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Understanding Collaborative Sensemaking for System Design — An Investigation of Musicians' Practice

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Abstract

There is surprisingly little written in information science and technology literature about the design of tools used to support the collaboration of creators. Understanding collaborative sensemaking through the use of language has been traditionally applied to non-work domains, but this method is also well-suited for informing hypotheses about the design collaborative systems. The presence of ubiquitous, mobile technology, and development of multi-user virtual spaces invites investigation of design which is based on naturalistic, real world, creative group behaviors, including the collaborative work of musicians. This thesis is considering the co-construction of new (musical) knowledge by small groups. Co-construction of new knowledge is critical to the definition of an information system because it emphasizes coordination and resource sharing among group members (versus individual members independently doing their own tasks and only coming together to collate their contributions as a final product). This work situates the locus of creativity on the process itself, rather than on the output (the musical result) or the individuals (members of the band). This thesis describes a way to apply quantitative observations to inform qualitative assessment of the characteristics of collaborative sensemaking in groups. Conversational data were obtained from nine face-to-face collaborative composing sessions, involving three separate bands producing 18 hours of recorded interactions. Topical characteristics of the discussion, namely objects, plans, properties and performance; as well as emergent patterns of generative, evaluative, revision, and management conversational acts within the group were seen as indicative of knowledge construction. The findings report the use of collaborative pathways: iterative cycles of generation, evaluation and revision of temporary solutions used to move the collaboration forward. In addition, bracketing of temporary solutions served to help collaborators reuse content and offload attentional resources. Ambiguity in language, evaluation criteria, goal formation, and group awareness meant that existing knowledge representations were insufficient in making sense of incoming data and necessitated reformulating those representations. Further, strategic use of affective language was found to be instrumental in bridging knowledge gaps. Based on these findings, features of a collaborative system are proposed to help in facilitating sensemaking routines at various stages of a creative task. This research contributes to the theoretical understanding of collaborative sensemaking during non-work, creative activities in order to inform

the design of systems for supporting these activities. By studying an environment which forms a potential microcosm of virtual interaction between groups, it provides a framework for understanding and automating collaborative discussion content in terms of the features of dialogue.

Keywords

Computer Supported Collaborative Work, Sensemaking, System Design, Music Information Behavior, Groupware, Non-work Information Behaviour, Creativity

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Glossary of Terms

API	Application Programming Interface
CA	Conversation Analysis
CSCL	Computer Supported Collaborative Learning
CSCW	Computer Supported Collaborative Work
Cardinality	RSA finding that is defined as the number of references of overlapping lifetimes in a conversation segment. Used as a heuristic for complexity inherent in the collaboration
Density	RSA metric defined as the occurrence divided by lifetime. It is a measure of the relative importance of a reference in a conversation segment
Frame	Concept from HCI theory of sensemaking. Frames are the placeholders for new data, and the means through which knowledge is organized and communicated
Groupware	Software designed to facilitate collective work by a number of different users
HCI	Human Computer Interaction
IE	Information Extraction
Lifetime	RSA metric defined as the number of lines of conversation text from the first mention of a reference type to the last. It is a measure of the overall relevance of reference.
LIS	Library and Information Science
MIB	Music Information Behaviour
MIR	Music Information Retrieval
NLP	Natural Language Processing
Object	RSA reference defined as the content of conversation in terms of musical ‘things’ (nouns). For example, chords, notes, verse, etc.
Occurrence	The raw frequency of a reference type
Ontology	A definition of the types, attributes and relationships of the entities that comprise a domain
Performance	RSA reference type defined as directives and instructions given between members
Plan	RSA reference type defined as content referring to objectives or strategies

Property	RSA reference type defined as characteristics (adjectives) of RSA objects
Reference	Unit of RSA analysis which is a term in the discourse, consisting of plans, properties, objects, and performance
Rock Lottery	Local rock music fundraising event in London
RSA	Referential Structure Analysis

Chapter 1

1 Introduction

The overall goal of the current research is to address the problem of designing information systems which have the capacity to support creative human tasks. The study builds on the premise behind Computer Supported Collaborative Work (CSCW), which is a design field aimed to facilitate group work through the application of computer technologies, driven by ever-changing contextual and environmental constraints (Schneider et al., 2010). Using field observation, and a systematic quantification of the content of group conversation, the study formulates a comprehensive description of collaborative sensemaking of practitioners, while accounting for contextual factors that steer the process. Although utilizing data- gathering methods similar to other studies of collaborative songwriting, the current approach differs in that it deals with short-term outcomes over observations in close succession. It also utilizes measured patterns in language to hypothesize about sensemaking routines with the goal of facilitating sensemaking within a collaborative system.

1.1 Dissertation Structure

This dissertation begins with a background and introduction to the information behaviour of musicians in relation to creating music. There is a timely problem intrinsic to this research of how to investigate collaboration in a real-world setting as a way to address and inform the design of collaborative applications. Previous research in sensemaking activities, creativity, and collaborative applications are discussed, while focusing on the lack of investigation regarding amateur musicians and the need for more robust, expressive collaborative technologies.

A three-pronged methodology is described, designed to capture and quantify user discussion as a way to learn about sensemaking, and thus inform the design. A model of the interaction is outlined, and the results are assessed with a concentration on sensemaking processes, together with possible design intervention used to overcome them. For each qualitative finding, system design feature(s) are proposed to address the exhibited needs of collaborators, and to help capture aspects of sensemaking routines as products of collaboration.

Chapter 2

2.1 Problem Statement

Thus far, only scant research exists from information science about how the design of collaborative tools is used to support the collaboration of creators. This gap exists despite the fact of current rapid development of technological resources and tools to support collaboration. As has been demonstrated in prior research, language behaviour offers many insights about the nature of collaborative practice in non-work, leisure domains. Building upon this research, methods of language analysis inform the hypothesis of this dissertation, with the focus on designing collaboration technologies and systematizing the study of collaborative music making practices.

In the climate of development of web technologies which support collaboration, a change is occurring in the practice of those musicians who rely on digital representations to exchange and develop across virtual spaces. One of the objectives of Music Information Behaviour (MIB) is to understand, through the incorporation of empirical user studies, how information systems can be brought into alignment with users' needs (Cunningham et al., 2003). Information behaviour may indeed be extended to include not only how music is used and searched, but how it is created as well. It is pertinent to ask whether collaborative systems can be improved to support activities aimed at producing content of a creative nature. The production process, it is hypothesized, provides a wealth of useful information in the form of collaborative interaction. As this interaction is made explicit, through language analysis for instance, it provides an abundant source for describing the music itself.

Collaborative music-making refers to the individual and social practices through which a piece of music is conceived, negotiated, and codified. The findings, although specific to the music domain, carry into collaborative problem-solving as a creative task in general, challenging models of how groups and communities innovate and progress over time. In many cases, today’s musicians depend on digital representations of music which are adapted, edited and shared using various software tools. The question of how these competencies can be more effectively cultivated and assessed at the collective level presents a major challenge (Tan et al., 2014).

A number of tensions identified in previous research suggest that “best practice” in the design of

collaborative systems may be fundamentally at odds with the requirements of such systems to support important aspects of creativity (Eaglestone & Ford, 2007). The creation of music (and performance) may be facilitated through the development of more specialized computer-supported collaborative applications, ones which adopt a transparent and mediating function in the musical discourse between creators and their musical experiences. As information technology evolves, so has access to music, and so have capabilities for managing, preserving, and retrieving musical information (Laplante & Downie, 2006). The field of music information systems suffer from a scarcity of viable and robust tools both to enhance these competencies, and to track the work of composers. The primary problems addressed in the current research arise from current information system designs, particularly with respect to those systems used to structure interaction as a way to support human tasks. Work on digital representations remains a highly individualized practice. The result is that the capacity for true collaborative engagements and peer negotiations in the course of making music is noticeably limited.

This thesis considers the co-construction of new, musical knowledge by small groups. It is critical to information system because it emphasizes coordination and resource sharing among group members, who come together to collate contributions into a final product. The aim is to improve upon the present situation by adopting a normative perspective which is informed by Computer Supported Collaborative Work (CSCW), Human Computer Interaction (HCI), and sensemaking theory. The objective is to establish the baseline for theorizing about collaborative products involved in collaborative music-making. I identify key dimensions of real world practices, including modes of communication and conversational topics which relate to sensemaking, and propose the theoretical scaffolding for computer-mediated collaborative engagements. The scaffolding is a dialogic framework for characterizing, fostering, and assessing roles of amateur musicians in the context of collaborative problem-solving. I propose system features based on findings, which capitalize on the products of collaborative interaction. Using a three-pronged method of conversational analysis, referential structure analysis and qualitative analysis on datasets consisting of field observation, conversational transcripts and interviews, I measure and assess patterns of participants' verbal and musical group activities. A profile of these trends is provided in regards to how they facilitate sensemaking and creative problem solving of musicians.

Chapter 3

3.1 Justification of the Problem

Over the past decade, dissatisfaction has arisen with the limitations of the information seeking approach to collaborative sensemaking (Case, 2002), and with the limited explanatory power underlying the concepts, models, and theoretical notions that underpin collaborative problem solving. The emphasis on collective creativity specifically stems from recent scholarly calls in the field to move beyond traditional measurements of creativity as an individual mental property toward a focus on its collective and collaborative aspects—that is, its social and interactional dimensions. By examining the real-world practice of experienced, non-professional musicians the study addresses this lack of understanding. It looks at how the products of collaboration, and the language patterns and behaviours of collaborators, are indicative of sensemaking and co-construction of knowledge. The goal of this research is to inform the design of collaborative technologies.

Research in Human Computer Interaction (HCI) has looked for tools which may help facilitate creativity in problem solving tasks and the composition of novel artifacts. Creative work such as music production is a cognitive activity operating within environmental conditions (Wiggins, 2007), and is a situated practice governed by rules, objectives, and opportunities for exploration. The rise in social computing has led to a shift from passive media consumption to cultures of participation (Blomberg & Karasti, 2013). What is more, the coordination and integration of collective design rationale and social creativity provides new opportunities in sophisticated socio-technically mediated collaborative communities. Collaboration patterns unite collaboration rationale and creativity by acting as “boundary definitions”, allowing generic lessons learnt to be uniquely modified, extended, and appropriated by individual communities to match the peculiarities of their situated reality (de Moor, 2012). Tools should, therefore, provide ways to build the domain knowledge of users by giving access to performances, encouraging sharing of musical experiences, donating results, and motivating learners through expert feedback (Fischer, 2011). Insights from the HCI domain are incorporated to help understand how design principles might address complex informational needs within music communities, while recognizing the ways musicians actively “regulate, elaborate, and substantiate themselves as social agents” (de Nora, 2000, p. 42). On a broad scale, it explores new ways that the artistic community may

benefit from technology by empowering them to be not only more productive, but more innovative. Informing design, for example through enhanced interfaces, allows the exploration of alternatives, and highlights key portions of the dialogue which capture design decisions involved in the creation of collaborative products (Hargreaves et al., 2012). By observing group songwriting behaviours, this study also builds on research of creativity which challenges the popular stereotype of the creative artist as ‘lone seeker’, and highlights the social nature of thinking and learning (Collins & Dunn, 2011, p. 198).

Chapter 4

4.1 Rock Lottery

To conduct the study, I have chosen a setting that is an ideal environment for interfacing with and observing musicians, collaborating in a live musical enterprise. Here, I briefly introduce the Rock Lottery event: a local charity event which is an invitation-only music performance show, organized by an arts organization, whereby 25-35 local rock musicians are assembled at random into distinct bands. Each band writes several songs over the course of three days, and then performs the songs at a local venue. The Rock Lottery has been an ongoing and popular event involving many talented experienced local musicians. Proceeds from the event go to support a local art gallery. The participants involved represent a cross-section of practicing, non-professional artists who perform in local bands. It forms the setting for my research and the avenue for sampling participants, as well as for information gathering and data collection.

4.2 Information Behaviour of Musicians

This is a study about learning the collaborative behaviours of a community in order to create systems designed to facilitate group sensemaking through the use of these tools. The question, therefore, hinges on a broader look at the target group, musicians, to property situate extending knowledge in three areas addressed in the literature. For musicians, technical resources are viewed as the catalyst through which people manage these needs. However, there is surprisingly little mentioned in information science research about how these same resources may support the creation of music itself. Historically, creating music has always been intimately linked, even synonymous with the human musical experience (Small, 1998). Indeed, it is a relatively modern phenomenon to view music simply as a reified, externalized “object” that is merely described and consumed. Notions of creativity have always been interpreted as highly individualistic.

The affordances allowed through collaborative technologies demands renewed investigation to help steer the development of tools which are able to consume and use these data in productive ways. Support has increased use of interactive systems and “human in the loop” methods, modelling how humans perceive content and how to integrate such a model in the development of cyber systems (Schirner et al., 2013). A host of ethnographic studies have examined

information behaviour in various real-world settings to help to understand MIB (Cunningham et al., 2003) and collaborative work (Schmidt & Bannon, 2013). A summary of the work by various researchers reveals a strong correlation among the preferred resources and channels of information and music information behaviour. Patterns in collaborative experiences have also been investigated through interviews and observation (Rasmussen & Conroy, 2012). With multimedia objects, there is often the need to look outside the visual, sonic, or even textual content and involve human intelligence in the description of media content. Musicians and music users develop and annotate their own content in new ways, access music from a wealth of web resources, and integrate it as part of their creation. Products are disseminated to vast audiences to an extent not before realized. Those persons who wish to explore ways that new music can be invented outside of traditional commercial channels have demonstrated ingenuity to capture performances, edit and share content in ways that are gradually redefining norms of music production (Tanaka et al., 2005). Innovations of this sort yields major implications not only for the future of the subdomains of music: commercial enterprise, education, and industry — but also for our concept of what it means to be a creator, and for our perceptions of creativity itself.

In this study, I explicitly concentrate on the pre-development activities which refer to all activities from idea generation until the implementation of a creative artefact. The creative process may be conceived of as a series of problem solving and sensemaking exercises, each requiring the rapid organization of knowledge, synthesizing new data, reshaping beliefs, and developing routines to achieve a common goal. The information operates on environmental factors in which the user currently exists. In this environment, generating knowledge, screening, evaluating and authorizing form the substance of decision making processes across time (Mintzberg et al.,1979).

Parallels to these ideas have been employed in the theory and practice of library and information science, as well as CSCW in non-work settings. Factors that constitute barriers or obstacles to information seeking include lack of specialized resources, a complication or problem that can be attributed to the specialized nature of a community. Results of these studies are discussed in detail below. Gaps in research informs the direction of the current study, a study which quantifies and analyzes both the products of collaboration, and the use of collective knowledge.

Chapter 5

5 Literature Review

This section includes a literature review relating to the current research in sensemaking, music and creativity and computer supported collaborative work.

5.1 Sensemaking

Sensemaking as a concept and a term is the product of a period of ongoing evolution of meaning and use. The concept has migrated from and between disciplines, and has been subsumed within, for example, the more precise task of information seeking, real world problem solving, and collaborative search. Most of the current sensemaking research has been focused on helping individual users make sense of large amounts of information. As it has been adopted in various domains, the term has undergone the business of morphing from rigid definitions towards flexible applications depending on the phenomenon under examination.

A body of research in the information science domain has emerged around system users and their engagement and use of information. In LIS, Sense-making theory creates an insightful picture of the ways by which individuals make sense of their experiences in problematic situations (Dervin, 1999). Dervin employs the metaphors of situations, gaps, bridges, and uses to depict information seeking as a process of interaction between operators emerging in the cognitive mental states of the individual, and actors in the physical world. Gaps refer to questions or information needs that develop — states of disharmony in understanding and missing links between states. In contrast, gap-bridging refers to processes of information seeking and use as the construction of a more proper definition of the situation. Although the Sense-making theory draws heavily on conceptual formulations, it has nevertheless gained empirical support, which in turn has strengthened the hypothesis that information seeking is a constructive process based on the utilization of categories of situations, gaps, and uses. The starting state of the process occurs as a gap, an anomalous state of knowledge, or an information need. According to Savolainen (2006) it is the way by which individuals orient themselves in non-work situations and seek information to facilitate problem solving. The dimension of cognitive versus affective indicates the degree of rational considerations in a problem-solving situation. On the one hand, cognitive orientation

emphasizes an analytic and systematic approach to problems. On the other hand, the affective orientation refers to an emotionally laden and unpredictable reaction to issues at hand.

In the Human Computer Interaction (HCI) field, sensemaking is addressed in the context of individual and group interactions with information systems. It has been viewed as a cyclic process of finding information based on an initial framework, and organizing information into categories or refining representations based on new information found. Russell et al. (1993) employ sensemaking as the process of encoding retrieved information to answer task-specific questions. Task completion can be described in terms of operations, where each operation requires particular resources. These can be either internal cognitive resources or external for information storage. While sensemaking has been modelled as an important aspect of information seeking activities, discussions of sensemaking have been in the context of individual information seeking (Paul & Morris, 2011). Within HCI, the related Data/Frame Theory of sensemaking (Klein, 2006) involves a series of closed loops of populating and reshaping frames which in turn shape the data. The data/frame theory assumes that meaningful representations, called *frames*, define what counts as data and how those data are structured for mental processing (Klein et al., 2006). Whereas frames define and shape data, data can mandate changes to frames. Cycles of searching for representations and then encoding them is identified as a four stage process: First there is a search for representations in the part of the sensemaker. The sensemaker creates representations to capture important regularities in a way that supports the use of the instantiated representation. Second, representations are encoded it in an appropriate representation. Third, data-driven representations shift and reduce the cost of the task operations (Russell et al., 1993). Hence, sensemaking can involve elaboration of a frame (e.g., filling in details), questioning a frame (e.g., due to the detection of anomalies), or reframing (e.g., rejecting a frame and replacing it with another). The data/frame theory proposes backward-looking processes involved in forming mental models that explain past events and forward-looking mental simulations that predict how future events will unfold (Pirolli & Russell, 2011). Thus, sensemaking iterates between the top-down representation instantiations and bottom-up representation search processes.

Collaborative sensemaking models are useful to delineate the activities at the point between "collaboration" and "information behaviour," and also to understand the sequence of activities in

facilitating collaborative work. They help contextualize information in order to create meaning to address the problem, and are organized into three broad phases: *problem formulation, collaborative information seeking,* and *information use (*Karunakaran et al., 2013).

The evolution of the term across disciplines is significant for this study since I utilize elements of the concepts of sensemaking from both these disciplines. The following discussion will highlight empirical findings that demonstrate the utility of sensemaking theory as it relates to understanding group interactions not only in professional occupational arenas, but in leisure (non-work) domains as well. Its track record in such environments has been useful in pointing to the function of discourse as a tool for constructing shared meaning within social communities, bound by common goals. A review of recent research of computer supported collaborative work and specifically non-work-based applications, is then used to draw connections between ways that sensemaking methodology can be used in the development of social software and groupware. I thus address a critical goal of HCI, which is to explore how collaborative sensemaking can be empirically leveraged to form collaborative instruments that assist members of groups, using technology as a means of group participation, joint authorship, and identity construction.

