and evaluation of ideas, working towards the explicit goal of realising a creative outcome. The tools that support this are often the most visible tools involved in the creative process, even defining the creative domains they are used in. The video camera, musical instrument and paintbrush are the most obvious symbols of the related domain. Productive interaction is marked by an iterative movement from idea generation using low-cost, exploratory sketching processes, towards convergent work in the outcome media. There are however various types of creative outcomes, such as an improvisation, performance or a physical artefact [22], and the characteristics of this affect the nature of productive interaction processes.

Computer technologies for the production of creative outcomes are also abundantly visible. Graphics or music software and word processors are used pervasively in production. Tools to support idea generation have also been developed, however the *sketching* processes that are key to productive interaction are often poorly supported by computer software [17]. In response to this, researchers have developed and analysed support for initial idea representation in a range of domains, including the 'Electronic Cocktail Napkin' developed by Gross and Do [12] and the 'Amplifying Reflective Talkback' systems developed by Nakakoji et al [17]. These focus on the need to develop and reflect upon partially defined representations in creative activities. Other practical research from a productive perspective has considered novel, useful representations of feedback [14] and multimodal interfaces to improve interaction [24].

Productive interaction describes low-level interactions that are central in creative tasks, however it is possible to overlook other essential aspects of creative interaction with this view alone. When Johnson-Laird considered the possibility of a creative computer, he argued that it was unsatisfactory for a system only to generate ideas and evaluate them, as creativity requires the consideration and application of structure to an ill-structured task. To produce highly creative outcomes, the structures within which productive interaction occurs should be explored and developed [13]. Analysing creative processes, Perez y Perez et al describe creative writing as involving periods of engagement and reflection. The reflection results in the development of constraints, driving the production of ideas during engagement [19].

So a second perspective to consider is the structuring of the creative process, including practices such as selecting or modifying tools, building conceptual goals or constraints or developing methods. This '*Structural Interaction'* is important because creativity inherently includes a self-reflective component, evaluating the effectiveness of the structures that currently influence production. It is logical that novel outcomes will be produced from novel processes and tools, and as the completion of creative tasks lacks an obvious path, thought is required to structure a path to completion. Structural interactions occur in the context of previous work in a domain, and adherence to some existing, socially accepted structure is expected in order to make a realistic contribution [8]. In art, points of reference are used to evaluate new work. In science, utilising tools in a new way to build upon, or break from, existing theory provides the basis for most creative contributions [2].

From this perspective, the malleability of tools and their ability to be appropriated is key, as well as support for defining novel concepts and constraints. Computer systems provide a unique malleability amongst the tools that can be used in creative practice. Turkle states that "the computer's chameleonlike quality, the fact that when you program it, it becomes your creature, makes it an ideal medium for the construction of a wide variety of private worlds" [29]. The nature of the tools used in productive interaction is one factor that determines the scope of outcomes that can be produced, and – particularly in complex interactive systems – determines the processes that are likely to be followed [6]. A system that provides low-level building blocks can reduce deterministic limitations, intentionally leaving the system loose and open to appropriation [20]. Structural interactions can also be supported by allowing users to modify or build upon existing systems [9]. Finally, computers can provide a platform for the representation and development of new and ill-defined concepts by individuals, or the mediation of these activities between members of collaborative groups [21].

The previous two perspectives have developed an understanding of creative interaction based around instances of creative tasks. An implicit assumption is that creative activities can be effectively considered in terms of these instances. Whilst most of the research cited above considers that these tasks are influenced by previous interactions, and influence future interactions, the focus is often a single explicit act of creation. In many cases this is useful as a reductionist method for understanding this complex phenomenon, but to complete the picture we need a third perspective, because there are interactions that affect

creativity outside of this, and these are perhaps the least visible or well defined.

Analysing creative professionals, Florida argues that their job necessitates a lifestyle based around the tight integration of work and leisure. They "*could never be forced to work, yet they were never truly not at work"*, seeking diverse experiences and social interactions that provide scope for new ideas and opportunities [10]. Also, Becker notes the importance of a range of interpersonal relationships to the successful production of art [1]. Our creativity takes as its raw materials our lifetime of experiences, and through a process Koestler termed *bisociation*, memories are associated in novel combinations to form ideas [16]. Creative ideas are a product of associated memories, and are evaluated based on past experiences. Gelernter argues that effective bisociation requires a spectrum of thought processes from emotional, loosely associative thought to logical analysis, occurring over extensive time periods. These processes do not occur on demand - the low focus thought that provokes novel associations between disparate items in memory generally occurs away from focused activity [11].