Since the 1970s, Dervin's writings have pivoted around a central theme—a call to focus on communication *as* communication rather than as transmission, and to reduce the disparity between user-oriented research and practice. It has been applied to users, for example, patrons, audiences, patients, employees, citizens, leaders, and customers, with an emphasis on an instance of dialogue. The practice of making ideas is what Dervin calls "verbings" (1983) that rise above the specific noun-based idiosyncrasies of formalized information domains to the universals of how humans navigate situations. Designing of information is based on the dialectical dance between nouns and verbs: nouns stand for relatively stable representations of reality—for example, *facts*—whereas verbings imply the ways in which these facts are approached as something malleable and designable in a specific context (Savolainen, 1995). The focus on language is evident in the work of a number of LIS researchers working within the constructivist paradigm (Talja, 2002), scholars who have put a primary emphasis on discourse as the vehicle through which the self and the world are articulated, and on the way different discourses enable different versions of reality to be built.

In collaborative sensemaking the idea is extended outside of the individual. Groups of people making sense of complicated and dynamic information, must coordinate not just their information sharing but also their intents, their interpretations, and revisions of past theories based on newly arriving information. In HCI there has been a recent emergence of collaborative and social sensemaking systems with a host of problems to address, including issues of common ground, communication, hand-offs, and coordination. In particular, there is a growing focus on understanding how teams working in different domains shift their attention individually, and as a group, to handle the sensemaking tasks (Pirolli & Russel, 2011).

DuPreez and Fourie (2010) looked at users in an occupational context with the aim of developing a framework of the collaborative behaviour of engineers. Theoretical models which are applicable to a study of this user group were analyzed, in particular Leckie, Pettigrew and Sylvain's general model of the information seeking of professionals (1996). The influence of sensemaking rests primarily in its linkage of the definition of information use to the user's situation. Context of behaviour was found to be understood within more narrow boundaries of social norms, which sets the parameters of acceptable standards and codes of behaviour. Although social norms do allow for a degree of social control, they also provide some assurance that people will behave properly, creating a framework within which members of a small world maintain their sense of order and balance. Thus, even though the boundaries of world are set by social norms, most members nonetheless feel disinclined to cross them (Huotari & Chatman, 2001).

Other workplace studies have shifted the focus from individual to collaborative sensemaking to examine the phenomenon in emergency room settings, where nurses do not simply provide an answer, but evoke past memories and re-contextualize them to apply to the problem (Karunakaran et al., 2013). Both the charge nurse and the attending physician are able to share frames of reference and understand when actors interactively make sense of the sought information that is fragmented and messy (Reddy, et al., 2010). These sensemaking processes thus give facts and experiences meaning, making the underlying information more salient—a result which, in turn, could lead to generative outcomes. Incidental forms of information behaviour emerge from an inclusive understanding of those practices. Here, a constructivist and discursive positioning paradigm was used, that is, the notion that meaning is constructed from

factors in the environment. Participants in a clinical care setting position themselves in ways that justify certain forms of information seeking and giving.

In HCI, there is a prevailing "user-centered" approach to information research, based on an implicitly systems-centric perspective (Julien, 1999). Sensemaking is not an outcome, but a process of authoring—one which is ongoing, social, and grounded in identity construction (Weick, 1995). Collaboration on creative, problem solving communication follows predictable, repeated structures. These are structures which provide a framework for discussing sub-problems, associated processes, and sequencing information (Shah, 2012). In terms of design, such a rule-based structures integrated in a messaging system can aid information users. Weinberger et al., (2013**)** studied the various ways students make sense of algebra lectures. In this case, sensemaking was the central process by which students construct personal meanings for phenomena they experience. Results show the importance of how their sensemaking practices influence what they might learn from the lecture, and identified three types of sensemaking frames: content-oriented frames to organize data related to the mathematical content of the lecture; communication-oriented frames related to the instructor's presentation and delivery; and situating-oriented frames to related to the purpose that the content and communicational aspects serve in the class (2013). A relationship is drawn between the choice of frame, the students' sensemaking practices, and in turn, the potential missed opportunities for learning from the lecture. The idea of a sensemaking frame is particularly useful since it helped to specify aspects of attention during the learning process, and anticipate categories of meaning that are constructed along the way.

Since its inception, sensemaking and design has been focused on how to influence technological output, particularly in human computer interaction research (Dervin & Naumer, 2009). Research emerging in 1993 from the Computer-Human Interaction special interest group from the Palo Alto research centre emphasized how to use and promote sensemaking through interface development. This approach focused on information retrieval according to well-defined work tasks. Individual characteristics of information seekers, as well as socio-cultural determinants of information seeking, seem to deserve closer attention than addressed in sensemaking theory. Using sensemaking theory as a lens to observe and analyze the decision making behaviour of senior management of international aid organizations in the Democratic Republic of Congo,

Muhren, et al. (2008) provide a concise set of design premises that have been developed for dynamic emergency response management information systems. The authors found that management is constantly acquiring and processing information from a variety of informal and formal sources that may indicate the possible surge of acute social crisis. Therefore, those information systems that enable effective and efficient information processing and decision making within, between and among the organizations are a critically important asset to these organizations.

Savolainen (1995) has used sensemaking as a way to concentrate on the situational aspect of information seeking, providing detailed anthropological analysis of everyday life information seeking situations. These studies have divided the environment of information users into a set of preconditions which shape behaviours of insiders and outsiders, and purposive and non-purposive information behaviour for making sense of a problem situation (Savolainen, 1995). Discursive positioning gives LIS researchers new insight into the social practices within which everyday life information seeking takes place. In particular, positioning offers a glimpse into the ways that information needs come to be constructed among participants, and how those constructions invite or discourage information seeking or giving (Prigoda & McKenzie, 2007). Sometimes, user behaviour is examined as it naturally occurs; sometimes it is examined in the context of specific design tools. Different operations during sensemaking require different cognitive and external resources, and representations are chosen to reduce the cost of information processing. The power of these representational shifts is generally under-appreciated, and invites studies to explain how externalization of representations may facilitate sensemaking.

A movement has emerged to push sensemaking research out of the workplace altogether. This concern is not new within LIS circles, even identified as far back in 1974 (Talja & Hartel, 2007), with a presentation of so-called “life information” research which includes discussions of the information needs of select groups. The discussion turns to certain major contributions of non-work information seeking, also called *citizen information seeking,* previously overshadowed by analysis of professional occupations. These activities take on great significance, particularly when one acknowledges the ubiquitous nature of technology in everyday communication. Non-work settings have become saturated with collaborative-type technologies; examples include mobile, ambient, ubiquitous, and wearable computing, as well as social software, virtual, and

mixed reality environments. Methods for understanding sensemaking theory application span both qualitative and quantitative approaches while engaging with and observing the non-work practices of a diverse blend of communities; for example, domestic and parenting (Massimi et al. 2012; Rode, 2009;), children and youth (Barkhuus & Lecusay, 2012), leisure (Durrant et al., 2012; Szymanski et al., 2008), and gaming (Crabtree et al., 2007; Nardi & Harris, 2006). The basis of the discussion of life information is the identification of what information is required for successful living in every sense, from basic survival to higher-order emotional and self-realization needs. Life information, therefore, includes a broad range of potential areas of exploration which do not necessarily demand individual justification apart from self-evident psychological and socially significant everyday life needs. Understanding sensemaking as a function of physicality, affect, and as a component of information creation is promising in that it provides potential generalizability to domains which themselves rely on actions as a component of information behaviour and creative authorship.

In his study of theatre professionals, Olsson (2010) developed a more holistic approach of information behaviour which acknowledges the complexity of sensemaking as more than the problem-solving behaviour of individuals, but as an embodied, social process, involving emotion as well as rationality. Rather than a series of isolated encounters with information sources, his participants reported the continuous nature of their relationships. Individuals' encounters with information sources, Olsson concluded, are built on previous experiences which helps to foster constructions of the dramatic text and other informants. In this case, professional lives are based on the ability to embody their knowledge: they need to manifest their understanding in the physical world as physical actions in a physical space. At the same time, professional designers need to do this through set and costuming, and directors through "blocking" the movements of their actors, constructing the action to suit the confines of the space.

As yet, no studies have addressed music as a design phenomenon in its own right. The field of music is extremely diversified, thus requiring an approach which that accounts for its many contexts and communities of practice. A generalizable characteristic as a leisure activity is that it takes on informal learning characteristics, with amateurs and professionals accessing data and materials through the Internet. Making music also necessarily involves physical engagement as well as potentially new constructions based on past experience. Qualitative studies and

interviews informed by sensemaking have been used to study various information-creating behaviours such as creating web-based magazines and newspapers, online media libraries, and Wiki articles (Koh, 2013). Applying various information sources as a method of learning has been noticed in the context of information creation and remixing. Information creation is postulated as one of the most complicated information behaviours, since intensive information seeking and use occur simultaneously (Koh, 2013). In spite of the current widespread practice of information creation by young people, little research exists to illuminate how creative users are engaged in creative information behaviour or how they make participatory contributions to the changing information world. Koh's study shows remixing as the creative reuse of information in order to produce new information. Previous studies on youth content creation identified that remixing is prevalent among today's youth regardless of gender, age, and socio-economic group (Lenhart & Madden, 2007). To create and publish reliable content, young people seek information from multiple sources and determine its accuracy (Koh, 2013).

Koh's findings illustrate the process of information creation, including content development, organization, and presentation, as well as noticeable patterns by youth such as visualizing, tinkering, and gaining a sense of empowerment. Creating information on the web includes identifying relationships between information pieces, connecting them with links, and developing categories of information so that people can navigate interactively. The act of remixing consists of a combination of skills such as gathering, blending, and recreating new expressive materials, and suggested and novel type of information behaviour applicable to technology in the new millennium (Lenhart & Madden, 2007**)**.

As with theatre professionals, a principal attraction of studying creative behaviour has been the opportunity it has afforded to explore the role of affect in their sensemaking processes. Information researchers have tended to regard affective factors as at best only an annoying interference with effective application of cognitive skills to information retrieval and, at worst, the primary barriers to information retrieval (Olsson, 2010). Previous research has reported that youth experience both positive and negative feelings when they interact with information in the digital environment. Young people feel confident, comfortable, and familiar with information on the web. These feelings include a sense of empowerment, a sense of ownership of the innovation within the current digital environment. At the same time, in their use of the web, young people

also experience anxiety and uncertainty, or and express difficulty using information in the digital environment (Bowler, 2010). The studies described above use sensemaking as an analytical framework applied across many domains including art, leisure, and ill-defined problem solving scenarios. As yet, no studies have addressed music as a similar design phenomenon, a phenomenon which also necessarily involves physical engagement, as well as potentially new constructions based on past experience.

5.2 Creativity and Music

Creativity and innovation are increasing sought after and desired in many parts of our lives. The value of creativity is recognized in many areas including science and technology, social development, education and the arts. Information technologies support the generation of knowledge by enabling rapid access and processing of information at a global level, and there is a drive to research and develop technologies to support growth in creative fields. However, there is often confusion between tangible benefits of technology and the novelty of unfamiliar and sophisticated applications.

Creativity does not simply describe a particular kind of individual action but the way in which such action is recognized and acknowledged (Burnard & Younker, 2004). Music making is necessarily a collective process, though some actors have more creative roles than others. There is a dearth of research on the creative process of music making, and few studies investigate the factors that inspire music composers or explore how initial ideas are synthesized into musical scores and products. Investigation is needed in several areas: How do composers begin a composition? Are they being influenced by factors outside of music, and how conscious are they of these influences? What representations do composers rely upon during the creative process? If the locus is with the individual, it is necessary to consider how to measure the capacity for creativity, such as through divergent thinking tasks (Hargreaves et al., 2012). If the locus is on the product, it is necessary to consider what criteria is used to judge its degree of creativity (Eaglestone & Ford, 2007).

The body of theories generally referred to as *stage theories* describe creative work in discrete phases, summarized generally as *preparation*, *illumination*, *incubation*, *illumination* and *verification*. Preparation is the period when a creator becomes acquainted with and evaluates a

problem. Illumination is sometimes referred to as the flash of insight when there are signs that the the solution is soon to come. Incubation is the period when a creator is distanced from the problem – when conscious work is put on the back burner so to speak. Verification is the stage of refinement and development (Thorpe, 2007).

Creativity in problem solving processes is marked by innovations which are novel, elegant and address the requirements of the problem definition. Burnard and Younker (2004) investigated how individual composing pathways are framed in terms of problem solving and creative thinking, using a range of datasets to track students' thinking through talk and reflection on action. The intention of this work was to help identify difference and diversity in composing and to look critically at how individual approaches to composition reflect an interplay of activities such as verification, incubation, preparation and exploration. They argue that problem solving is a crucial part of the process of learning how to compose. Studies by Collins & Dunn (2011) confirm that many composers engage in experimentation and problem solving as they write, particularly during the initial stages of creation. They found that the composer was reluctant to abandon or alter the main ideas that arose on the first day of creating.

Ill-structured problems are those characterized by their lack of a clear path to the solution, or a clear problem statement at all (Rosen, 2014). In the case of ill-structured problems frequently found in music (such as composition and improvisation), the goal of musically creative tasks is to produce dissociation through the auditory channel. The 'Eureka moment' of the composer, which after further processing leads to the final work, is a moment of dissociation. To be considered creative, music must take the listener to dissociation through a different neural pathway, for example, by introducing unusual changes in tempo, tone, or key (Hargreaves et al., 2012). The related concept of *spreading activation* postulates that information is stored as a collection of small discrete nodes which are activated by other nodes through links (Collins & Loftus, 1975). A series of pitches in a tune may activate a tonal system, such as a major key, and the major key may then activate a happy emotion node (Hargreaves et al., 2012).

For music makers, periods of incubation are focused on creating a piece that leads to an experience stemming from the mechanics of dissociation. The concept of 'flow' (Csikszentmihalyi, 1996) is another conscious manifestation of dissociation that takes place during the period in which pieces are played as well as during the compositional process. The composition process

incorporates two basic phases: 1) the creative, subjective-intuitive phase, or state of flow, in which new musical material is produced; and 2) the evaluation of the material on the basis of knowledge and previous experiences in the context of the composition.

Addressing innovation in songwriting, McIntyre (2008) considers the veracity of the systems model of creativity which, like other models, may be investigated through qualitative research methodologies such as verbal protocol analysis. She found substantial evidence of three components of the systems model: *domain, field,* and *person.* Songwriters rely on existing background knowledge with regard to melody writing, song structure, harmonic and arrangement components (domain). They also operate within a broader sphere of social influence (fields) which dictate whether to accept innovations in domain knowledge through a feedback process. Finally, the limitations on autonomous decision making are constrained through expectations of their roles as songwriters (persons), and these decisions centre around the basic cognitive practice of nonlinear parallel processing of multi-categorized information. Folkestad et al. (1998) report finding two main strategies of composition: horizontal (conceptually completing the composition in form and content from beginning to end), and vertical (completing the composition in discrete, fully-formed, consecutive sections). Composers develop their own ideas and then explain them to peers through both verbal and non-verbal means (including singing, rhythmic speech, non-verbal imitation of sounds, demonstration of ideas on instruments, and graphic representation of ideas). These resonate with other findings in that they identify strategies that both conceptualize a composition as a whole and also involve passing through a series of processes until a composition is created (Thorpe, 2007).

The choice of musical genre like rock, punk, reggae, or classical is also an important variable in task design since the freedom to explore and develop new ideas should be an intrinsic part of the musical tradition. Campbell (1995) focused on the socio-musical aspects of songwriting by garage bands as a way to access the fundamental "realness" and anti-establishment character of rock music. She describes the processes of teaching and learning amongst members of the groups, as a rigorous form of musical transmission that she refers to as "song-getting." McGillen and McMillan (2003) assert that the characteristics of a "garage" band (amateur modern rock ensemble) revealed that participants' shared drive and focus, and their sense of identity and validation through membership in the group resonates with what young rock musicians had to say

about why they play and compose together in bands. On the other hand, Seddon and O'Neil (2003) found that those with prior experience of formal instrumental training tended to adhere to musical parameters associated with traditional forms and structures which are learned. For this group, experimentation played less of a role than those who had no formal musical training. They postulate that, as Webster had proposed, the acquisition of performance skill focuses on convergent thinking (coming up with a single best solution to a particular problem), while improvisation and composition focus upon divergent thinking (generating creative ideas by exploring many possible solutions).

Existing relationships between musicians is a factor of strong intuitive import to collaborative creation. Wiggins (2007) argue that there is a greater likelihood of transactive communication between groups of friends than those with no prior relationship, and that communication is affected by the existence of friendship. Open-ended and creative activities invariably involve tasks secondary to the creative process, namely, those which function to construct a shared social reality and maintain mutual engagement. Utilizing an open ended task design allows exploration of the nature of composition in a holistic sense, without the influence of classroom expectations. The use of closed, highly-structured creative tasks involving scientific reasoning are not well suited to understand real group composition (Wiggins, 2007). It is therefore helpful to explore the significance of divergent thinking for those with limited formal music training, yet with substantial musical competence and domain knowledge.

Certain research has measured the links between the incorporation of certain technologies and the qualitative increase in creativity and group learning. Studies of collaborative creativity using music technologies and of students' perspectives on composing with MIDI (Burnard, 2008) establish that technology provides an enabling environment in which learners and teachers enter a co-participative process around activities (Draper, 2008). There is now general consensus that the creation of a substantial new work or idea involves problem-solving and reworking over time as opposed to one "Aha moment" during which the entire piece is suddenly formulated (Thorpe, 2007; Collins & Dunn, 2011; Rosen, 2014).

Research in Human Computer Interaction (HCI) has looked for tools which may help facilitate creativity in problem solving tasks and the composition of novel artifacts. Creative work such as music production is a cognitive activity operating within environmental conditions (Pearce, &

Wiggins, 2002). Like music itself, the use of systems in music-making involves a sociocultural and theoretical approach which assesses behaviour with an emphasis on context (Hargreaves et al., 2012). Therefore, by applying reasoning based on contextual data such as task requirements and user information, tools provide ways to build domain knowledge by giving access to performances, encouraging sharing of musical experiences, donating results, and motivating learners through expert feedback (Shneiderman, 2000, Fischer, 2011). Insights from the HCI domain help us understand how design principles might address complex informational needs within music communities, while empowering and encouraging development, education, and innovation.

5.3 Computer Supported Collaborative Work

Group work is a process of connecting different agents together for a harmonious action. This exercise often involves bringing people or systems under an umbrella at the same time and place. During the process, the involved agents may share resources, responsibilities, and goals. Unlike coordination, and in contrast to cooperation, collaboration involves creating a solution that is more than merely the sum of each party's contribution. It involves various agents that may see different aspects of a problem that no individual has the skills to design, develop, and deliver alone, and it recognizes that shared artifacts are created over time (Schumann et al., 2013). In collaborative work that involves creation and design projects, designers require notation that communicates a sense of accommodation of ambiguous goals, and to clearly communicate uncertain ideas. Uncertain information finds its way into many typical design scenarios including co-authoring papers, iterating designs, negotiating plans, or decision-making. Group members engage in a process through which they can go beyond their own individual expertise and vision by constructively exploring their differences and searching for common solutions. Passing such messages among the participants during collaboration based on structured content can be helpful in distributing the messages with some sort of filtering, or the following rules and roles of a system, or both.

On a process level, free riding, dominance, group think, or hidden agendas are a few phenomena in group work that make it a non-straightforward effort (Nunamaker et al. 1997). Research in information behaviour has examined activities such as information seeking and retrieval from the standpoint of an individual user; however, the authority in such a process is vested in the

collaboration rather than in an individual entity (Karunakaran et al., 2013). On a group level, it is essential to create a shared understanding, define rules for decision-making, and facilitate interaction in such a way that effective collaboration becomes possible.

CSCW has emerged from a process of interlinking a range of research activities and communities. The technological array in which CSCW is embedded is in continual flux. The World Wide Web, initially launched in December 1989 to facilitate large-scale collaborative work in scientific research at CERN (Berners-Lee, 1990) underwent extensive development over the following decades to become a cross- platform facility for communication and interaction (Schmidt & Bannon, 2013). New technologies with collaborative potentials are emerging, developed for various purposes. Researchers engaged in their development or application may join the CSCW movement because they realize that their problems are related to problems already studied within CSCW; while researchers already engaged in CSCW research may explore the potentials of these new technologies. In sum, CSCW did not emerge as a specialization of an established discipline or as a joint venture and was not formed with a defined and generally agreed-to research program.

Communication on mobile devices plays an important role in people's use of technology for leisure. Mobile Internet connectivity can support a variety of group-based messaging and media sharing scenarios, and group-based messaging can enhance the social and leisure aspects of the communication (Reddy et al., 2010). Researchers, developers, and users are still asking in what ways and to what extent. Systems for text and photo messaging pervade daily work, and the use of mobile devices for one-on-one and group communication are witnessed to be used for their social qualities, utility, and "fun" (Count, 2007). The use of qualitative feedback has shown that for leisure activities, the use of these technologies is often and importantly about establishing and maintaining the emotional connection between people. In the context of computer-mediated communication, desktop-based systems supporting passive social awareness among groups have been shown to support coordination, and social psychology literature shows that cohesive groups encourage cooperation (Bentley et al., 1992), which in turn leads to positive feelings among group members.

Building on this infrastructure, a range of technologies has emerged, ranging from "collaborative working environments" for organizational settings, to advanced forms of computer conferencing,

such as “social media”, and free-form hypermedia technologies, such as wikis (Grasso & Convertino, 2012). At the same time, the mosaic of CSCW is rapidly evolving to also facilitate location-based, mobile communication, and other forms of “context-aware” computing (Schmidt & Bannon, 2013). Also termed “groupware”, these programs are used to support collaborative work by sharing tools and resources between group members and by giving communication opportunities within the group, and to the external world. They are generally of two kinds: task-related and communicative. Task-related tools support the performance of the task and the problem-solving process. Communicative tools provide not only access to collaborating partners, but also to other resources, such as external experts or other information sources (Erkens et al., 2005).

In recent reviews of the literature, it has been accurately noted that most field work studies of collaborative information behaviour have been developed in the healthcare environment and hospitals (Schmidt & Bannon, 2013)**,** since they are becoming more information-intensive and collaborative. As a result, the findings from these field studies are generalizable and transferable to multiple settings (Blomberg & Karasti, 2013). Researchers have also become aware that organizational work cannot be reduced to a series of individual activities and have consequently recognized the need to move beyond traditional interaction patterns between an individual user and a certain technology, or a closed set of environments. Shah (2012) has outlined 12 key dimensions to collaborative systems, which are integral to the development of any system which is intended to enhance sensemaking work. Of these dimensions, 4 (*intent*, *activeness*, *user roles*, and *awareness*) are highlighted and discussed below as a way of demonstrating how gaps in non-work sensemaking research can be aligned and applied to state-of-the-art CSCW research in specific collaborative dimensions. The state of the research has yet to address fully technological applicability to non- work and leisure domains, and in particular how a concrete understanding of these components can translate supporting group sensemaking in a system. Joint interpretation of and the meaning attributed to shared artefacts and representations by the actors is a central theme in CSCW examples (Schmidt & Bannon, 2013).

The first dimension of Shah’s collaboration scheme is *intent.* Intent is defined as the degree to which various aspects of collaboration are stated and understood (Shah, 2012). For example, students using a system to create a project know they are collaborating with each other, and

know who is responsible for doing what part. On the other hand, collaboration may happen without explicit specifications, such as visitors to Amazon.com receiving recommendations based on other people's buying behaviour. This dimension is an important consideration when defining how explicitly task requirements are established at the outset. Benefits can emerge when these are not precisely laid out and instead remain ambiguous. Ambiguity is beneficial in design communication, communicating imprecise, uncertain and provisional ideas is a vital part of design teamwork (Dalrymple, 2001). With reference to knitwear design, where communication using inadequate representations causes severe problems, Eckert and Stacey found that systematic use of meta-notations for conveying provisionality and uncertainty can reduce these problems (2003). However, a caveat in this circumstance is that uncertain and provisional elements need to be expressed as clearly as possible. Understanding what uncertainty information designers can and should communicate, and how they should do so, is an urgent task for research. In collaborative work that involve the creation and design projects, viewing design communication as conveying permitted spaces for further designing is a useful rationalization for understanding what designers need from their notation, to achieve clear communication of uncertain ideas.

Sketches and other representations of designs can be both intrinsically ambiguous, and ambiguous or misleading by failing to convey information about uncertainty and provisionality. An effective collaborative system should provide support for passing such messages among the participants during collaboration, as well as some kind of structure imposed on the messages passed to incorporate additional information, such as time stamps, tags, and associated processes (Shah, 2012). Such structure and information can be helpful in distributing the messages with some sort of filtering, or following rules and roles of a system, or both.

Shah's second dimension of *activeness* is about the involvement of a user in a group activity, whether there is an agreement about collaboration, and the difference between active and passive control over the actions. The coordination of activities is a major problem when considering teamwork. This is especially true when team members are distributed. Consider, for example, a team of distributed software developers that in parallel changes the source code of a project. Without any kind of support from the software, it is almost impossible to maintain an overview of activities and changes to the source code, or to discuss possible changes. In user- mediated

collaboration, the work is highly transparent to the involved parties, and the control rests with the users. In this case, the system serves as a passive element that helps with aspects such as communication and awareness, keeping the control with the users. Pickens et al. (2008) demonstrated a collaborative video search system where one of the participants was responsible for issuing queries, and the other participant was responsible for going through the results mining for information relevant to that person's information needs. In its most basic version, this system enjoyed predefined roles and these roles followed a fixed set of rules. However, with the ability to have structured messages with appropriate information comes more flexible roles with dynamic distribution of control among the participants and the system.

In the *Ariadne* system (Shah 2012), the collaborators, a reference librarian and an information seeker, work through their information seeking process using the co-browsing interface. Other systems such as *SearchTogether* (Morris & Horovitz, 2007), and *Coagmento* (Shah, 2010) could each be seen as interface-mediated collaborative tools in which the control rests within the users, though such systems often employ a few system-mediatory components. For instance, *SearchTogether* has a split search feature, whereby a team could ask the system to intelligently split the search results intelligently among the collaborators. The *Coagmento* system provides a transparent interface, in which a user can be aware of the task at hand, the shared workspace, as well as the group's history and products.

On the other end of the spectrum, the system drives collaboration, as in the *Cerchiamo* system (Karunakaran et al., 2013) where the users have limited and filtered access to their collaborators' actions and results. Other approaches attempt to combine the best of both of these techniques. Instead of imposing the roles onto the users or having the users explicitly come up with their roles, roles of collaborators may be inferred through mined behaviour within a collaborative session: the system learns how the participants in a collaboration are different and uses that information to suggest roles (Soulier, et al. 2014).

Applications derived from research in human-computer interaction have looked at ways to facilitate group communication and sensemaking through the use of visualization tools. They have also examined systems that allow users to explore facets within a domain, and trends for comparison. *Facet Lens* is an example. It is used to expose and explore relationships within faceted datasets; *Bungee View*, *Relation Browser++*, and *InfoZoom* are other examples, each of

which use bar graphs to show value distributions (Lee et. al., 2009). Whereas attribute values are intrinsically categorical, linear facets, in contrast, permit the visual representation of order within a facet in a way that allows data trends such as temporal relationships to be preserved and exposed. Visualizations of this sort are aimed at inspiring connections between disparate sets of data and overcoming barriers to understanding that would otherwise be difficult through static representations. As well, the act of joining in with others and accomplishing different tasks can be empowering, and creative activities can provide new and novel ways for people who otherwise have difficulty communicating (Riley, et al., 2009).

The creative formulation of new ideas through interface development is a goal that can be achieved through co-ordination and collaboration among users. Novel ideas of this sort have been hinted at in the music domain. Research on creativity in people with dementia, and prototyping music interfaces to promote creative collaboration—for example through simple tactile manipulation of music qualities such as emotion, tempo, and instrumentation (Riley et al., 2009) —have led researchers to believe that creative art expression might play a major role in expression of their unspeakable emotions, such as excitement, anger, or joy. Discoveries of this sort export both the idea and the potential investigative area that the notion of "invisible work" is one which may also be explored through non-workplace settings—in this case, music —for aesthetic and emotional realization. In these cases, hidden processes important to the task at hand were communicated through music in a way that works both from and towards collaboration.

The third dimension of Shah's collaboration scheme is *user roles,* which is how labor is divided, whether it is inclusive or hierarchical, and how skills are combined and organized. This encompasses how information is used, and describes features of work that allows users to see how the information flows in the system. Components of this dimension are information seeking, information synthesis, and sensemaking (Shah, 2012). A simple example of this might be a help service conducted via a chat interface. A number of workplace studies have been undertaken to investigate more general aspects of cooperative work such as "diagnostic work" (Büscher et al. 2009) and "invisible work" (Nardi & Engeström, 1999). These studies have led some observers to call for more flexible workflows where the system acts as a resource for coordinating work while at the same time not too strictly regulating action. The MUSE collaborative system (Reddy et al., 2010) is a Java-based tool derived from an assessment of work practice collaborative

information behaviour that allows two users to search independently for information while sharing that information at the same time. Subsequent evaluation showed that team members continuously exchanged information about the search process as they collaborated during information seeking and retrieval activities.

Appropriation is a key concept that is found in studying collaborative workflow support, and is the process by which people adopt and adapt technologies, fitting them into their respective working practices. It is similar to customization, but concerns the adoption patterns of technology and the transformation of practice at a deeper level. Studies of workflow systems have shown how a lack of flexibility often leads to elaborate "work arounds" where workers bypass the systems or engage with them in unexpected ways, and not always the most efficient ways to complete their work. In an engineering design domain, Dourish (2006) analyzed how collective use of documents or "project files" that consist of maps, drawings, permits, etc., and an intricate set of organizational practices, govern the ways in which project files are used and organized. Organizations, Dourish argued, lay down a specific categorization scheme by which documents are coded and located. That categorization, he continued, is not simply a resource through which the work of filing is conducted: it is a *part* of that work. It is an object of collaborative activity, in the way in which it is subject to collective adaptation, and an appropriation to suit the work at hand.

The generalizability of the findings as they pertain to Shah's dimension of users' roles is here made clear since appropriation of technology can incorporate the design principle of supporting multiple perspectives on information. Appropriable systems need to support the different perspectives that different people might have on information, implying a separation between information and the structures that describe it. There has yet to exist a general understanding of how leisure activities, rather than work domains, reside along the continuum of user control versus system control. The current study addresses this question. It explains how technical functionality can negotiate those appropriation and control schemes designed around the authorship of shared artefacts, as well as how their respective meta-notations improve communication between group members. The compositionality of properties of objects in the collaboration—for example, static and active values about who is collaborating, the state of the object of collaboration, the situational context—allow members of a group to organize a

common document corpus for their different individual needs, while properties also act as points of coordination between them. Examination of natural behaviour and data analysis are useful ways to explore this question, since such methods have been an essential resource in furthering the development of concepts such as situated action, flexible workflows, situated awareness, articulation work, invisible work, material resources for action, and common information spaces (Blomberg & Karasti, 2013).

Finally, *awareness* is Shah's dimension of collaboration which conveys knowledge to the group of what other people are doing. Although the theoretical status of the notion of awareness is contested, various technologies have been designed to "support" awareness with early explorations of the role of media spaces or permanent video and audio connections to enable awareness in distributed environments (Gross, 2013). Motivated by studies showing how awareness is achieved among co-located groups, these technologies are aimed at providing peripheral awareness, where the actions of others could be casually observed without requiring intentional awareness generating actions. A study of emergency call centre workers, for example, shows how attentiveness to others is "specifically occasioned by a situation, which becomes recognizable as problematic as the interaction develops" (Blomberg & Karasti, 2013, p. 378). In other words, awareness is motivated by what is going on at the moment and is not a generalized experience. Many things exist in the environment that one could be aware of, but it is those entities that are relevant to the situation at hand that become notable and available for inspection. Workspace awareness support is mandatory for group support systems, since it allows users not only to follow actions of others, but also to understand and respond to any changes others make to the workspace. Tam and Greenberg (2006) conclude that in the case of missing asynchronous awareness support, collaboration slips out of control and missed changes can ravage the whole collaborative process unintentionally. Participant observations have guided the development of systems geared toward making the actions of others more visible thus enabling the alignment of work tasks across workers, groups, and organizations. (Schmidt & Bannon, 2013). Efforts in development depend on several factors, including the cost and benefit of awareness, available technology, and privacy. Applications such as Google Drive use workspace awareness, whereby one can work with the group's artifact in collaboration, but does not also allow the participant to see others' individual contributions.

Over the years, the concept of situated action has led technology designers to rethink the role technology plays in the unfolding of action. Two studies highlight how each team member's awareness, in terms of an overall understanding of his or her circumstances, is not limited to showing that awareness is in many settings essential for successful coordination. Instead, that awareness goes beyond static and constant information and involves both careful attention to on-going events and actions. The first study, that by Heath and Luff (1992), conducted an early investigation of cooperative work in London Underground Control Rooms. Intense cooperation between line controller and information assistant were among many examples the authors explored of how workers exchanged information with each other in their respective environment. The second study of the London Air Traffic Control Centre produced new insights into the cooperation that takes place in radar suites (Bentley et al., 1992), a location where work happens without communication. The authors provided examples in which communication does not take place during the handover of an airplane between sectors.

The *Coordinator* (Winograd, 1994) was designed to help order work, to facilitate people working together, and to manage interdependencies among workers and work tasks. The system defined a coordination-based workflow that was grounded in theories of communication and cognition. Constant awareness systems also aimed to provide coexistence awareness, but compared to the original media spaces, had additional functionality. Media space systems have proceeded to provide permanent connections between two (or more) sites via audio and video in order to provide general awareness of who is around as a basis for chance encounters. Media spaces have a long history in CSCW, and provide excellent examples of early and on-going awareness research. Examples of this type of system are *Polyscope*, *Vrooms*, and *Portholes*. The Polyscope system (Borning & Travers 1991) was developed at Rank Xerox Research Centre in Cambridge, UK, and was aimed at providing general awareness information to facilitate social encounters over distance using a matrix of frame-grabbed video images of other users' offices. Observers could control the amount of information captured about them, which ranged from no information, to short text messages, or to automatic video. A successor to this system was *Vrooms*, a metaphor of virtual rooms (Borning & Travers, 1991). It offered improved functionality to make the handling of privacy and symmetry specifications easier. The importance of peripheral awareness in virtual meeting technology goes back to users' response feedback from using one of the one of the first media spaces: the Palo Alto-Portland Video Wall

system, which linked the Palo Alto Research Centre (PARC) (Blomberg & Karasti, 2013).

Design principles derived from testing media space prototypes reflect the need to preserve visibility in an appropriable system (Gross, 2013). Users need to be able to understand how a system works in order to comprehend how to make it work for them. This fact in turn requires that users see not just the opportunities for action—the affordances that characterize traditional user interface design—but also the consequences of those actions. Being able to understand the consequences of action is critical to being able to incorporate the system into patterns of work. Users must have an overview of others' presence and activities without being forced to start a conversation. User response studies of the MUSE system (Reddy et al., 2010) have highlighted awareness as a significant feature, through chat and conferencing amongst many users as a means to support communication, and enhance information seeking. Visualization also helps to facilitate users' discussion of each other's searches and of how to improve search. Privacy is a tradeoff cost for increasing awareness, pointing towards those designs that support user control of this variable.

Schumann et al. (2013) present a novel approach for asynchronous awareness support by offering different filters both to retrieve relevant awareness information and to visualize the evolution of the shared artefact. Their approach was a tool for collaborative non-linear storytelling in which users can jointly create a story graph of interconnected audio files that visualize how the collaborative story has evolved over time. Their evaluation results show that the visualization approach helps group members to assess who has modified the shared story, how it was modified, what exactly has been modified, and when. Different filters allow users to become aware of who has made changes and when changes happen. The replay of the story evolution explains how changes were conducted. Within collaborative storytelling users often work on the shared story as time and opportunities arise, without explicitly coordinating it with the other participants. Today, shared workspace and group editing applications, such as Google Drive, provide awareness support with even greater flexibility. As well, large scale game environments and distributed collaborative virtual environments, originally derived from the MASSIVE (Model, Architecture and System for Spatial Interaction in Virtual Environments) architecture (Gross, 2013) now populate the digital sphere, providing the possibilities of exchanging audio and video in realtime, conferencing and immersive 3D capabilities. It is

important to maintain, however, that while providing mutual person-oriented information can facilitate chance encounters over a distance, privacy concerns of users should be a top priority.

The 4 components of CSCW technology instrumental to sensemaking in groups, namely, (1) Intent, (2) Activeness, (3) User Roles, and (4) Awareness, have been investigated in group behaviour studies and implemented, to varying extents, during the past several decades. Designing technologies that support work requires an understanding of competing definitions of the situational context in order to not mask the invisible aspects of work, a concealment which would consequently result in an underrepresentation of resources of time and people. Although most of this effort has focused on organizational activities, the promotion of technology suited to the non-work domain and leisure activity is lacking due to a preference for a system-oriented approach. Further, the lack of extensive in-depth investigation of creative, authoring activities means that many insights from these complex group information behaviours remain hidden and unrealized in more generalizable applications. Activities such as drama, music, design, joint creative authorship, and the use of shared artefacts, are all shown to rely heavily on collaborative sensemaking, meaning construction through discourse, and relationship building, yet recent studies are only now beginning to explore these areas. The need for increased research is all the more striking when one acknowledges the ubiquitous nature of mobile social computing and its utility in leisure activities, and its creative empowerment in current digital environments.