So finally, creativity must be considered beyond the performance of individual focused tasks. An understanding of this *'Longitudinal Interaction'* is essential because ideas, inspirations, experiences and relationships develop over long periods of time, affecting processes and outcomes and requiring distinct forms of support. Our creative potential in a specific instance of a task is based in previous actions and remembered experiences that have occurred over the course of our lives. Collected resources form possibilities, and experiences inform decision-making in the productive and structural interactions described above. When we visit an inspirational place, browse through divergent materials on the web, or attend a social gathering like this conference, we are shaping our future creativity. Associating ideas and inspirations for later use in the correct context, retaining structures and outcomes, and building and maintaining collaborative and social relationships requires a range of support over the long term.

It is telling that only one of the four sections of Shneiderman's Genex framework for supporting creativity is explicitly called 'create' – the others being collect, relate and donate [26]. This acknowledges that a narrow focus on producing creative outcomes is inadequate. There are however, fewer cases where existing research related to computers and creativity has focused on longitudinal interaction, although there are relevant findings from other fields – for example Personal Information Management – that provide some basis for understanding these needs.

Considering the need to retain and organise ideas and knowledge, Shibata and Hori produced iBox and IdeaManager, systems to support long-term creative thinking utilising a stored database of knowledge [25]. Weakley and Edmonds have developed WISA – the Web Interactive Scrapbook Application, a system for designers to store and organise references to online materials [27]. Recently, commercial systems such as Evernote (www.evernote.com) have focused on collecting and organising ideas and resources across various devices. Research has also considered social interactions, such as trAce, a web site that has been connecting writers since 1996 [28]. Bruns analysed online creativity, defining *Produsage* as a term for the combined roles of user and producer in systems for social creativity, such as Flickr and Wikipedia [3].

Contextual Factors

The three perspectives provide generic lenses through which to view creative interaction. However, understanding particular instances of this requires the incorporation of contextual factors. In the findings we consider - where appropriate - how the following can be integrated:

Firstly, there are *domain-specific* characteristics that affect creative interaction. Whilst we can identify a set of concepts and processes that characterise creativity, there are clear variations between the work of the scientist, engineer or artist, and within the sub-disciplines of those. When designing for creative interaction, the activity and the desired outcome need to be understood, alongside its adherence to an abstract conception of creativity.

Secondly, creativity occurs across a range of *interpersonal* contexts. It can be tightly collaborative, or aimed at satisfying another person. It can be reliant on the abilities of others in various ways, even if these people are not explicitly defined as collaborators [1]. In addition, novelty and value are socially constructed concepts [7], and the social context of a practitioner is an important element in determining what it is possible to achieve or disseminate [1,7,22].

Finally we must consider the *expertise* of those involved in the creative activity. Creativity is a common human trait, present across a broad range of human activities. However distinctions and consequences can be identified between the processes of the beginner, of those responding to an everyday need for creativity, and of the expert in a domain. The professional hones skills and understanding of a domain, and simultaneously must strive for a higher level of novelty and value than the beginner, closer to Boden's *historically* unique creativity. Everyday creativity is more likely to be *psychological* – novel to the mind of the person [2]. Its value can often be related to a specific issue that has arisen for the person, e.g. making a gift for a friend or finding an effective way to organise family events.

METHODS

The findings described in this paper are based on 4 years of research focused on the design of interactive systems to support creative activities. This section describes the methods used. More thorough descriptions of these methods and our application of them can be found in [4,5,6].

The research began with *observational studies,* initially of *musical composition*. We observed two separate groups of experienced musicians composing (10 people in total), resulting in 6 hours of material [6]. We also observed 2

groups of 4 participants performing a *filmmaking* task. Groups were asked to produce a short film to promote local environmental awareness over a three-week period, with meetings in a room where we observed their interaction with technologies and each other. In both cases task analysis methods were used, leading to initial models of creative interaction.

An *open questionnaire study* was used to gain further insight into practitioner's interaction with tools. We received 27 responses from professionals and amateurs in a wide range of domains, including web designers, artists and researchers. Questions focused on the devices used for developing and organising idea representations, processes of developing ideas, and processes of communicating ideas with others. A major focus of the questionnaire was the longitudinal interactions that were apparent, but not fully observable in the observational studies. The data was coded and analysed in response to common themes that emerged. [5].