Chapter 6

6.1 Research Questions

The objective of the current study is to seek ways to develop collaborative information systems which provide benefit to musicians. To accomplish this, the study explores group creating behaviour, an exploration which seeks to address pertinent gaps in current literature. Two research questions are proposed:

1. What are the communication patterns of collaborators and how do these patterns affect sensemaking of musicians in the act of creating music?

2. How can the determination of these patterns inform the design of an effective Computer Supported Collaborative Work (CSCW) system?

As corollaries to these two research questions, the investigation also addresses a few related design-focused issues which are independent of the musical domain. Three closely related sub-questions are also proposed:

i. How can we make visible the process of collaboration activities to facilitate learning, and to track ownership of media items through metadata?
ii. What are the benefits of technology to aid sensemaking during the process of collaborative creation?
iii. How can we make the products of collaboration reusable for collaborators?

I define creativity as a long-term, everyday rational activity by members in small groups to co-construct new knowledge recognized as novel and relevant to the community. The long-term aspect of creativity implies that the process is a significant endeavour directed at a major goal. The everyday aspect of non-scientific creativity suggests that the process can be found to be an occasional occurrence (e.g., an "Aha" moment) and not a routine practice of the members in small groups. In my definition, the novelty and usefulness of new knowledge is domain-dependent, relying on subjective assessment by one's relevant community.

The context for this investigation is in integrated settings (face-to-face) where group members

collaborate synchronously, or asynchronously, or both, and through real-time rather than use of such collaborative tools as chat, and shared displays. The aim is to study the process of CSCW in a non-work, naturalistic setting as involved agents engage in the sharing of resources, responsibilities, and goals while contributing toward a group solution. Creativity is a rational, problem solving activity. During collaborative activities, making sense of information is often closely intertwined with finding and retrieving information. I am interested in exploring the process of collaboration, how they make sense of information to achieve shared goals in an ill-defined problem.

Chapter 7

7 Data Collection

This section includes a description of the data collection methods for the research, including a description of the participant recruitment strategy, the task description, the research setting and the post-session interviews.

7.1 Participants and Recruitment Strategy

The inspiration for the study and target group for my research is based on Rock Lottery, an annual fundraising event run by a London-based arts organization. The participant pool or this study was based from the response to the Rock Lottery recruitment. In recent years I have become involved in this community as a musician myself. A fellow bandmate of mine informed me of the event where several of his friends, former bandmates and local acquaintances, were getting involved and had invited him to join. This, combined with fortunate timing, presented the opportunity for me to gain access to the organization, planning, and practice locales for the event.

The event participants, although not typically full time professionals, were by no means beginner musicians as demonstrated by their involvement in the local music scene. Participants in Rock Lottery are known as up and coming musicians who continually develop their craft by recording and selling music, playing local shows, and attending musical events. In some cases, participants shared some familiarity with other members, although each member had no prior experience performing together. The population was deemed as a desirable source for recruitment since they represented an active and diverse blend of amateur local artists with prior musical knowledge, past performance and group composing experience. Beyond meeting the basic criteria in terms of musical skill and background, my study participant sample also represented the potential target user group for a hypothetical music system. Given the demographic, I could very well imagine them using technology and online tools to engage with and create music with other players. Those subjects who were most active within the sphere of amateur musicians

integrate music-making as part of a social identity. This necessarily includes promoting their own music through music sharing sites, social media and other communication technologies.

I went with my bandmate and friend to the orientation event in a local eatery where the members of the London Rock Lottery were assembled for a meeting with the primary organizers. The point of the meeting was to introduce the event, describe the locations and times set aside for practice spaces, and to announce the location of the final performance. At the first meeting, I introduced myself to the musicians. Here there was a group of young players (aged mid 20s to late 30s), and although some female members were present the majority of participants, to my knowledge, were male. Participants' names were entered into a hat and selected at random in order to assign players to each band. Each band had a drummer, and the other members were selected during the selection process. The assignment of members was posted on the event's Facebook page, together with the schedule of each session. I would be attending the sessions of the band my contact belonged to.

At the first scheduled rehearsal I explained my study to the members and requested their permission to audio record and observe them during the rehearsal sessions. I also presented the study description and a letter of consent (Appendix 13.6) for their perusal. Potential participants read and asked questions about the study and then agreed to cooperate. They were happy to learn they would be receiving 5 dollars apiece for their participation, but mostly just enthusiastic they would be participants in the study. I also made a request for interviews at the end of the sessions. They seemed quite interested in the goals of the study itself, and expressed their motivation to perform to the best of their ability both in the playing and planning of the music. I also explained that I too was a musician, and had played in bands with my contact.

From these initial contacts, participants helped recruit future participants from among their other participants in the Rock Lottery, following a snowball sampling method. These sessions would extend beyond the scheduled Rock Lottery rehearsals. I intended to continue attending the rehearsal sessions in order to gather enough data, and thought it useful to incorporate variety in the band makeup for these subsequent sessions. In total, I selected three amateur rock bands and observed each over three separate two-hour sessions, totaling nine observation sessions. Each group was comprised of four participants, although certain players participated in more than one band. There were a total of 9 different participants altogether. The participants used in the study

were all males, between the ages of 24 to 41. The majority of the players grew up in the London area and had been playing music for at least 5 years. They were essentially self-taught musicians, with the exception of 2 participants who had studied music and recording in school. In addition, some were able to play multiple instruments, such as different stringed instruments and keyboards, as evidenced by their work in previous bands.

One potential downside to the decision of relying on independent rock bands as part of the research was that it may have reduced the generalizability of the data, and therefore, the ability to make predictions of group behaviour which utilized more formal compositional styles such as those used for jazz, orchestral, or classical music. As the focus of the current study was to address the needs of amateur songwriters, data-gathering decisions were based on expedient ways to observe how users, who might lack more formal musical technique and resources, deal with the problem of music creation in a defined popular music genre. At the same time, decisions regarding the sampling method and participants were made since the participants rely heavily on collaboration which is the target phenomena of the study. They are representative members of the community who have adopted music as a serious leisure activity. This, in turn, offers up the opportunity to make design conclusions derived from behavious of potential users of a hypothetical system.

7.2 Task Description

The first variable in the study is the collaborative task itself. The goal inherent in the task was to encourage experimentation and uncover the convergent and divergent thinking in a creative context involving artistic competence and exploration. Participants were provided simple instructions to engage in face-to-face open-ended songwriting— a task with which they were familiar. The content and style of the music being composed were both left completely to the discretion of the group. Their 'think aloud' (Burnard & Younker, 2004). Responses during the group composing task were recorded as part of the observation. Questions or other interactions with the observer were kept to a minimum in order to prevent interference interfere with the thought processes of participants.

The methodological design involves using observation and transcription, which generally conforms to previous examinations of the compositional process (Wiggins, 2007) and studies of

music information behaviour (Cunningham et al., 2003). A body of research has focused on novice or “less-expert” composers working within task constraints being imposed, and where composition is viewed as a means to developing and gaining access to musical or creative thinking. In contrast, the current approach uses musically-experienced participants, familiar with writing and performing music, as a way to overcome the shortcomings of lack of musical training. The task is kept open-ended, allowing participants freedom to form the content and style the creative work as they see fit. The songs were not restricted to being entirely original either, and were permitted to be interpretations of existing music or cover songs. For my purposes, I considered songs in terms of the musical layers only, and omitted the analysis on the inclusion of lyrics. Other studies in group composition have followed this method to build a dataset without having to classify and distinguish text content which is not part of group deliberation.

7.3 Research Setting

The second variable in the study is the research setting. I used a triangulation of data to apply multiple sources as a means to measure the same phenomena. This includes the use of field observation, transcript analysis, and follow up interviews. My data collection methods coincided with the predefined rehearsal schedule of Rock Lottery. To collect enough data to exhaust the findings, I felt it appropriate to conduct more observations and data collection beyond the initial sessions scheduled in Rock Lottery.

I studied participants over nine, two-hour sessions in total. The length of the sessions was chosen by the participants according to their level of comfort and energy. The use of multiple sessions also allowed me to generate sufficient transcripts and field notes for data saturation, and gave participants time to reflect and think about the composition between sessions. The bands were scheduled to meet once a week, after a suitable time was arranged and agreed upon through verbal and text correspondence. The first 3 sessions proceeded in succession according to the event schedule. I was then able to arrange times for 6 additional sessions that involved new members arranged from the selection process.

As the principal researcher, I stayed in close personal contact with the owners of the rehearsal space, as well as certain participants in the Rock Lottery event. The location of the compositional

sessions was established at a predetermined studio/rehearsal venue. I conducted observations by standing in close proximity with the musicians where key activities (such as inventing arranging, playing, modifying and other communications) took place. I also did so in places where technological artifacts, computers and hand held devices were available. The observer was seen by the participants but kept at a significant distance so that all interactions and influences remained at a minimum. Participants also had access to standard performing/recording equipment including drum kits, guitars, microphones, amplifiers, effects pedals etc. It was assumed that participants would be playing and improvising music in real time, drawing on their own respective expertise and knowledge. I noted interactions between members as they communicated, generated, discussed, and integrated information. Data collection during observations was performed using pen and paper, and all interactions were audio-recorded. All data apart from digital audio were then transcribed into electronic text for analysis. In summary, this study consisted of participant observation, to witness and record how participants engage in collaborative open-ended songwriting in a natural environment.

However, the research method was incomplete in the sense that it involved decisions which were made to restrict the working variables to gauging only *one* mode of communication: verbal language. Of course other modes were present, namely gestural communication in the form of bodily actions, and musical, in the form of the sonic output which provided rich and detailed flow of information about the state of the creative output. Although music and music-related activities were gathered and recorded, they did not serve a primary and detailed target of analysis. As described in the analysis Section 8, both gestures and music were seen to be important to helping participants collaborate. But for the purposes of limiting complexity of the study, I focused on language patterns in the quantitative and qualitative analysis. The research was also partial in the sense it did not involve a deep study of individual characteristics of participants. As noted in studies of creative music making and group dynamics, independent actions of individuals can significantly affect the outcomes of learning and collaboration (Rosen, 2014). Diversity in group members' characteristics in terms of personalities, perspectives, musical expertise, collaboration expertise, cultural background, age and gender certainly plays a substantial role in shaping activities. For this reason, future work analyzing these influences more fully could provide useful insights. For the purpose of simplifying the current examination to the content of the interaction, this variable was not regarded in the analysis.

The final performance of the Rock Lottery show was conducted at downtown London tavern at the end of the week, an event which I attended and recorded for prosperity. In addition to being a terrifically loud rock show, it was a widely attended and showcased impressive performances of all the bands involved. I found it rewarding to witness the band whose participants I had come to know, learn about, and observe in their craft, playing with such excellence in a public venue. Songs which began as mere rough, distorted ideas had evolved to final, fully-developed rock songs actually worthy of airplay.

7.4 Post-Session Interviews

Interviews were performed by one or two members of each of the bands, group A, B and C as a follow up of the rehearsal sessions. For various practical reasons, I was not able to interview each individual participant in depth, so my decision for a research participant was based on the willingness and availability of the interviewees. Often there were members who were more talkative and tended to assume leadership roles in each of the bands. These were the members who were eager to follow up with the research and share their insights by verbalizing to others.

Following each composing session, the select group members were asked a series of 5 to 7 interview questions about their subjective experience participating in the composing session. Other questions had participants elaborate on their background and prior experience with music, including thoughts about songwriting, influences, inspiration, and working with others. A total of 28 interview responses were collected, and the audio was recorded and transcribed. Excerpts of these responses are included in the Discussion (Section 10). I include this section to elaborate on qualitative findings, to suggest valid areas of further investigation, and to illustrate important components of collaboration. The interview questions used are provided in Appendix C.

Chapter 8

8 Data Analysis

My study is about how collaborators collectively construct and share knowledge in the creative process of making music. Although it is often preferable to restrict the study to a single research paradigm (Creswell, 2013), I chose to deviate from this standard and employ a mixed method approach, integrating of quantitative and objective paradigm focused on acquiring numeric measures of data, and a qualitative paradigm to deduce the existence of sensemaking processes and construction of knowledge based on the numeric data. I therefore use a triangulation of methods to apply qualitative and quantitative examinations of the same phenomena. The goal of my sequential two-stage method of data analysis and qualitative analysis was to directly answer my first research question: *What are the communication patterns of collaborators and how does this impact sensemaking of musicians in the act of creating music?* I used a linear research path in order to incorporate metric data, produced from data analysis coding. This involved obtaining clues about how participants manage and organize new incoming data, revise existing knowledge structures, and evaluate the usefulness of knowledge according to the task at hand. In this way, I utilize observable patterns in language behaviour as empirical evidence of elaboration, questioning and reframing processes underpinning group collaboration.

The data analysis phase was comprised of two forms of quantitative analysis: conversation analysis and referential structure analysis. The conversation analysis provides a profile of communicative acts over time and I can see how identified forms of deliberation are concentrated in time segments in the collaboration. Referential structure analysis provides data about the content of the discussion itself: what things are being talked about. Studies in collaborative work do not specify a principled way to draw quantitative conclusions about observations. To address this shortcoming, I have adapted specific mixed methods approach through content analyses of face-to-face discourse as way to gain insights about the how knowledge is represented and shared.

The first data analysis method, *conversation analysis* (Tan et al., 2014), was used to examine the minutiae of interaction at the conversational level. It identifies the specific devices, such as

conversational openings or adjacency pairs, that participants use to organize their talk. Characteristics such as turn-taking, speaker choice and speech act type were subsequently flagged and counted in the transcript. This data was used in a qualitative examination to identify breakdowns in co-ordination, and as a way of highlighting departures from a standard model of interaction. The method looked at recurring conversation about coordination, and secondary structure in the discourse. Examination of the duration and type of conversational utterances has also been used previously as a way of determining the impact of alternate representations on conversation (Feinman, 2006).

The second quantitative method, *referential structure analysis* (Feinman, 2006) is a method of tracking the content of conversation. In RSA analysis, I can see the content of the discussion: what are the topics of interest? And how are they distributed and changed over the course collaboration? Clusters are identified in the summarization of key metrics: occurrence, lifetime, and density. The clusters of data points directed me to similarities between different references, potential simultaneity and overlapping importance, and which sections of the collaboration offer the most salient indicators of sensemaking processes. While conversation analysis tracks how objects are instantiated, edited, filtered, and selected, referential structure analysis is concerned with what those information objects are, that is, the 'things' participants discuss and how they are being referred to. These two methods use a coding process that flags elements in the conversation content in order acquire frequency counts.

The data analysis method is summarized in the following steps:

1. Code transcript using Conversation Analysis (CA) to produce frequency metrics for conversation codes over time. See Section 8.1 for a detailed description of CA process and related metrics.

2. Code transcripts using RSA methodology to produce reference metrics describing conversation content. See Section 8.2 for a detailed description of the RSA process and related metrics.

3. Analyze metrics on a time-dependent scale to identify portions of the transcripts for further investigation. Take note of cues such as reference repetition, common reference metric values, overlapping reference lifetimes, and conversation code clusters.

4. Locate transcript sections and related field note reports and follow cues of sensemaking based on hypothetical underlying processes. Form conclusions based on the data. Use evidence of sensemaking including examples of groups' searching, filtering, adjusting knowledge to suit the task situation. See Section 8.3 for a detailed description of the qualitative evaluation process.

5. Repeat step 3 and 4 until findings are exhausted. Analysis is a cyclical process of visiting and revisiting data to determine relationship between quantitative metrics and sensemaking. Each step is described in turn below.

8.1 Conversation Analysis

The unit of analysis used in the Conversational Analysis (CA) was defined as a line of discourse, a statement or indicated musical action (such as the playing of a musical excerpt) that is produced by a participant at a certain point in time.

I present a simple model of possible response structures in conversation, and discuss how these patterns are related to social-communicative and problem-solving interactions that are fundamental to collaborative creative activities. The approach makes use of the connectivity between conversational statements of the collaboration session to construct a representation that captures the flow and relationships of the interaction. I mined the most frequently occurring structures which I then analyzed more closely to identify the patterns of collaboration, and the sequential organization of interaction under a specific setting.

The coding was performed over a period of 30 days. After the sessions the conversations were transcribed and entries loaded into an SQL database for processing. The field observations and audio transcripts sources were scanned and analyzed to extract communication instances for which a code type could be assigned based on the implied role of the communication. Since each communication behaviour was also operative in an identifiable suggestion or introduction of a concept, a relation could be drawn on between them to establish a general model of the solution.

8.2 Referential Structure Analysis

Referential Structure Analysis (RSA) is an analysis method that tracks the references via a thorough examination of the discourse. From this, I can examine what information is

communicated, and in what fashion (Feinman, 2006). The method focuses on identifying the information that users share, and on following its subsequent use within the discourse to build a model of the information within the interaction.

I applied referential structure analysis to the entire set of conversation data from the 9 sessions, in order to identify information types, topics, and their respective properties involved in the interaction. In RSA, the unit of analysis is at the word level, examining words from each line of discourse. To distinguish different bits of information from each other, the coding assigned designated types to each reference. These included plans, objects, properties, and performance references. Given a set of collaborative tasks, the hypothesis embedded in this method was that reference types reflect the structure that participant will use to share information and organize his or her activities (Feinman, 2006).

A type or token distinction needs to be made here. The types of referents identified tell the analyst the referents that participants discuss. The specific instances of a reference, treated as token or "label," can be used to form conclusions about how each piece of information is handled by participants. In reality, the observation and the definition are intertwined; two reference types that are handled the same way may be better represented as the same type, whereas a class of information whose use can be split into two or more distinct usage patterns may need to be reclassified as being made up of two or more reference types.

For every different reference type I identified I counted up instances of references belonging to that time. I tabulated three different metrics from this data: lifetime, occurrence, density, simultaneity which are each described below. For each reference type, I noted how often it occurs overall, then used the first and last occurrence of a reference type to measure the lifetime of relevance in terms of lines of conversation. Finally, the number of times a reference is mentioned in its lifetime produced a measure of density. The outcome of quantitative analysis is summarized as follows:

1. *lifetime*: how long an reference is relevant. This value is calculated by the number of lines of conversation between the first occurrence of a reference and the last.

2. *occurrence*: how frequently a reference of a particular information type appears in the dis- course. This calculation may include synonyms or different labels, so long as the

label refer to the same referent. A dialogue where every exchange of information contains a new reference of this type would have a frequency of 100%.