An additional method employed was *participatory design and task modelling* [18]. This was performed with two groups of musicians – 11 participants in total. Firstly the participants described their own processes of individual and collaborative composition (e.g. figure 1). Next, they were asked to describe areas of this model where they felt computers were or could be useful or not. Finally they used this as a basis to design systems they felt would be useful and produced paper prototypes of these. The sessions were used to analyse how users understand their own processes and needs, and to refine and validate our understanding.

Figure 1: Example model of musical composition developed during Participatory Task Modelling

Finally, we have performed 3 *iterative design and evaluation studies* to directly explore design for creative interaction. In each case these have aimed to fulfil needs recognised through our findings, and to extend previous research. Systems were developed from initial design ideas through to functional prototypes evaluated with prospective users: 3 highly experienced musicians were involved in evaluations of *Sonic Sketchpad* in 3 individual and 2 collaborative sessions [6]. 12 participants with varied musical experience were involved in evaluations of *Music Builder* in 2 individual and 6 collaborative sessions [4]. *Associative Scrapbook* has been the subject of 4 in-depth case studies in different domains, and usage statistics have been received from more than 60 users, along with extensive comments and email discussions on the software.

FINDINGS

This section describes some of our major findings related to each perspective on interaction. A model of each perspective is described, combining a description of *human processes (inner circle)* and *external artefacts (outer circle)*. Arrows describe links within (*black*), and between (*white*) the perspectives. This is followed by a description of the related prototype design and evaluation study, and an exploration of contextual factors. This paper can provide only an overview of this research, so readers are pointed to references that give further details of individual studies [4,5,6].

Productive Interaction

Figure 2 shows our model of productive interaction. It describes a cyclical process of representing ideas, considering their use in context, representing evaluations and decision-making. All of this is informed by each individual's internal conception of what the outcome will be, and produced through mental processes of ideation and evaluation [6].

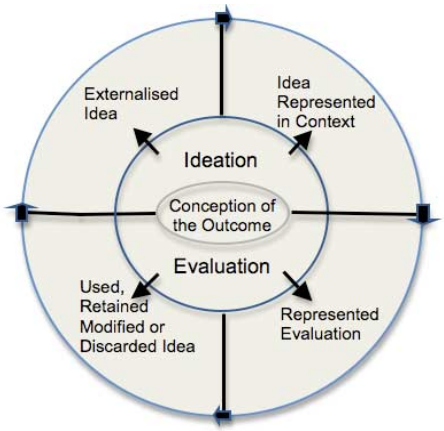

Figure 2: A Model of Productive Interaction

Productive interaction requires the representation of ideas and their evaluation as candidates to form part of a creative outcome. We analysed the use of representations in the observational studies, finding domain-specific differences based around the form of the outcome to be produced. The paper or verbal representations of ideas were often produced where ambiguities were possible, and where the language and processes of interaction were user-defined. A taxonomy of the idea representation forms used in musical composition and filmmaking provided understanding of the requirements for representation tools in the domain, feeding in to our design work [6].

The design project used to understand productive interaction produced '*Sonic Sketchpad'*, a tool for musical composition. The design was based on requirements drawn from observations of musical composition with and without computer support tools. An explicit aim was to support 'sketching' processes in the domain of music, exemplifying

the idea that the production of rough, ambiguous representations using user-defined language pervades all forms of creativity. The interface included a free form space in which users could freely organise, combine and annotate recordings, and provided low-cost support for recording through a foot pedal so as not to distract from play. The 2nd design iteration was network enabled for co-located or distanced collaborative use.

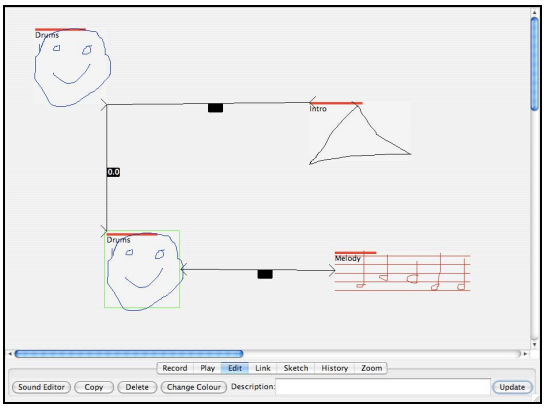

Figure 3: Sonic Sketchpad

Sonic Sketchpad provides an effective interface for the initial sketching of musical ideas, but improving it as a holistic tool for production would require more functionality for producing high quality outcomes. The integration between 'sketchy' interactions and production of outcomes at a satisfactory quality for dissemination was explored: In the questionnaire study extensive re-representation was seen as central to exploring the solution space. Producing and comparing multiple representations is a form of interaction few computer systems are designed to support, yet it is central to productive interaction [5].

Evaluating Sonic Sketchpad as a tool for collaborative composition produced interesting variations in process. In particular, when used by two collaborators at a distance, we observed a shift to a '*call and response*' form of interaction due to network latency and a lack of visibility. Rather than simultaneously develop ideas – as observed when co-located - one person would record an idea to the system, which the other person would evaluate and then contribute a corresponding idea. This less synchronous form of collaborative production – enforced by the constraints of the technological structure - provided scope for collaborators to develop and individually evaluate ideas before sharing them. It offered more control for each individual's focus, and although it may increase the time taken to produce an outcome, it could be seen to have a positive rather than a detrimental effect on the process.

Sonic Sketchpad formed a shared representation of the *conception of the outcome*, focusing discussion on specific represented ideas and their relationships. Participants in the filmmaking study spent extensive time defining and redefining their ideas using verbal communications, storyboards and film footage, as increasingly formal, shared idea representations. Formalisation is required to produce an outcome, however a balance is apparent, as divergence should provoke more novel ideas to emerge, while work converging on an effectively defined and evaluated outcome should increase value.

Structural Interaction

Structural interaction involves a meta-level reflection on the process of productive interaction, and the development of structural elements that affect this process. The forms of structure that simultaneously afford and constrain the space of actions a person or group can take are varied. These range from developing goals or direction to adopting tools that enforce behaviour and afford / limit the possible actions available to the practitioner.

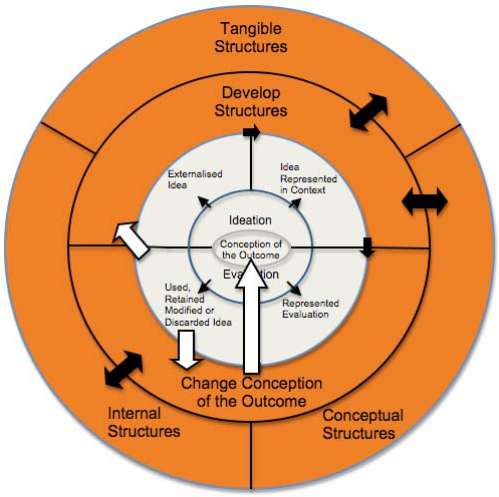

Figure 4: A Model of Structural Interaction. White arrows show relationships with Productive Interaction.

Through our research we have analysed how forms of structure can provide useful distinctions for considering the design of interactive systems. Figure 4 shows our model of structural interaction, in which we distinguish *tangible structures* – those that provide defined affordances in a physical or virtual system, *conceptual structures* – those that are mental constructs such as a goal, set of rules or genre, and *internal structures* – in which new ideas need to fit to work with the existing conception of the outcome. These distinctions are important in understanding the role of structural interaction in an interactive system, where concepts can be developed in to tangible structures because of the malleability of the interface.

After cycles of productive interaction, decisions may be made that *change the conception of the outcome*, or further *develop structures*. A familiar path of ideation, representation, evaluation and decision-making is apparent in structural development. An essential difference is that structures provide a *'how'* and *'why',* used to direct, describe or produce the *'what'* - an idea or outcome.

The expertise of the creative practitioner – their longitudinal involvement in the domain and experience with tools for

production - influences structural interactions. The following excerpt from the filmmaking study shows how two novices (A and C) and a participant with experience of film making (B) explore the tension of producing ideas in the structures they could use:

A: *(explaining film idea)* "and so it could maybe be kind of speeded up as well."
C: "Yeah definitely"
A: "Cos it need to be short, and that would make it entertaining if it was sped up"…
B: "Windows Movie Maker, I've not found a way that it can speed up, or slow down, or reverse or anything like that… My theory would be that if we can come up with something without needing any gimmicky kind of effects, other than some editing, it would probably be better…"
C: "Yeah I mean, that's an idea, if it's easy we do it, if not… whatever."