3. *density*: the ratio of referents to lifetime; it is a measure of conversational importance
4. *simultaneity*: A measure of how many items of a particular type are generally relevant to the concern same time.

Examples of RSA coding, types of references identified, their descriptions, and examples are provided in the Findings, (Section 9.4).

8.3 Qualitative Analysis with Collaborative Sensemaking

Collaborative sensemaking, as it is employed in this research, is defined as a group process that adheres to the data/frame theory of sensemaking, where knowledge representations are created, populated and modified iteratively based on the ongoing presentation of new data within the group. Similarly, I utilize notions of sensemaking knowledge gaps and bridging processes from LIS as a way of determining how the groups overcome blockages in problem solving in a creative context. The applicability of new data is judged through group interactions against a measure of utility for a task situation, and is thus an encoding based on a top-down schema, which in turn may be modified and expanded. The intuitions associated with key terminology of sensemaking are employed since they serve practical and applicable tools for addressing the phenomena, as well as analogs of reasoning based on predictable patterns of knowledge co-construction.

I analyzed 18 hours of transcript data. However, to direct this analysis I needed to look for areas in the transcript which corresponded to trends in the quantitative findings. Concentrations of certain conversation codes, for example, were assessed to determine the relationship between their prevalence, and seeming success or blockages the collaborators experienced. The numeric results provided by both conversation analysis and referential structure analysis was the input which served to inform my qualitative assessment of the data.

The method I followed was to look at the data for overall patterns, concentrations, outliers, and clusters of codes that would warrant further investigation in the transcript text. For example, examining the results of conversation analysis I could look for periods of repetition and salient

concentrations of codes in a specific time frame. A cluster of generative dialogue would indicate a high frequency of information being generated within the group, divergent thinking, and new data to contend with. According to sensemaking theory as it is defined, knowledge represented within the group undergoes periods of revision, elaboration, and evaluation and this, in turn, corresponds with the prevalence of related conversational actions. Therefore, high instances of convergent or evaluative dialogue may indicate points where such processes are particularly dominant. At a minimum, identifying segments of the transcript in this way allowed me to pinpoint the investigation to particular instances, and cite empirical manifestations for theorizing about underlying sensemaking processes at work. I developed and categorized findings according to problems and how collaborators resolved these through the co-operative sensemaking. The results and trends from RSA findings, such as the most relevant topic references, were also used to deduce underlying patterns of sensemaking, such as problems adjusting to new data and filling the content of knowledge representations themselves. The results of this analysis are described in detail in Section 10.

8.4 Justification

While the mixed method approach was a linear form of research, the qualitative analysis itself was non-linear, being cyclical, iterative and subject to revision and reworking. I approached the data in a flexible and adaptive perspective to refine an understanding of sensemaking that may be derived from hard numeric information. The quantitative information provided the empirical support for the theories that comprised the qualitative discussion. The analysis process was then subsequently applied in a practical manner to answer the second primary research question: *How can the determination of (sensemaking) patterns inform the design of an effective Computer Supported Collaborative Work (CSCW) system?*

The decision to use a mixed method approach was to provide a qualitative assessment of collaboration in the form of rich descriptions, while expanding on the emergent patterns of language which are measurable and repeatable. In the quantitative data analysis method I provided a formal, value-free assessment in the form of code frequencies and metrics. In the qualitative method, I formed subjective, deductive conclusions based on an interpretation of the data. In this sense, the qualitative analysis was shaped by my assessments, and particularly how findings relate to the design of CSCW systems.

Self-reported data, culled only through interviews alone, is a limited method as it leaves much of the learning and group sensemaking processes unexplored (Ziegler et al., 2014). The reliance on self-report data hinges on the belief that social reality can best be understood through accounts of the lived experience of individuals. One way to explore the action orientation of written and verbal conversations is through quantitative conversational analysis. Social reality is that which is visibly constructed through dialogic talk, rather than the individual mind. Previous research has looked at long-term longitudinal case studies as a way to examine group composition, by focusing on the changes in students' composing processes, explored over time through the systematic mapping of their composing strategies (Wiggins, 2007). Other research in group creativity has utilized data banks generated from participant observations, video observations, and recordings. Based on a rich understanding of behaviours, an ontology can describe them in a structured way with the final aim of highlighting technological solutions. The current approach relies on the immediate domain knowledge of the participants and limits the impact of external factors and long-term incubation which are known to also influence creativity (Csikszentmihalyi, 1996). The analysis of text-based conversations produces innovative ways to improve the design of specific online system, as persistent aspects of the data could be examined in meaningful ways not easily replicated in face-to-face contexts. Evidence of social group cognition which is necessarily publicly visible provides a framework for exploring content for online communities and informal group learning. I then applied a qualitative review of sensemaking difficulties, summarizing trends and notable breakdowns in communication for which data-based design may alleviate difficulties.

The unit of analysis for CA was a line of discourse, while for RSA it was at the word level. This level of data granularity was used since language communication was of primary interest. Other possible choices include comparing differences between groups, or addressing differences at the individual level, where the effects of learning style, expertise, personal background, culture, gender or other social and personal factors may shape the process and outcomes. The decision to fixate on language limits the research in a direction appropriate to the goal laid out in the outset, which is to understand the communication patterns of collaborators for the purpose of CSCW design. Certainly, the understanding the characteristics of collaborating participants brings potential insights that may in some sense be inseparable from collaboration itself. This avenue may be explored in further detail in subsequent research.

In CA, the analysis of fine-grained patterns of interaction in small groups is important for understanding collaborative work. The aim of the referential structure analysis method is to discover what sorts of things participants in a joint activity spend their time talking about, how much they talk about them, and for how long. For example, I might examine how frequently participants refer to some domain object such as a chord progression or melody; a property of an object such as its tone or duration; or how long they spend discussing a plan for action. To do this, the analyst tags the referents made by participants and consolidates them according to the reference they refer to, classifies the resultant referents into types, and computes various parameters about each reference identified in this fashion.

RSA grew out of an expansion of techniques for extracting discourse structure. It did so by incorporating concepts from literature on coherence and reference resolution, as well as on the formulation of and grounding of referents (Feinman, 2006). The method involves tagging referents in the discourse and combining them into co-referent chains (Clark & Brennan, 1991). By assigning types to the referents, and computing statistics, I was able to make visible the ways participants handle different types of information. Grounding anaphoric referents (a word in a text refers back to other ideas in the text for its meaning) and forming reference chains can be problematic. I have nonetheless achieved good results by restricting the set of referents under consideration and aiming for investigative rather than comprehensive results. The purpose of using interview data is to provide a snapshot of the participants' impressions of the collaborative process, and to uncover positive and negative reactions experienced within the group, ones which may have occurred during the session.

The occurrence of a reference type, concentrated in a specific segment of time, was used as potential evidence of particular topical difficulties in the problem-solving process. In examining conversational transactions, I can specify how information is generated, shared and modified to overcome blockages as they arise during the collaboration. A blockage is defined loosely by a momentary halt to collaboration due to some identified sensemaking knowledge gap which is made apparent by the group. I can quantify how subject area of the discussion translates to the product of collaboration as a shared objective. In this sense, the values produced from quantitative methods, trends in the discourse in the form of reference usage and concentration of types of deliberation types (generating, evaluation, revision, and management), and topic areas

(performance, properties, objects and plans) allowed me to form hypotheses about what goals and strategies are used, and how collaborators manage social interactions over the long and short term. Features of the discourse can inform design by taking information out of these "margins" of communication and migrating it to custom-built representations. This process can then be repeatedly applied and refined until a successful system is achieved.

Methods of data analysis are well suited to system design. Ideally, software would be built to match emergent practice (Hollan et al. 2001). Collaborative work on a computer system is generally supported by asynchronous threaded discussion forums and by synchronous chat rooms. Conversation analysis has emphasized the centrality of turn-taking conventions and of the use of adjacency pairs (such as question-answer or offer-response interaction patterns) (Rosen, 2014). One way to understand emergent work practice is to take the same techniques used to examine situated activity of participants in face-to-face activity and adapt them to online collaboration. I have adapted concepts from conversation and reference structure analysis to investigate the interaction at a discourse level. These methods organize observations and generate concrete conclusions about the emergent work practice of participants: what sorts of information are exchanged, what areas of the interaction are problematic, and where the system needs to intervene to reduce coordination effort.

I wanted to ensure research rigour in the study as a way to verify the consistency and veracity of data analysis codes. A shortcoming of the current study that given the time constraints and extent of the coding process I was not able to perform an inter-coder reliability by using a secondary coder on the raw data. I did perform the coding process to a point of saturation on the data, meaning no new categories, references or examples emerged from the raw data that my existing scheme could not accommodate.

8.5 Summary of Analysis

In this analysis I took to following steps:

- Conversation Analysis (CA) to formulate a set of codes and use relative frequencies to determine the seeming occurrence of break downs in collaboration

- Referential Structure Analysis (RSA) to formulate the use and persistence of information

items applied in the interaction.

- Qualitative evaluation based on the results from conversation analysis and reference structure to determine the relationships between language and sensemaking.

Chapter 9

9 Findings

This section includes a description of the quantitative and qualitative findings. It describes the various conversation categories and Referential Structure Analysis code categories uncovered, together with a summary of the frequency totals and metrics.

9.1 Quantitative Findings

Based on the process described in Section 8.1, transcript data from 9 sessions was analyzed to quantifiably summarize patterns in reference instances which reflect how participants organize information and activities. This section summarizes the quantitative findings which result from the methods described in Section 8. It will describe referential structure analysis (RSA) results as follows:

i. *Referent Types*. These were identified as plans, properties, performance, and objects. Descriptions and examples are provided for each of these types. Subtypes of each major type are also described as an exhaustive list based on discussion data. Multiple labels used for unique references were collapsed onto their relative subtype and totaled for each session.

ii. *Reference Metrics*: Four metrics were used to describe the RSA data: lifetime, occurrence, density, relative frequency, and simultaneity.

iii. *Reference Patterns:* Each reference type is evaluated for overlap according to lifetime, density and occurrence relationships. Scatter plots are presented to illustrate frequency distribution of reference types to identify clusters.

The data were also examined through conversation analysis (CA). As described in Section 8.1, lines in the discussion transcript were defined either as a statement or as an indication of musical action that are produced by a participant at a certain point. (An example of musical action is the playing of a musical instrument.) Verbal protocol analysis was used to offer confirming evidence of the context-dependent and domain influences of decision making in the creative process.

Metrics assigned to conversational are based on category frequencies, and then totaled at different time points. A summary of the time-dependent conversation codes are provided in section 9.3.1.

9.2 Transcript Summary

Over the course of the data collection 9 sessions were conducted using 3 groups of participants. The participants were labelled Group A, Group B and Group C for simplicity. Each group met a total of 3 sessions at the rehearsal studio, each session of which lasted approximately 2 hours. A total of 18 hours of /rehearsal sessions were conducted and recorded in the form of field observation notes and recorded audio. Field observations were used to append sections of the dialogue and musical behaviours of all groups. 18 hours of audio files were transcribed to text for analysis, including both the actual statements and the participant who was the originating source of the dialogue. The data were cleansed and organized to separate lines of dialogue for further coding and analysis. Below are the dialogue totals, a summary of complete transcript data collected in terms of lines of transcript text. A line of text is considered to be the total words included in a "turn" taken by a speaker. Further below, in Section 9.2, are the names and descriptions of each conversational category. Examples from the discussion transcript which typify dialogue belonging to that category are also provided to help to clarify the description.

Table 1: Total lines of transcript dialogue collected for all three groups, for three sessions each totaling 9 sessions.

Dialogue Totals				
Session	**Group A**	**Group B**	**Group C**	**TOTALS**
	Lines of text	**Lines of text**	**Lines of text**	
Session 1	205	180	217	602
Session 2	182	166	174	522
Session 3	232	265	178	675
TOTALS	619	611	569	1799

9.3 Conversational Categories

Conversational Analysis was performed on each line of dialogue to code each line to assign exactly one of the categories of dialogue categories. The conversational categories were derived from the conversational analysis schema outline in Tan et al. (2014), and loosely correspond to sensemaking processes (elaboration, questioning, and reframing) defined in the data/frame sensemaking theory of HCI (Klein et al., 2006). The categories were merged and modified to suit the current study and adequately capture data as it was uncovered.

I define four major categories of conversation categories: 1. *generating* (divergent), 2. *evaluation* (convergent), *management* (reflexive) and *revision* (elaboration). In addition, 2 to 4 more specific subtypes were included to add specificity to the coding scheme. Each of the types and subtypes is described in the following sections.

9.3.1 Generating (Divergent) Dialogue

Divergent dialogue is the type of talk characterized by innovation, the active perusal and acquisition of new ideas and insights that contribute to the overall result. This dialogue helps to move the group through the problem-solving space via a set of alternatives. Creation of musical ideas is often a result of cooperation and dialogic activity. In total, these instances describe the group's ability to generate a variety of ideas, options, alternatives, and methods to address the problem at hand. One person starts something that someone else picks up, changes a little, and while exercising it a new motif is born. Generating Dialogue includes two sub-categories:

i. *Epistemic* dialogues or actions indicate new ideas and possible solutions that are criteria-related in nature, or concern general decision-making. Epistemic dialogue is exemplified when members organize themselves, set goals, establish rapport and implement parameters of decision-making.

> Rhythm: For this song lets just try not playing all together at once. We can't really hear what's going on when that happens so it's better just to let one person start on their own.
>
> **Example 1: Group A Epistemic Divergent Dialogue**

ii. *Concrete* dialogues or music actions indicate tangible new ideas and innovations that

are specific and repeatable by others. These actions form the initial components of a solution, as in Example 2 below:

> Drum: Can we change the way we end this song? (looking to the other members) Bass: Ok, look, here's how it should go. (He plays a small motif of repeating four notes on his instrument, way up high on the neck.) Bass: And I do this alone. Joy Division all the way.

Example 2: Group A Concrete Divergent Dialogue

Generative dialogues are concerned with the presentation of musical ideas, and the adaptability to certain exiting problem-solving situations. Generating instances are those conversational transactions, either verbal or musical, whereby the elements in the problem space, or set of relevant problem solving concepts, is expanded.

9.3.2 Evaluation (Convergent) Dialogue

Evaluation (convergent) dialogues concerns those instances demonstrating the group's ability to evaluate and narrow diverse opinions into one opinion only either by reaching consensus on the best idea or by integrating solutions. It consists of three subcategories.

i. *Critique* dialogue, which disputes, doubts, or probes criteria development or solution suggestion statements.

> Bass: I feel like there should be a part when we don't play like you were suggestion, instead we just stop and then go into a thrash-type ending.

Example 3: Group A Critique Convergent Dialogue

ii. *Justification* dialogue evaluates alternatives to the proposed criteria development or solution suggestion statements, and provides reasons, explicit or implicit, for the evaluations.

> Drum: I was thinking that if we play that last line, maybe 4 more times it will be enough to transition to the chorus a little easier.

Example 4: Group B Justification Convergent Dialogue

iii. *Checking* dialogue indicates simple agreement with criteria development or solution suggestion statements. It can also indicate the evaluation of solution-suggestion statements (e.g., asking for confirmation from partner of the suggested solution or

decision).

Rhythm: After that last hit, stay on the low notes.
Bass: Ok, and I'll do that. Something like (plays on the line on the lowest octave.)

Example 5: Group C Checking Justification Dialogue

Conversations involving testing and evaluating musical ideas in practice consist of an explicit or implicit decision alternatively to accept or reject. Groups typically employed an "on the fly" method of evaluation of the alternatives being generated in real time. These alternatives are offered based on the individuals' insights and on knowledge of the group's situation and their characteristics. The assumption is that if others members are able to replicate the music, it is coherent to the group at large, and some weight reflecting its priority in the solution is implicitly assigned with some level of agreement. Whether or not a particular alternative was accepted depends on its implicit inclusion in the final composition.

9.3.3 Management (Reflexive) Dialogue

Instances of management dialogue were instrumental in reinforcing existing ideas, and are distinguished from attempts to alter existing content or introduce new idea. This type of dialogue involves four major category classifications:

i. *Regulation* dialogue indicates regulation processes directed to influence the partner's cognition, motivation or action.

Lead: And yeah we'll decide on the order of the song preference for when we're playing. Yeah, it will be fun!

Example 6: Group B Regulation Reflexive Dialogue

ii. *Grounding* dialogue represents attempts to establish shared understandings with partner through the use of questions (e.g., clarifying what is meant by the preceding statement; whether it be related to the problem task, proposed solution, a strategy, or a future activity).

Lead: Did you come in on new verse deliberately like that? It sounded cool that way.

Example 7: Group B Grounding Reflexive Dialogue

iii. *Affective* dialogue expresses positive affect or emotion related to task. It includes exclamations, humour, teasing, thanks, apologies, empathy valuing partner's perspective

and contribution (e.g., referencing others, acknowledgment, polite markers, encouragement).

Bass: We're going to sound like a million bucks — we'll sound like iron maiden up there!

Example 8: Group C Affective Reflexive Dialogue

iv. *Disaffective* dialogues express negative affect or emotion, including disengagement from the task. Altogether, these instances demonstrate the group's collective ability to collectively self-examine, and to reflect on and repurpose group objectives, strategies, processes and solutions.

Lead: Yo, you're really going to have to play something more forceful. It's not sounding good like that at all.

Example 9: Group A Disaffective Reflexive Dialogue

9.3.4 Revision (Elaboration) Dialogue

Revision (elaboration) dialogues consist of conversational categories that provide further information on, explanation of, or justification for a on a previously-instantiated idea. The greatest amount of decision making routines are associated with revision dialogue, as confirmed in the findings. Typically, this category is associated with property references. That is, elaboration is concerned with altering the characteristics of musical solutions, and are made to construct alternatives for group deliberation.

For reasons of clarification, a distinction is made between dialogue pertaining to *high level content*, such as long-term revisions, vague modifications, or affective qualities pertaining to larger structures, and *low-level content* which address short term goals, and finer grained details of specific musical structures. Examples of each are given:

Lead: Lets just try to play this last song with everything toned down. For the sake of understanding where everything goes let's just keep it straight you know what I mean.

Example 10: Group A High-level Elaboration Dialogue

Bass: No wait, my bass should play higher notes, not low. Kind of like an arpeggio style. No drums. And then the second time through, the drums come in alone.

Example 11: Group C Low-level Elaboration Dialogue

9.3.5 Conversation Analysis Summary

Examining the series of conversational acts described in the method described in Section 8.2, I observed and flagged each line of the transcripts for all nine composing sessions according to one of the eleven conversational codes described in Section 9.2. A summary of the totals are divided by group and given in the table below and histogram. Each value represents the conversational category totals for 3 session transcripts.