In this session the tangible structure of the selected editing software - and the participants understanding of this structure - bounds the production of ideas. A externalises ideas but is unsure as to their feasibility, he looks to B for advice, who feels the idea could be difficult or impossible to implement using the software the group have currently adopted. C's input shows how the affordances of the editing tool significantly affect the outcome they will produce. After this excerpt B offers examples of ideas that could be implemented, and the group discuss adopting alternative editing software. The excerpt shows the ill structured nature of creative tasks. Both *what* the group would produce, and *how* and *why* was not at all clear. Through structural interactions such as adopting software and considering its limitations, the groups explored how their ideas could possibly be realised. This type of interaction inspired the design study described below.

The system produced to explore structural interaction was entitled '*Music Builder'*. This system allowed users to build their own musical instruments. As we found that productive and structural interactions have a close relationship, this system built upon the Sonic Sketchpad composition space for productive interaction. Where that relied on external instruments from which recordings were made, Music Builder supported the development of screen-based musical instruments played using a pen and tablet PC. This provided users with a basis for both developing the tangible structure of the instruments, and producing musical compositions.

Figure 5: Playing a Music Builder Client

In 21 of the 36 evaluation sessions users developed their own instruments, and in 18 of these 21 cases they switched multiple times between instrument development and play, modifying the tangible structure of the instrument in tandem with productive interaction [4]. These findings suggest the value of supporting instrument development as a form of structural interaction, and show how structural and productive interaction can be tightly integrated.

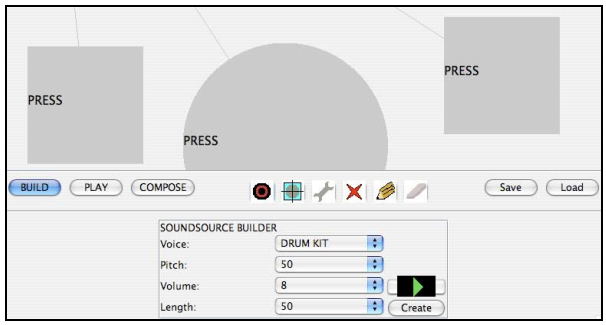

Figure 6: Music Builder Instrument Building Interface

The instruments were individual, but the composition space shared. This provided a situation where collaboration could occur over the development of the composition but was not required in creating the instruments. Despite this, some of the most interesting findings related to the ways in which collaborating musicians discussed the construction of their instruments, negotiating a shared structure as a platform for constraining their composition and co-ordinating their play. Allowing users to move between designing and playing instruments provoked reflective discussion and negotiation of the structures underlying production. This type of reflection could encourage creative thinking, as well as supporting the sharing of concepts and coordination in creative collaborations. The ability to create instruments allowed users to turn the conceptual structures in to tangible structures, as shown in the transcript from a Music Builder evaluation below:

P1 and P2 discuss how to proceed
P2: "Ah, shall I make a jazz scale keyboard?"
P1: "Yeah go on then"
P2: "Do you know jazz scale?"
P1: "Um, not really, tell me the notes"
P2: "OK hang on I'll load up the piano and ..."
P1 and P2 both load the piano template
P2: "That's A, D, C ... so we need to get rid of that one"
P2 removes several keys from the piano, P1 looks at the shared screen and removes the same keys
P2: *(looks at P1s actions on the shared screen)* "Yeah, look at the screen, you can see what I'm doing"
P1 plays the new keyboard, P2 puts the notes in order across the screen, P1 copies this action.
P2: "I think we need two octaves of these *(keys)*"
P1 and P2 add a second set of keys an octave higher.

Comparing this with the transcription from the filmmaking study - and relating this to the model in figure 4 - it is evident that in this case a *development of structure* occurs, rather than a *changed conception of the outcome*. The system

supports a structural modification, rather than enforcing a change of direction by the users.

Allowing structural interaction with a system can therefore support various forms of interpersonal interactions. Domain-specific needs for structural interaction may relate to the nature of constraint in a domain – for example a scientist or architect may implement enforced tangible constraints within a system so that s/he knows that a requirement is being fulfilled. Contrastingly, an artist could explore a novel structural development, breaking with existing constraints because it offers opportunities for new forms of productive interaction.