A total of 1799 unique dialogic acts were counted across all 9 songwriting sessions. Overall, Group A produced the most identifiable conversational dialogic acts with a total of 702 unique acts across 3 sessions averaging 234 acts per 2-hour session. As indicated in the proportion column of Table 2, there is a noticeably even distribution of each category of dialogic acts, when considering only total frequency. Across all groups, the most frequently used dialogic act was management dialogue (516 instances across 9 sessions), and the least frequently used was divergent dialogue (330 across 9 sessions). As indicated in Table 2, 30 % of conversational instances belong to management type dialogue. Communication which involved revising musical ideas in practice was the second most common functional use of music in the transmission context with roughly 26% of musical communications belonging to this category. Below in Figure 1 is a histogram graph summarizing and comparing total conversational acts as lines of texts for all 3 groups. For actual count summary for each group see the Appendix.

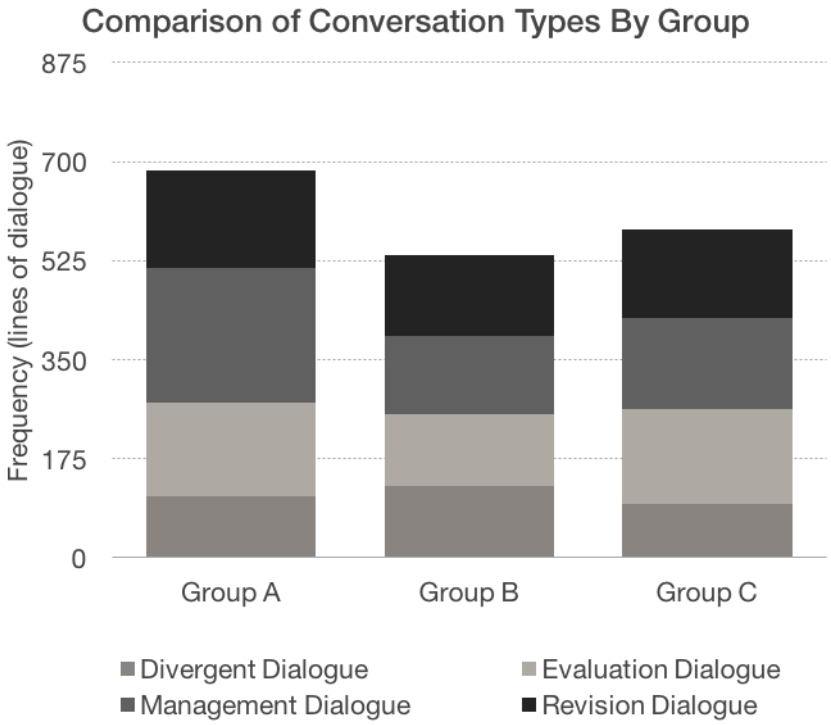

Figure 1: Histogram summarizing dialogic acts as lines of text, totalled over Sessions 1, 2 & 3 categorized by Group A, B, & C. Data shows speech act categories Generation, Evaluation, Managment and Revision instances.

Table 2: Counts of dialogic acts as lines of text, totaled over Sessions 1, 2 & 3 categorized by Group A, B, & C. Data shows speech act categories Generation, Evaluation, Management and Revision instances.

Conversation Types by Group					
CATEGORY	**GROUP A**	**GROUP B**	**GROUP C**	**TOTALS**	**PROPORTION**
Divergent Dialogue	109	127	94	330	18.3%
Evaluation Dialogue	165	126	168	459	25.5%
Management Dialogue	239	138	162	539	30.0%
Revision Dialogue	172	144	155	471	26.2%
TOTALS	685	535	579	1,799	

Table 2 highlights the averages across all 9 sessions. Comparisons of the data for each subtype show a higher prevalence of concrete rather than epistemic generation instances, justification type evaluation instances, grounding management instances, and low level revision instances. The tendency for these types of dialogic instances to dominate, on average, the content of the collaborative discussion yields broad implications for understanding the evolution of problem solving, how solutions are structured, and the importance of group management which is shown in greater detail in the qualitative findings, as provided in Chapter 10 of this research. In general, the comparison of the frequency of dialogic acts helps to highlight general patterns of those patterns of discussion which are common to all three groups (Figure 1) and constitutes areas of further investigation and rationale for groups problem solving, and of the related issues which inform an information system design.

9.3.6 Conversational Trends

Table 3: Average counts of dialogic acts across time, as lines of text, totaled over Sessions 1, 2 & 3 categorized by Group A, B, & C. Data shows speech act categories Generation, Evaluation, Management and Revision instances.

Average Dialogic Acts by Time									
Time (min)	**15**	**30**	**45**	**60**	**75**	**90**	**105**	**120**	**Summed Total**
Generation (Divergent Production Dialogue & Action)									
Epistemic	2.7	4.0	5.7	7.7	11.0	6.0	8.7	2.0	47.0
Concrete	6.7	7.0	10.3	12.3	4.0	6.0	8.7	8.0	63.0
Total	9.3	11.0	16.0	20.0	15.0	12.0	17.3	9.3	110.0
Evaluation (Convergent Production Dialogue & Action)									
Critique	2.0	6.7	4.3	5.0	10.7	5.0	3.3	8.0	45.0
Justification	4.0	3.0	5.0	6.7	13.3	6.7	7.0	10.0	55.7
Checking	2.0	4.7	5.3	11.7	8.0	8.0	7.7	5.0	52.3
Total	8.0	14.3	6.0	23.3	32.0	19.7	18.0	23.0	153.0
Management (Reflexive Dialogue & Action)									
Regulation	7.0	6.0	6.0	3.7	5.7	10.3	6.0	10.0	54.7
Grounding	4.7	7.3	9.3	8.3	7.7	8.0	6.3	4.7	56.3
Affective	5.3	7.0	5.0	6.0	4.0	5.3	9.7	3.0	42.0
Disaffective	2.3	0.7	3.7	2.3	5.3	8.0	3.0	8.7	26.7
Total	19.3	21.0	20.7	20.3	22.7	26.3	23.0	26.3	179.7
Revision (Elaborative Dialogue & Action)									
High level	8	9	14	3	4	0	2	4	70.0
Low level	8	3	6	5	15	16	10	14	87.0
TOTAL	16	12	20	8	19	16	12	18	157

A time-based trend plot of conversation data is provided in Figure 2. Generating or divergent type dialogic acts are more prominent at the beginning of the collaboration, then drop off

towards the end. This finding characterizes the task of collaboration as necessitating the generation of new possibilities and ideas to start off the collaborative session. It was evident across all groups. Certain aspects of the visualization in Figure 2 are worth noting here. As described in more detail the in qualitative findings, Section 10.2 divergent dialogic acts occurred at the early stages of collaboration, similar to the "germinal idea" indicated in compositional studies. As time transpires, existing solutions undergo more revision and elaboration as the groups work to modify the state of the solutions towards a final product. Such revision is seen to co-occur with efforts of the group to evaluate, keep or discard these modifications as necessary. Finally, group management efforts remain consistent across the collaborative session, although of greater importance towards the beginning. This overview of the conversational characteristics provides some a general understanding through which to understand sensemaking phenomena and factors which are discussed and illustrated in Chapter 10.

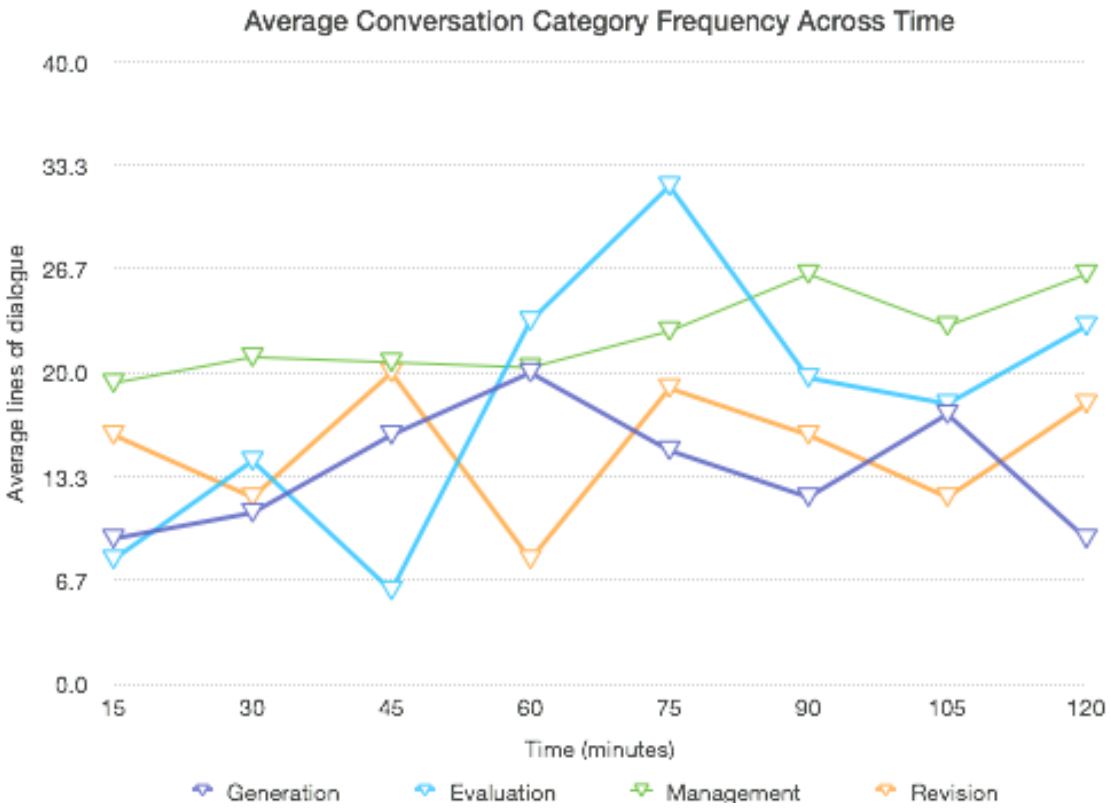

Figure 2: Average frequency over time of dialogue categories (Generation, Evaluation, Management and Revision) compiled across all sessions for all groups.

9.4 Referential Structure Analysis

To quantify the properties of the conversation, I determined which words were used as the contents of the collaboration. This process entailed categorizing nouns in the dialogue, then categorizing them according to logical subtypes. The purpose of this classification exercise was to determine the concerns and topics of conversation on the part of the subjects, and thus realizing the content of the items which are exchanged in the process. In addition, this process involved identifying adjectives in the conversation to see how the components of the dialogues are described in terms of characteristics and properties. Properties were also categorized in terms of logical subtypes.

The analysis was done in a combined fashion, first using automated language analysis to produce statistics concerning which nouns were used. Objects were labelled according to noun tokens. Many different tokens can reference a common object type; for example, properties are labelled according to adjective tokens. Likewise, one property can be referenced by varying tokens. The analysis was performed in a combined fashion of using automated analysis to extract unigrams, bigrams and trigrams from the text. The index of the text produced was then used to provide lifetime measures, described in Section 9.4.1 below.

9.4.1Coding Example

Line #	Transcript Text	RSA Code
75	Bass: On the very end we'll rock out on the main riff. Or hold it... We'll do the chorus and end on the big “E”	Ref–2B:”main riff” Ref–2C:“chorus” Ref–1A:”on the Ref–4A:“rock out” Ref–2D:“big E”

Example 12: Transcript excerpt showing an RSA coding for one line of dialogue. Reference types are coded as a number, and the specific instance as a letter. The textual label for the reference is described in quotes. The references identified here are 3 objects, “main riff”, “chorus”, and “big E”; one sequence plan “on the end”, and one performance style “rock out”.

In Example 12 is a portion of coded transcript as demonstration of the coding process. It is an example RSA analysis is shown below, taken from the conversational transcript. Here I have

identified a handful of references that are important in the discourse. On line 75 of this transcript, the coding notation shows that the speaker (the bass player) introduces several new objects into the discourse: a chorus, a chord, and references a pre-existing object “main riff”. Note several references and reference types may easily occur on a single line of dialogue. The speaker also introduces a plan, which is to establish a section sequence in the song. A stylistic performance direction is also mentioned, “rock out”. If these references are then subsequently referred to or otherwise modified at later lines in the discourse they are indication by their assigned reference codes.

9.4.2 Reference Metrics

The metrics were gathered to produce a profile of the conversation in terms of what items form the content of the conversation, and how dominant each of these items are at different points in the discourse. In this way a quantitative description of the collaboration can provide an insight about which are the most relevant aspects of the collaboration, and specifically at what points in the collaboration they are dominant. The goal is to combine this data analysis with the conversational elements which were described in Section 9.3. The top-level reference types are described in Table 1, together with their RSA metrics. Below are descriptions of the four statistics produced in the RSA analysis. RSA metrics are described using Example 13 below to illustrate the coding process based on transcript text.

Line #	Transcript Text	RSA Code	Occurrence
75	B: On the very end we'll rock out of the main riff. Or hold it... We'll do the chorus and end on the "Big E"	Ref–1A: "on the Ref–2C:"main riff Ref–9A:"rock out Ref–2D:"big E"	1
76	Lead: It sounds pretty bad when I play that last chord.	Ref–2D:"last chord"	2
77	Rhythm: Should I come in at the same time?	Ref–4B: "same time"	
78	Bass: No wait it goes like this. (plays)	Ref–2D :"it"	3
79	Rhythm: Yeah!		
80	Bass: So we're going to do that big E once and then you should come in with the drums.	Ref–2D :"big E"	4

Example 13: Excerpt from transcript showing RSA coding of identified reference types and subtype for each line of text.

Occurrence is the measure assigned to the frequency count of all occurrences of a particular reference type. Oftentimes, different names or *labels* are used to refer to the same reference. The descriptions include individual references to specific uses of a particular object, such as a chord; a property, such as volume level; a performance direction such as a strumming pattern; or a plan, such as sequencing of song. When multiple labels are used to refer to the same instance, they are collapsed and counted as one unique reference. Example 13 is an illustration of calculating occurrence, based on transcript data. For clarification, an *Occurrence* column is provided to show the frequency of an object.

Average Lifetime. Lifetime refers to the time of relevance, measured in lines of text, of a particular reference. It is calculated by determining the difference between the first instance of a reference to the last mention of a reference. All lifetimes of a particular reference type are summed across all instances and divided by the number of lifetime scores to compute its average lifetime. Lifetime is a calculation reflecting the relevance of a category of reference and is used in the calculation of density, or concentration of a reference. The example (Example 13) above shows a lifetime for an object reference (Ref-2D "last chord) of 6 lines of dialogue.

Average Density. Density is defined as the number of times a reference is mentioned

(occurrence) during its entire lifetime. In example 13 above, a chord object is referenced 4 times over a lifetime of 6 transcript lines. The density score for this reference is therefore 4/6 or 66.6%. Note that the dialogue in this example is shortened for simplicity sake and that the actual transcript in fact contains a longer lifetime and occurrence count for this reference. Also note, the chord in this example is referenced with three different labels--“last chord”, “it”, and “big E”--yet they pertain to the same individual chord object co-reference. The average density is computed by averaging the entire set of density measures for a particular reference type. Density is a measurement used to describe the concentrated relevance of a reference type. A high density score therefore describes a reference which was highly pertinent to the discussion, albeit for a relatively short amount of time. A low density score reflects less concentration. Even though a low density reference could be of of general importance to the collaboration over a long period time, it was not mentioned often in relation to its lifetime, and was not a topic of particularly intense discussion or interest. This contrast in referential structure—a long lifetime versus a short one, and a period of frequent references versus a lower-density but more continuous pattern of references—is the sort of observation the RSA method is designed to find. By examining patterns of references, I can gauge accordingly how participants are exchanging information. The prevalence and concentrations of topics at certain points in the discourse determine how best to mediate that exchange.

9.5 Reference Typology and Trends

A process of categorizing and counting reference types is the first phase of the RSA analysis. The means of identifying an appropriate set of reference types provides valuable insight into exchange, since it allows me to see how topics of conversation are tracked along the dimension of time. It also allows a summary of the entire RSA analysis, which is described in Section 8.3 is given in Table 4 and 5 below. These figures represent the average and total data of all 18 hours of transcript data, divided according to the major reference types. Each major reference type is composed of several subtypes as well as its associated dimensional values.

The types of references used in the problem-solving discourse can be grouped into four general main types, described below in Table 4. The ontology derived from the RSA analysis also includes subtypes of these major types. Tokens were counted as specific instances of each type.

Table 4: Reference totals for all reference types: Performance, Property, Object, and Plan for Groups A, B, C.

Reference Occurrence by Group				
Reference Type	GROUP A	GROUP B	GROUP C	TOTALS
Performance	75	136	85	296
Property	174	227	159	560
Object	214	203	249	666
Plan	110	83	109	302
TOTALS	573	649	602	1824

Table 5: Average lifetime, total occurrence and average density of all major reference types: Performance, Property, Object, and Plan for Groups A, B, C. for all 9 sessions.

RSA Summary			
	Average Lifetime Lines of text	Occurrence Lines of text	Average Density Occurrence / Lifetime
Performance	16.3	296	54.5%
Property	20.7	560	50.55%
Object	32.3	666	56.8%
Plan	25.7	302	45.9

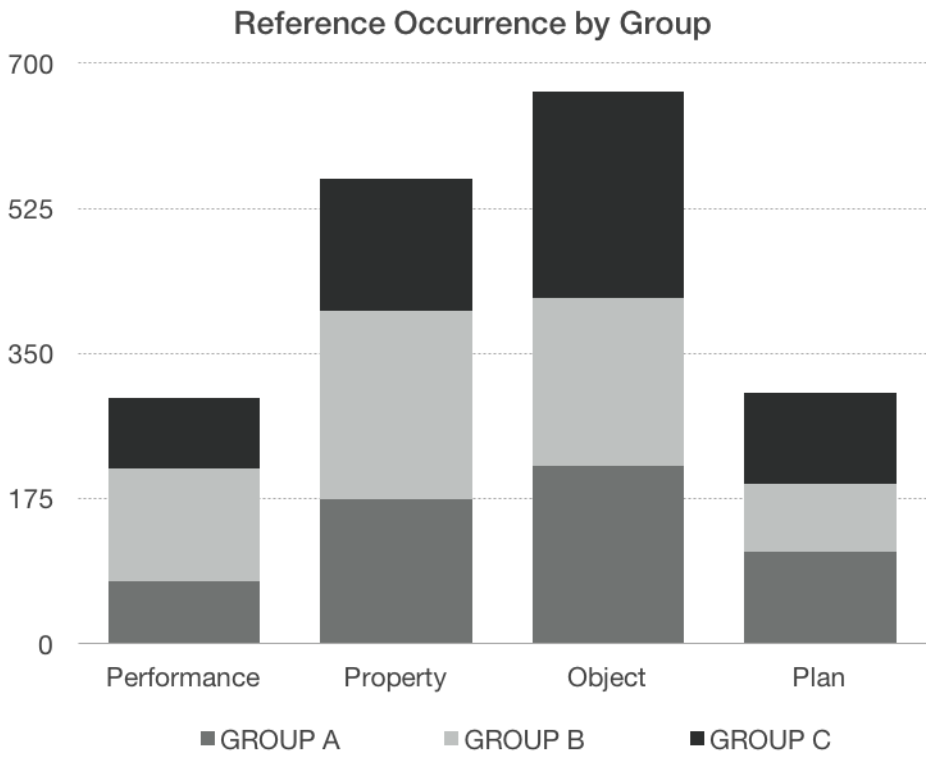

Figure 3: Histogram of occurrence totals for Performance, Property, Object and Plan references for all groups A, B, and C. Totals reflect all accumulated counts for all 9 composing sessions. Property and related object references are most frequent overall.

For reasons explained in Section 9.3, reference density is a rough measure of how dominant the topic referred to is in the conversation, during the spans denoting the reference lifetime. It should be noted that density measures of any type or subtype indicate the presence of more references within a *block* of text than in *lines* of text. For the purposes of the current study, references with a long lifetime but low density are generally less relevant to identifying blockages and breakthroughs in the collaboration than are references with a short lifetime but high density. The latter group represents instances where particular discussion topics are highly concentrated in the discussion collaboration. This finding is hypothesized to indicate points where knowledge gaps occur and the sensemaker uses repetition to encode an appropriate representation. The tactic employed by the group is to reformulate the problem based on incoming data and construct new representations so that the problem-solving pathway is thus advanced (Paul & Reddy, 2010). With the former group, references with high lifetime and small density are still relevant to the group collaboration but in the opposite sense. They instead indicate topics which form the baseline, agreed-upon knowledge base. Since they are non-

controversial topics, they form sparse distribution over the discourse, but are still maintained as relevant elements in the baseline knowledge of the collaboration. These two distinctions noticed in the distribution of nouns in the discourse analysis help to form insights to the sensemaking process in general, which is not specific to a musical domain.

Most of the time, the density of a particular subtype shows that the lifetime of that reference far outweighs its frequency of use. In general, it is possible to conclude that these high scores are a function of the variability of the lifetimes. The implication of the low density score for properties is less clear. It may indicate they do not dominate the conversation as strongly as performance details do.

Across time, the diversity of references is a useful indication of the complexity measure of the collaboration. The discourse analysis demonstrates that low-lifetime, low-density references are more frequent towards the early part of the collaboration. In other words there are more concept overlaps in the early part of the discussion. Over the course of collaboration, the working concept set diminishes, and less reference co-occurrence (less complexity) than in the initial stages. This finding is indicated in the measure of variation in the noun counts over time.

9.5.1 Performance

References of this type describe the manner in which playing actions are performed and identified in the transcript typically as directions, given from one member to another. They include textual references which in turn incorporate adverbs and verbs connected to and affecting one or more existing musical objects. As seen in the performance types listed in Table 8 below, performance references may involve multiple properties and levels of music, such as specific musical techniques, directions about punctuation of a particular section or line, or alterations of the dynamics of the music, including fluctuating ranges in volume or tempo. Below is an example (Example 14) from the transcript of a performance reference, underlined in a statement from the bass player.

> Bass: Yo, play something more forceful, but the same idea as before, and repeat it.

Example 14: Performance Reference

9.5.2 Performance Summary

Table 6 below shows summary of performance references for all 9 sessions. Lifetime is the average duration of relevance of a reference, measured in number of lines of dialogue. Performance references are grouped according to direction and intention of the physical performance of music as they pertain to different qualities of the music. Occurrence is the total number of lines of dialogue that consist of references to a Performance Type. Density is the average concentration of a reference type, measured by the average occurrence divided by average lifetime. As shown in Table 6, performance references occurred the least frequently (296) relative to the occurrence counts for other major reference types, when compared to the other reference types. The short average lifespan of performance references accounts for the relatively high density score (48%) indicating that when performance is discussed, references on average on mentioned over half the lifespan. Interestingly, one performance type is dominant during the collaboration, which are directions about ways to play in order to achieve a particular affective outcome or "feel" to the music. In the following chapter, in Section 10.3.1, the degree to which participants are aware of emotional quality and the affect this awareness has on moving the collaboration forward is an important aspect to sensemaking and knowledge construction itself. The consistent importance of social management using reflexive discourse across time (Figure 2, Section 9.3.1) is evidence of this importance. In this case, this aspect of collaborative discourse was transferred into the discussion about solutions when participants also use the performance of music to achieve a positive affective outcome.

Table 6: Performance Reference RSA Metrics. Above is a summary of all performance references totaled across all 9 sessions (Groups A, B, C x 3 sessions).

Performance References				
Type	**Average Lifetime** Lines of text	**Occurrence** Lines of text	**Density** Occurrence / Lifetime	**Relative Occurrence** Occurrence / Total
Dynamics	5	30	62.3%	10%
Affect/Feel	18	103	63.3%	35%
Improvisation	10	35	22.7%	12%
Punctuation	15	44	78.7%	15%
Technique	18	50	66.3%	17%
Genre	32	34	33.7%	11%
TOTALS	16.3	296	54.5%	

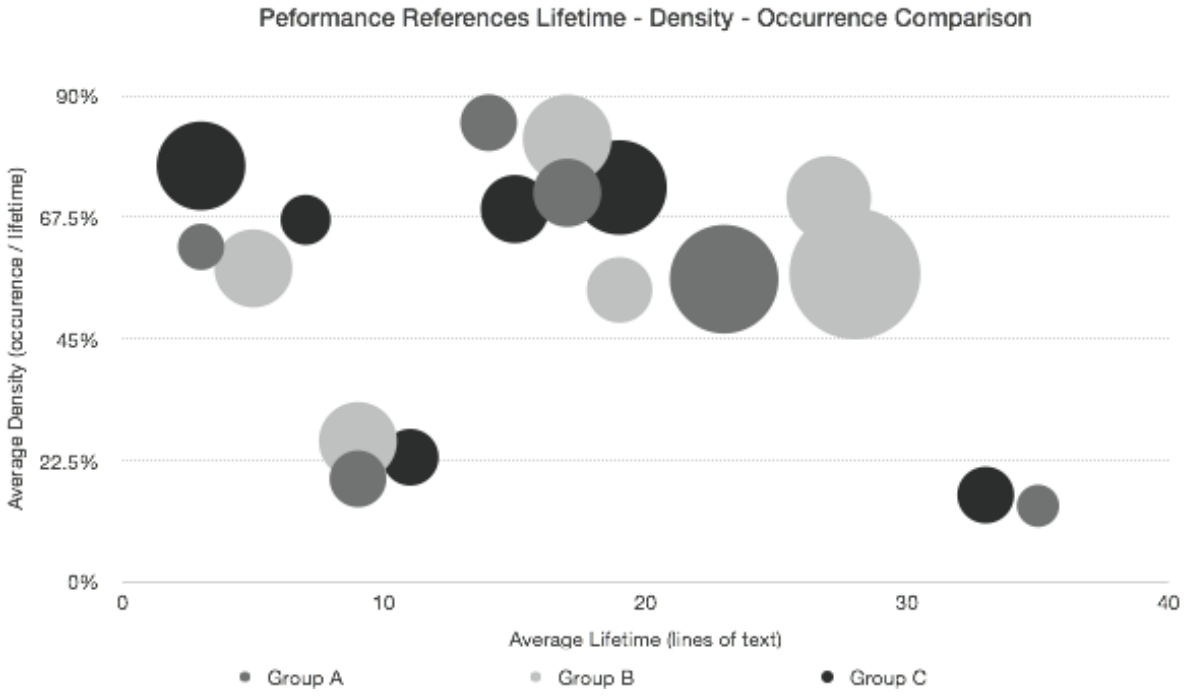

Figure 4: Bubble plot of performance reference relating average lifetime, average density and occurrence totals for all groups A, B, & C for all 9 sessions. Bubble size correspond to relative occurrence. Bubble size represents relative occurrence.

The above lifetime-density-occurrence bubble plot (Figure 4) shows the common groupings, or clusters, of reference-performance similar references, ones which match around lifetime and density. In this visualization, the size of bubbles reflect the occurrence counts: the larger the bubble the more frequently the performance type is mentioned. Examining this relationship shows 3 distinct clusters of performance references, with 2 outliers. The first cluster, in the lower left corner of the plot shows low-density, low-lifetime performance reference. The low value of both shows that a substantial portion of all performance references were not especially relevant to the conversation, mentioned briefly and with sparse concentrations. Conversely, other performance references, such as technique, punctuation and affect, enjoy relatively high average density and are consistently relevant to the concerns of the group over the collaboration sessions. This grouping of performance references are clustered in the top middle of the plot. Performance of certain types, therefore, are significant to how groups compose music and are a necessary way for participants to transmit meaning in the form of direction of physical action. This issue is discussed further in Section 10.

9.5.3 Properties

Properties are those instances where the quality or characteristics of the musical object is mentioned in verbal communication or through musical action. As seen in the occurrence figures provided in below in Table 7, property types are the most frequently mentioned reference in comparison to other reference types. References of this type describe the characteristics of the music, in which certain musical objects are mentioned in terms of their existing or intended musical description. The references are often identified as adjectives connected to and affecting one or more existing musical objects. As seen in the property types listed in Table 7 below, property references may involve a range of musical description terms, from low-level details, such as tempo, duration, and tonal characteristics; to more broadly perceived, high-level properties, such as key, tempo, and genre. Below is an example (Example 15) from the transcript of a property reference, underlined in a statement from the rhythm player.

> Rhythm: You should remember, it sounds like(sings line); it has to be really heavy and loud, because the verse has got to be sparse against it.

Example 15: Property Reference

9.5.4 Property Summary

Property types are summarized in Table 7 for all 9 sessions. Properties are grouped according to the characteristics of musical objects and correspond to references mentioning those characteristics. Average lifetime is the number of lines of text from the first occurrence to the last, averaged across all references of that type, across all sessions. Occurrence is the total lines of text which contain a reference of the property type. Density is the occurrence divided by the average lifetime.

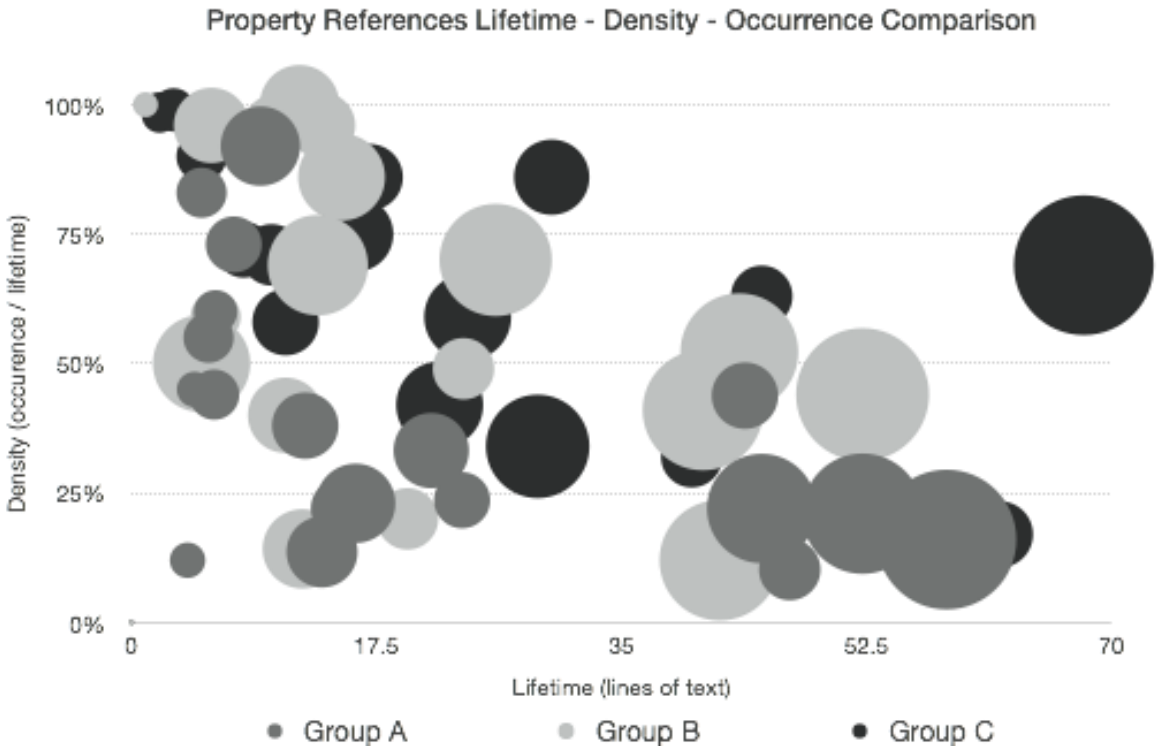

Figure 5: Bubble plot of property references relating average lifetime, average density and occurrence totals for all groups A, B, & C for all 9 sessions. Bubble size correspond to relative occurrence. Bubble size represents relative occurrence.

Table 7: Property Reference RSA Metrics. Above is a summary of all property references totaled across all 9 sessions (Groups A, B, C x 3 sessions).

Property References				
Type	**Average Lifetime** Lines of text	**Occurrence** Lines of text	**DENSITY** Occurrence / Lifetime	**Relative Occurrence** Occurrence / Total
Equalize	6.0	14	70.3%	2.5%
Interval	15.3	27	61.0%	4.8%
Harmony	14.0	28	64.3%	5.0%
Reverb	9.0	19	51.7%	3.4%
Treble	13.2	23	46.0%	4.1%
Delay	7.0	14	37.7%	2.5%
Vector	13.3	28	73.0%	5.0%
Pitch	11.5	27	74.7%	4.8%
Chroma	30.2	37	37.7%	6.6%
Shape	3.0	6	86.0%	1.1%
Bass	12.5	28	76.0%	5.0%
Sustain	21.2	36	32.5%	6.4%
Feedback	34.7	22	29.1%	3.9%
Noise	6.5	16	62.7%	2.9%
Volume	38.6	21	22.3%	3.8%
Meter	16.1	19	59.2%	3.4%
Key	7.1	9	11.1%	1.6%
Tempo	50.9	61	51.3%	10.9%
Duration	45.5	59	38.7%	10.5%
Order	57.5	66	25.7%	11.8%
TOTALS	20.6	560	50.5%	

Similar to performance references, property references as indicated in Table 7 also enjoy a density of roughly 50%, meaning that they occupy roughly half the space of their relevance lifetime throughout the discussions. Despite the higher overall occurrence of these reference types, indicating they are indeed significant components of the collaboration, they are still

concentrated in the same proportion to less significant, less frequently mentioned reference types.

The above lifetime-density-occurrence bubble plot (Figure 5) shows the common groupings, or clusters, of property references. Similar references match around common lifetime and density scores. To show the connection to frequency of occurrence, the size of bubbles reflects the occurrence counts: the larger the bubble the more frequently the property type is mentioned.

Examining this relationship visually shows three distinctive cluster formations, as well as a negative linear trend between data points. The first cluster in the top left of the plot represents high-density, low-lifetime references. Another cluster, in the lower right of the plot shows low-density,high-lifetime, references. A third group in the middle of the plot represents a grouping of middle scores for the two metrics density and lifetime. The distinctive clustering was discovered to occur in other reference types, particularly object references. Closer examination of these reference clusters, as well as of object reference clusters shows a correspondence between how solutions are discussed among participants and how the song solutions themselves are structured. This relationship is discussed in detail in the following chapter, in Section 10.2.1. The negative linear trend shows a transition between those properties which were situationally relevant, and mentioned in high concentrations over a short lifetime, and properties which pertained to longer sections of the discussion but were never pressing issues, and thus not deliberated on in great detail. A notable outlier (top right of Figure 5) are references to tempo properties. The pace at which music is played commonly formed a dominant topic of the discussion, indicated by their relatively large frequency and high lifetime, in a way which was unique from other properties.

9.5.5 Objects

Object references are terms which refer to musical “objects” which are either conceptual components or layers of a musical composition or both. Table 8 shows a summary of object types. Table 8 indicates the range of categories of object types: rhythm, chords, melody, harmony, pitch, verse, chorus, timbre, orchestration and other concepts. Various forms and synonyms of these words were marked as well and studied in their use relative to the domain. Average lifetime is the number of lines of text from the first occurrence to the last, averaged across all references of that type, across all sessions. Occurrence is the total lines of text which

contain a reference of the object type. Density is the occurrence divided by the average lifetime.

Objects are the second most talked-about reference — accounting for over one third of references — and of long lifetime (see Figure 6, Table 8). These figures describe only the overall frequencies and percentiles exhibited on average during the collaboration sessions for all groups. The differences in average lifetimes between types, which is the number of lines separating in the conversation that separate the first and last occurrence of a specific reference type, illustrates that musical objects form, in general, long-term sections of the collaboration, when compared to performance or plan references. The total reference count from the trials which show a clear preference to discuss actual music items, as opposed to say, performance instructions or physical objects.

For clarification of some object types listed in Table 8, the rhythmic dimension can be defined as the organization of the duration of sounds over time. In a musical score rhythm is related to time signatures, to accent layout, and to figures within a bar. The harmonic dimension is the vertical aspect of music, related to the use and study of pitch simultaneity. Chords were often expressed in terms of their “chroma” without octave information, (for example “A”, “C#”, etc).

9.5.6 Object Summary

Table 8: Object Reference RSA Metrics. Above is a summary of all object references totaled across all 9 sessions (Groups A, B, C x 3 sessions).