It was found that an important concept related to structural interaction and expertise is *scaffolding* – supporting learning through structures that can be removed, or modified, when the person has gained greater understanding. In 30 of the 36 Music Builder evaluation sessions, the users' first action was to load a template instrument. Creative processes – particularly in novel structural settings - tend to begin with exploratory productive interaction, users expect to be able to produce something immediately, find their bearings and then explore the structure. By scaffolding the interaction with initial malleable constructs, scope for extensive structural interaction can be effectively integrated with the ability to produce immediately in an example structure.

Longitudinal Interaction

The purpose of longitudinal interaction is the development of a platform from which creativity can occur in the future. This perspective does not focus on the production of a specific outcome as it occurs, but rather the furthering of opportunities, and the gathering of resources that may be of use in future creative activities. Longitudinal interactions form a collection of processes with the aim of enhancing creative potential, building the supporting context for productive and structural interaction.

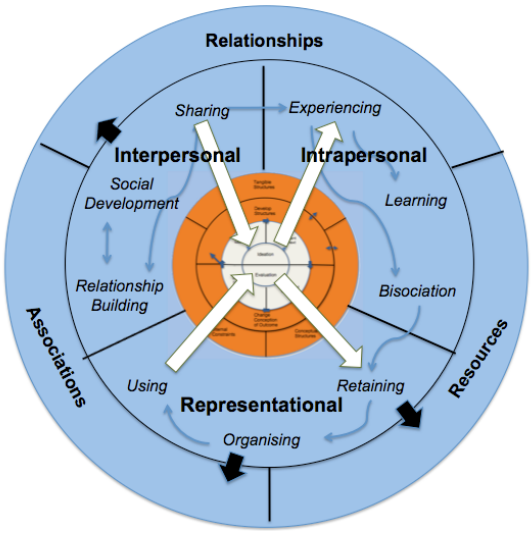

Figure 7: Model of Longitudinal Interaction. White arrows show relationships with the other perspectives.

It is difficult to observe longitudinal interaction holistically due to the lengthy nature of the processes it describes. We therefore drew extensively on the questionnaire study and the participatory task modelling and design sessions, as these were suited to understanding aspects of creativity external to focused task instances.

The model above describes longitudinal interactions and their inputs to and outputs from structural and productive interactions. The processes involved can be categorised as *intrapersonal* – experiences, learning and low focus bisociation, *representational* – involving the retention, and organisation of ideas, structures and inspirational materials, and *interpersonal* – the building of collaborative and supportive relationships, the sharing of ideas and involvement with the development of domains or other platforms for social creativity. Representational processes result in the collection of resources and the associations between these, while interpersonal processes result in relationships that can form ground for collaboration in productive and structural interactions.

Longitudinal interaction provides resources used in productive and structural interactions (*using* and *sharing* in figure 7). The inputs to this include previous productive and structural interactions that form one part of the persons' *experiences*. These may affect future *bisociation* as items in memory, or be *retained* in some form.

In support of Gelernter and Florida's research [10,11], the questionnaire study found that intrapersonal processes leading to the development of ideas often occur away from intentional periods of work, and from the context of work. Respondents reported being in bed, walking and driving as occasions where ideas commonly occurred, but recording them could be difficult. Some representational aspects of longitudinal interaction are less inherently domain-specific: We found that notebooks, cameras and voice recorders are used across domains because initial representations can often be made without requiring the specific qualities of the expected outcome. For retained ideas and materials to actually be used, they need to be available when needed. Respondents considered the review and organisation of collected materials particularly important before new periods of productive interaction [5].

Some interpersonal aspects of longitudinal interaction are also less domain-specific, and through these social interactions, interdisciplinary exchanges can occur and inspirational concepts spread. Where productive and structural interactions are often collaborative, interpersonal longitudinal interactions involve collaboration building, and the sharing of ideas and structures. Representations are often produced only for either intra or interpersonal use: The questionnaire study showed that scrapbooks and notepads were rarely shared in their original form. The common reason for this was an unwillingness to make personal representations legible to others, as this would form an unnecessary overhead [5]. Relationship building and social

interactions are important interpersonal aspects of longitudinal interactions, but these generally occur through representations developed with communication in mind. An interesting development on this topic is the surge in blogging, wikis and other forms of public communication of early thoughts or work in progress. These shared, semi-formal representations are an example of a middle ground between personal idea representation and the dissemination of an outcome. Sharing ideas in this way, or – as seen in the questionnaire responses - through discussions with peers or friends, plays an important role in the long-term development of ideas [5].

Enabling creativity pervades the lifestyle of the serious creative practitioner, so representational interactions, such as retaining and organising ideas and inspirational materials for later use, play a major role in the life of a professional. Social development processes such as developing a society are also likely to involve serious amateurs or professionals. However there are opportunities for supporting longitudinal interaction in everyday creativity: As we generally collect and store more and more materials in the digital age, even the novice may have repositories that can be appropriated for creative purposes, although it may not have been their original intention to use them in this way. The novice or leisure user can also make use of social systems for help from experts with production and structure, or take part in interpersonal interactions that have a different focus to professional creativity. The Produsers described by Bruns develop and disseminate their creative output through systems that exemplify these kinds of interaction [3].

The design project used to explore longitudinal interaction is the '*Associative Scrapbook'*. This provides a repository for the retention, development and association of ideas and inspirational materials. A scrapbook metaphor was adopted due to the interesting behaviours and use of scrapbooks or similar devices amongst the creative practitioners studied. To explore how longitudinal interaction can be generically supported, it was decided that rather than provide domain-specific features, the scrapbook should aim to be of general use. As such the system acts more as an overlay to a file system and integrates with the software structures the person already uses for production.

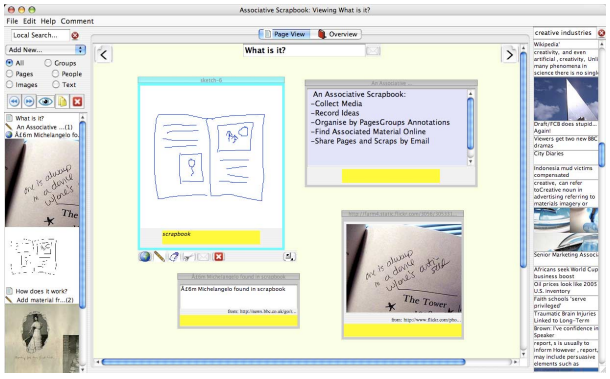

Figure 8: The Associative Scrapbook

The system allows users to add files, links and other materials to pages, along with ideas represented through notes, annotations and sketches. It provides several forms of functionality for associating these items together, for example through one to one links, grouping of items and tagging. In the case studies, it was found that cutting up or pointing to parts of scraps is also essential, so functionality for these purposes has been introduced.

A novel feature is the Web Association Panel. This allows user to passively or actively find related materials online. The system automatically searches for links relevant to currently displayed scraps, and displays these on a panel in the user's workspace. This provides a passive mechanism by which the user is exposed to possibly interesting materials as the software is used. If they wish to actively find related items, they can search either for items related to a particular scrap, text that forms part of that scrap, or by entering search terms in a more conventional manner. In the case studies, participants were found to make use of the passive functionality in divergent periods where they were open to exploring associated materials. In more focused work, active searching for specific information is more commonly of use.

The questionnaire study found that practitioners do not generally share their initial idea representations [5], so the system currently supports communication by sending scraps or pages rather than by sharing the whole scrapbook. A possible expansion of interest is making use of the web association panel to share ideas between users with similar interests or in a community. This could encourage awareness of possible collaborators, and as the application is domain-general, could support interdisciplinary dialogue.

Functionality like the web association panel could also be of use in accelerating the creativity of amateur or little–c creative users who are unlikely to have collected amounts of resources with which to produce outcomes. Building functionality for finding associated content into software tools improves the scope for exposure to new resources, which could support more everyday creative thinking.

One issue with the study of longitudinal interaction is the need to understand and evaluate use over the long term. For this reason the Associative Scrapbook has been made available as a downloadable application (see www.cs.bath.ac.uk/~tc225/AS/) from which usage statistics are sent and users are asked to give their comments through online forms and a questionnaire.

UTILISING THE PERSPECTIVES IN DESIGN

This section considers how the perspectives can be used in design. We focus on integrations of the perspectives, how contextual factors can be included, and how support tools can be evaluated from each perspective.

Integrating the Perspectives

The term 'perspective' is used in this research as each form of interaction represents a different viewpoint on the phenomena. Viewing creative interaction from each perspective provides a basis for considering requirements

that may not otherwise become apparent, and integrating the perspectives provides a wider, holistic view. Of particular interest are the relationships and the replicated processes that occur across the forms of interaction. For example sketching initial ideas can be seen in productive interaction with a focus on producing an outcome, and in longitudinal interaction where the purpose is to retain the idea and develop it at a later stage. The relationships between structural and productive interactions – for example choosing or manipulating a software environment – are a strong focus in creative practice. Longitudinal interactions are the platform on which productive and structural interactions occur.

Structural interaction includes the *production of structure*, and computers can be particularly effective in this regard. By supporting the production of musical instruments, and the use of these instruments as a tangible structure with which to produce compositions, Music Builder gives an example of how the production of structure can be integrated in an environment for producing ideas and creative outcomes.

Collaborative structural interactions also influence production, supporting negotiations through which teams build a shared conception of the outcome and how it will be produced. By defining and developing shared structures in Music Builder, collaborators co-ordinated their play. Responding to the structure given to them in distanced evaluations of Sonic Sketchpad, users adopted a call and response model of collaboration.

An alternative paradigm for integrating our creative interactions with computers is presented by generative and A.I approaches to creativity. Here humans develop structures, and computers produce ideas in them. It is conceivable that such automations could also integrate our longitudinal interactions: Systems could be envisaged that took as an input a repository of resources regarded as interesting, and used this as the basis for generating outcomes. In these cases, the computer takes the role of a colleague as defined by Lubart [15]. These examples show how the perspectives can be used to describe or explore new forms of human – computer interaction in creativity.

Longitudinal interactions integrate with productive and structural interactions through the retention of previous work, and the development of rough ideas and structures. Retention is only useful to production if the resources are available and visible at the point where they might be used. Effectively alerting users to the possibilities for using previously collected resources in productive interactions is central to the value of such tools. Support for association is key to making collected resources visible and usable.

Including Contextual Factors

The utility of a generic understanding of creative interaction to designers is partially dependent on their ability to consider the influence of contextual factors on instances of these interactions. Two possible approaches to design are either to negate differences across contexts, or to specialise the use of a tool towards specific contexts.

Sonic Sketchpad and Music Builder are specialised for the domain of musical composition. At a productive level, this required an understanding of the forms of idea representation and their uses to be integrated. In designing the structural interactions possible in Music Builder, an understanding of primitives underlying the structures to be manipulated (qualities of sound and styles of interaction) was required. Alternatively, with the Associative Scrapbook we negated variations by supporting generic longitudinal interactions with common media. The system integrates with domain-specific needs by opening files in external applications. Affording structural interactions also increases the scope of the interactions a tool can support: In Music Builder, various paradigms for interpersonal interactions were possible or are conceivable, such as the sharing of developed instruments. The scaffolding provided by templates made Music Builder suitable for use by novices and experts, and supported experts to guide novices through the sharing of structure.

Evaluation from Each Perspective

An important and complex task in designing systems for creative interactions is evaluating whether they are effective. As a starting point, we suggest some high-level principles for evaluating systems from each perspective:

Support for productive interaction should provide effective idea representation methods and feedback suited to understanding the place of an idea in the context of the current conception of the outcome. A set of representation forms suited to the context of use should be elicited and provided. In collaborative settings, systems should support the sharing of evaluative opinions leading to negotiation over whether or how the idea will be used.

Support for structural interaction should allow users to convert conceptual structures into tangible elements of an interface, as this supports exploration and sharing and allows users to bound production into a desired space. Systems should link structural interaction closely to production, so that the evaluation of structure can utilise the evaluation of ideas. In collaborative structuring, development requires support for the negotiation of the structures within which collaborative production occurs.

Longitudinal interactions are supported by immediate access to tools for initial idea representation across a range of contexts. Equally important is the ability to amalgamate and organise these materials, and to make them available as a resource for productive and structural interactions. Tools should integrate exposure to relevant inspirational materials, ideally in a social context where relations can be developed between those who share interests.

CONCLUSIONS

The perspectives on creative interaction presented here can form a conceptual framework with which to consider needs and possibilities in the design of new technologies for creative activities. They describe processes that are generic

across creative activities, but provide scope to understand and integrate contextual factors.

Our future work will aim to understand in detail these forms of interaction, their relationships, and how to utilise the perspectives in the design process. In particular, using the perspectives to understand types of social and collaborative interaction will extend our understanding of interpersonal needs, and further understanding of how longitudinally collected resources can be integrated with productive interactions is seen as a fruitful area for design. Methodologies for utilising the perspectives and integrating contextual factors in design will also be explored in more depth. Through this, it is hoped that further theoretical and practical contributions to understanding creative interaction can be made.

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