Music Object References				
Type	Average Lifetime (Lines of text)	Occurrence (Lines of text)	Density (Occurrence / Lifetime)	Relative Occurrence (Occurrence / Total)
Annotation	7.2	6	92.0%	0.9%
Note	11.0	38	86.9%	5.7%
Chord	17.8	87	84.2%	13.1%
Scale	10.7	26	79.7%	3.9%
Melody	16.7	37	84.0%	5.6%
Phrase	23.3	16	84.1%	2.4%
Pre-Chorus	12.6	15	88.7%	2.3%
Bridge	23.3	36	39.2%	5.4%
Instrumental	22.2	9	93.3%	1.4%
Interlude	10.8	10	43.8%	1.5%
Beat	32.7	49	41.6%	7.4%
Solo	43.7	55	73.7%	8.3%
Outro	39.9	17	41.1%	2.6%
Verse	53.9	78	30.3%	11.7%
Intro	51.5	20	49.4%	3.0%
Chorus	51.8	65	67.3%	9.8%
Progression	70.1	32	26.1%	4.8%
Song	54.9	22	9.4%	3.3%
Lyrics	72.8	38	15.6%	5.7%
TOTALS	32.3	666	56.8%	

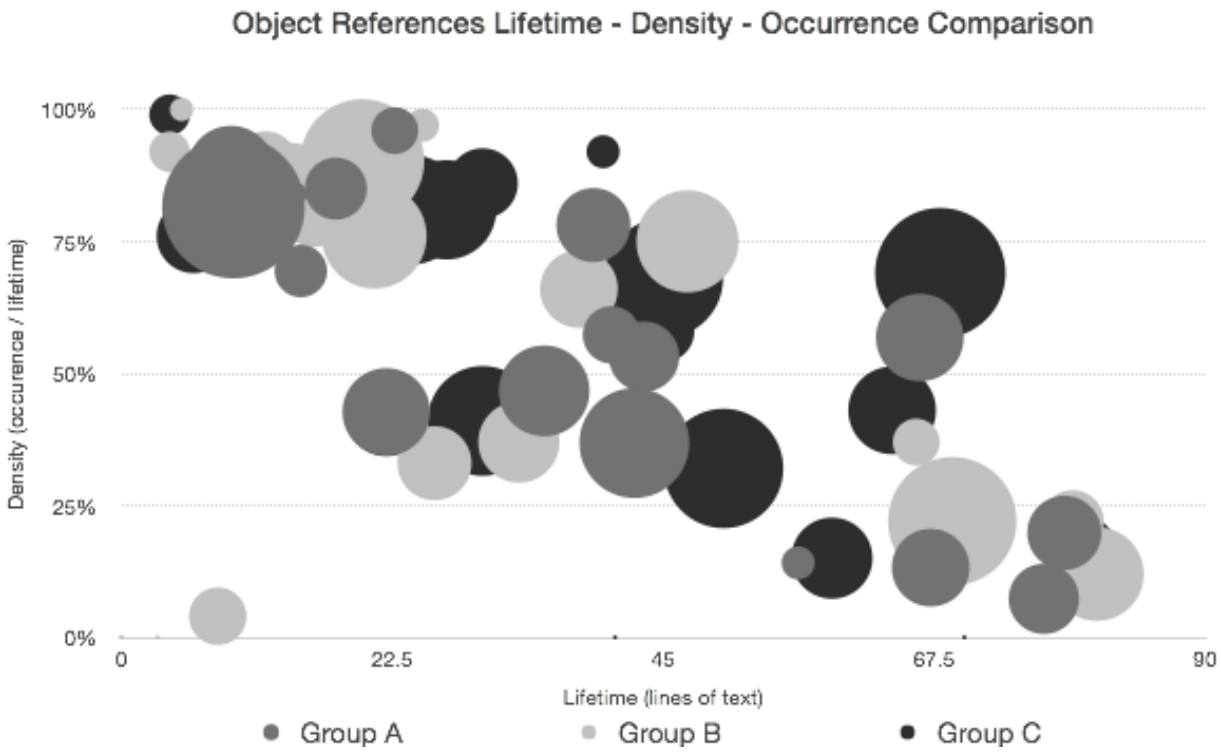

Figure 6: Bubble plot of object references relating average lifetime, average density and occurrence totals for all groups A, B, & C for all 9 sessions. Bubble size correspond to relative occurrence. Bubble size represents relative occurrence.

The above lifetime-density-occurrence bubble plot (Figure 6) shows clusters of object references. Similar references match around common lifetime and density scores. To show the connection to frequency of occurrence, the size of bubbles reflects the occurrence counts: the larger the bubble the more frequently the property type is mentioned. Certain object types are noteworthy and show their significance to the collaboration and how music is discussed by the band members. In particular, sections such as chorus, verse and lyrics were often dominant objects which persist as relevant to the conversation for long periods of time. These sections performed as the structure to the piece overall, however, they were never noticeably dominating portions of the conversation, given there were references with greater density values also emerged. Highly dense references, for example, chord progressions, notes and scales, dominated short sections of the dialogue as indicated by the high density score

Examining this relationship visually shows three distinctive cluster formations, as well as a negative linear relationship among the references. The first cluster in the top left of the plot represents high-density, low-lifetime references. Another cluster, in the lower right of the plot

shows low density, high lifetime, references. A third group in the middle of the plot represents a grouping of middle scores for the two metrics density and lifetime. Closer examination of clusters shows a correspondence between the frequency of topics being discussed, and how the song solutions them- selves are structured. This relationship is discussed in detail in the following chapter, in Section 10.2.1. The negative linear trend shows a spectrum between those musical objects which were situationally relevant, and mentioned in high concentrations over a short lifetime, and musical objects which did pertain to longer sections of the discussion but were also never pressing issues, and thus not deliberated on in great detail.

9.5.7 Plans

References to plans are discourse items that pertain to an explicit strategy to alter or create a musical object or property, and are the generic category of short-term and long-term goals defined in the collaboration. Creating a song opening, choosing an appropriate chord, deciding how or when each instrument should enter, sequencing of musical sections, durations, or intentions to place musical objects in a relative position in time—all are considered plans. Considering music as multi-layered information, it is the course of action the group uses to assemble and structure the time and spatial information of the music. Plans that affect the quality of music were also used, such as that for altering the volume and tonal dynamics of music.

> Bass: So next will go to the E part, wait 2, 3, 4, And then go into the verse.
>
> **Example 15: Plan Reference**

In approximately half of occurrences, a plan was proposed or reported once and never mentioned again. The other half of the time the plan was referred to a handful of times, indicating some negotiation. Only in a few cases did a plan continue to be relevant for more than five lines of chat. Plans may also overlap in terms of their lifetime of relevance. The group discussed one plan while hashing out another. Two density statistics of note: *affect* plans (20%) and *sequence* plans (19%) indicate that when plans of these types were discussed they tended to dominate the discourse. They were mentioned often in a short time frame, indicating they were pressing, critical issues for the group to resolve. The presence of less dense plan types, such as *arrangement, instrumentation* or *quality* means that the planning of this type of work was done over a long period of time and did not generally dominate the conversation.

Such examples demonstrate how to begin interpreting RSA results by combining the total number of references identified in the discourse, then combining that figure in a function of the average lifetime associated with that type. The relative importance of concepts as indicated by these scores provides many clues about their relevance to the collaborative process in general and can also be used to infer similarities between concepts.

A problem with plans, and with any reference type, is that density can become skewed easily if there is a mention of the that reference type significantly later on in the dialogue. The lifetime increases greatly, and even though the majority of the instances may be concentrated in a short lifetime in a previous dialogue excerpt, revisiting that concept even briefly in the discussion may make it appear as though the plan was relevant throughout, when in fact it was not. Such findings are noticed and validated with qualitative examination.

Closer examination of how users talked about plan references revealed properties of plans. Users initially spent some time discussing assignment of the plans (e.g., “We still need a bridge for this song — we should work on it.”). However, after this brief discussion, references to plans only occurred in the context of instances: nominating instances for a task (“Now let’s try second chorus”) or querying or reporting on the status of the plan (“How long is the solo?”). In other words, generic plans had only a short lifetime outside their attachment to instances.

9.5.8 Plans Summary

Table 9: Plan Reference RSA Metrics. Above is a summary of all plan references totaled across all 9 sessions (Groups A, B, C x 3 sessions).

Plan References				
Type	Average Lifetime Lines of text	Occurrence Lines of text	Density Occurrence / Lifetime	Relative Occurrence Occurrence / Total
Instrumentation	18.0	4	63.0%	1.3%
Arrangement	44.3	27	29.7%	8.9%
Excerpt	33.7	38	29.0%	12.6%
Quality	9.0	15	54.0%	5.0%
Version	31.7	43	25.3%	14.2%
Affect	29.2	62	51.3%	20.5%
Tone	16.7	53	61.3%	17.5%
Sequence	23.3	60	53.3%	19.9%
TOTALS	25.7	302	45.9%	

Plan references are summarized above in Table 9. Plan types are grouped according to the subject and correspond to references about developing and strategizing elements in the collaboration. These can include changing or creating the arrangement, tone or sequencing of the music. Average lifetime is the number of lines of text from the first occurrence to the last, averaged across all references of that type, across all sessions. Occurrence is the total lines of text which contain the reference of the plan type. Density is the occurrence divided by the average lifetime.

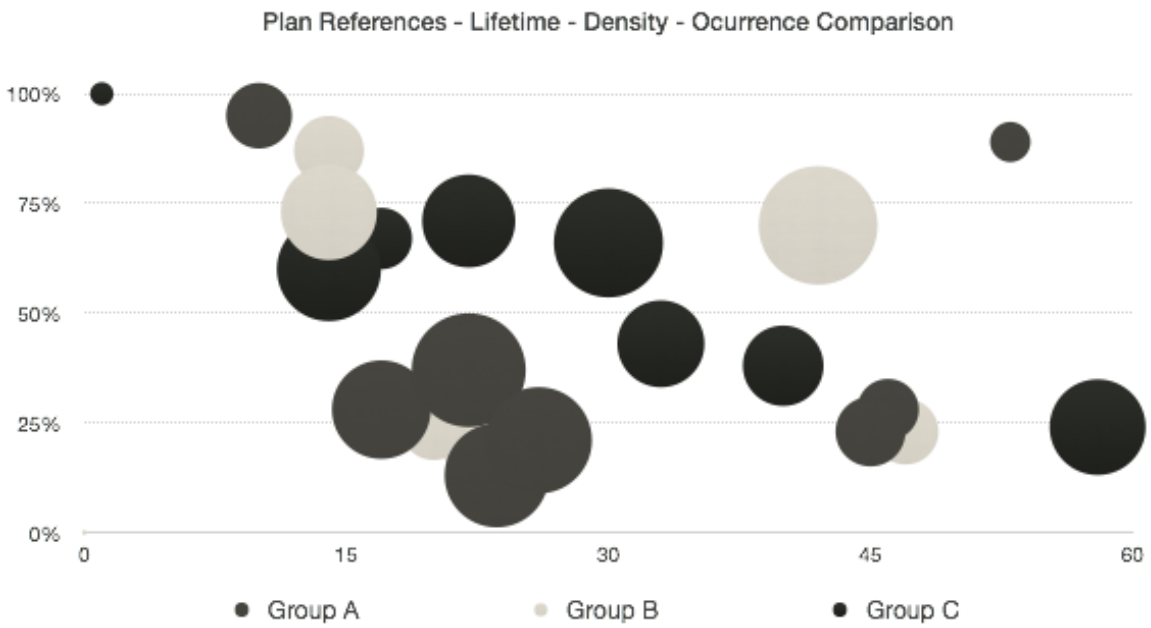

Figure 7: Bubble plot of object references relating average lifetime, average density and occurrence totals for all groups A, B, & C for all 9 sessions. Bubble size correspond to relative occurrence. Bubble size represents relative occurrence.

The above lifetime-density-occurrence bubble plot (Figure 7) illustrates the clusters of plan references. Similar references match around common lifetime and density scores. Section 10.2 in the discussion elaborates on the tendency for high diversity, low density references as a signal that the group is searching for ways to resolve gaps looking for resolution, and may not be indicative of successful collaboration. Examining this relationship visually shows a loosely clustered, negative linear trend. As with object references, examination plan reference clusters show a correspondence between how plans are discussed between participants and how the song solutions them- selves are structured. Highly discussed plans, those data points with large diameter in the plot are low density references. From this it reasonable to conclude that frequently discussed plans, may impose problems for sensemaking, and are relevant over long periods of the collaboration. The details of such plans show discussions about topics such as affect, excerpt planning and tonal quality of the music indicating they are likely complex notions for the group, requiring more deliberation. This finding is discussed further in Section 10.2.

9.6 Quantitative Findings Summary

This chapter describes the outcome of two forms of quantitative analysis methods of transcript data: RSA Analysis, and Conversational Analysis.

- *Performance* references describe how the music is executed by individual band members on their respective instruments.
- *Property* references are the characteristics of objects. They may describe volume or affect of the music, duration of a musical segment, or style of a song.
- *Object* references are the broad category of references for the content of music or physical items being referenced. Examples include verses, musical notes and melodies, chords, or tonal features.
- *Plan* references describe short term and long term objectives in the collaboration, for example, the creation of song structures, deciding on genre, or tonal properties of the music.
- Over the course of collaboration, the working concept set diminishes and there is less reference co-occurrence (less complexity) in the initial stages. This is indicated in the measure of variation in the noun counts over time.
- Clustering of lifetime-density-occurrence plot reflects relevance similarity and simultaneity of topics of collaboration.
- Patterns of clusters often distinguish 2 groups of objects and property references which were either contextually relevant or broadly relevant to the collaboration.

Conversational Analysis uncovered 4 main categories of conversation. These categories were applied as codes to transcript data and their frequencies were totaled and plotted against time to reveal trends in the dialogue. They are:

- *Generation* (Divergent Production Dialogue & Action) : dialogue which indicates innovation and creation of new concepts in the collaboration.

- *Evaluation* (Convergent Production Dialogue & Action) : dialogue which indicates checking and justification between group members during deliberation.

- *Management* (Reflexive Dialogue & Action) : dialogue used to establish group rapport and social building and maintenance.

- *Revision* (Elaboration) Instances : dialogue which indicates altering the characteristics of tentative solutions.

- Divergent dialogic acts occurred at the early stages of collaboration based around developing a “germinal idea”. As time transpires, existing solutions undergo more revision and elaboration as the groups work to modify the state of the solutions towards a final product.

- Group management efforts remain consistent across the collaborative session, although reveal greater importance towards the beginning.

Chapter 10

10 Discussion and Qualitative Findings

Linguistic references, their types and frequencies, and the kinds of conversation are the foundation for a qualitative analysis. This section interprets the quantitative findings in the context of overall language patterns and trends, their correspondence with collaboration, and the impact on group sensemaking. In doing so, I answer my first research question, restated: *What are the communication patterns of collaborators and how does this impact sensemaking of musicians in the act of creating music*? This analysis relates trends to problems in group sensemaking, targeting key areas of the collaboration: 1. problem solving, 2. awareness, 3. language, and 4. group learning. Each area is related to a specific design recommendation, answering the second research question, restated: *How can these patterns inform the design of a Computer Supported Collaborative Work (CSCW) system?*

I am considering the co-construction of new knowledge by small groups of 4 members. Co-construction of new knowledge is critical to the definition of an information system because it emphasizes coordination and resource sharing among group members (versus individual members independently doing their own tasks and only coming together to collate their contributions as a final product). I am situating the locus of creativity on the process itself, rather than on the output (the musical result) or the individuals (members of the band). However, the evaluation of novel outcomes may be based on implicit assessment of the output at various stages and judged in terms of novelty. The examination will be cast in the terminology and concepts of sensemaking theory, namely, knowledge frames and structures which are used to think with and organize incoming data to suit the context of the given task. Knowledge gaps, or difference between what is understood and what collaborators need to make sense of the current situation, are triggers which initiate sensemaking so that information is used to facilitate thetask. The data shapes the understanding of existing frames so that they may be used subsequently to move the collaboration towards new situations (Shah, 2012).

Four main components of sensemaking and collaboration were found:

1. *Problem Solving.* The participant groups reliably follow a problem pathway, a cycle of

generating, critiquing and evaluating the working set of tentative solutions during the course of collaboration, and use sensemaking to overcome blockages in problem solving. Preserving and passing on the solutions and processes of individual sensemaking across group members is important during collaborative activity.

2. *Awareness.* In sensemaking tasks establishing affective awareness and activity awareness in real-time were both crucial for achieving breakthroughs. Coordination effort deducts time and effort from production.
3. *Language.* Problems of ambiguity created gaps in group understanding. Sensemaking frames influence the nature of any gaps that may arise. After encountering a gap, particular pieces of speech, and gestures are used for mentally grouping (i.e., bracketing) pieces together (Weick, 1995). The development of secondary languages structures was a strategy used to overcome blockages and prioritize pieces of information as relevant to the given task.
4. *Learning.* Peer learning was an issue of continuous process, and a tool for bridging knowledge gaps during collaboration. Different roles of group members might lead them to assign different priorities to different pieces of information, leading them to share information with others only selectively.

10.1 Design Implications

One of the corollary research questions proposed in Section 6 is the following: *What are the benefits of technology to aid sensemaking during the process of collaborative creation?* As part of the research I discuss how design features can be utilized to address the findings and properties of the collaboration.

The core requirements being outlined are derived to support the predictable patterns in sensemaking exhibited within the group, and made substantive with an analysis of the content of language. The model being proposed includes two forms of interaction. The first is *person to system,* a scenario typically encountered in day-to-day life and commonplace system usage. The second model involves a g*roup of people mediated by a system.* This model is a scenario in which two or more users maintain a system between them, and mediate the interactions; an example is online messaging. The foundation set in place by these two models allows for

understanding of the use cases being envisioned of such a system (Shah, 2012). The design utilizes ontology for reifying the normally invisible structure of the discourse, and therefore provides a way of structuring the domain and talking about the micro-world of the composition. Automated extraction of concepts and speech acts are methods to indicate areas of successful social knowledge construction and successful collaboration. Likewise, each system design recommendation has one or several collaborative affordances, which are aimed to overcome sensemaking gaps and to utilize elements of collaborative discourse involved in the co-construction of social knowledge. Socio-technical systems in the case of innovation require that many detailed design decisions to be made, with respect to links between constraints on workflows, role authorization, and configurations (Feinman, 2006).

Below is a summary of the major design features that are address in more detail in the following sections:

1. Meta-notations allow for g*roup articulation* and support communication used to exchange ideas, to discuss, to learn, to negotiate and to make decisions. Increasingly complex datasets can be developed from collaborative content creation tasks, combining video, audio, screen capture, and physical and digital artefacts, including a history of the creative process and collaborative interactions, as well as the learners' final digital object or objects.

2. Visualization of the problem space, specifically through timelines and scripts support situation awareness which, in turn allows a remote participant to be informed of the actions of the group and the group itself. Tools should support persistence of the process and products of sensemaking by visualizing such pathways. An exemplary system allows quick visual identification of each contribution (Trausan-Matu et al., 2007).

3. Natural Language Processing (NLP) ontology, and text mining technologies are language tools to model the domain and disambiguate redundant terminology. They are responsible for identifying themes or subjects in dialogue content. These multiple streams of data, subjected to technology-enhanced analytical methods, can inform our

understanding of the relationship between the designable elements of a task and the learners' behaviour. Automation offloads the work that impedes collaboration and minimizes the change in discourse practices as far as possible.

4. Frame-based communication tools structure discourse to make it more effective by extracting structure from a naturalistic discourse to make the record more reusable.

In the design of CSCW features I consider a range of technologies which provide users ways to adapt to situations and activities. Collaborators are, in effect, agents which are restrained by the system. The environment itself can support both cognitive activities and provide ways to manipulate situations. The physical system, or in this case, the software that interfaces with the real world contributes to the cyclical interaction process. The properties of the system are described in the affordances of Gibson (Greeno, 2010). An *affordance* refers to things in the environment that contribute to the kind of interaction that occurs. The abilities of the agents are supported and facilitated by the properties of the system that guide behaviours in ways that conform to the range of tasks, needs, demands, and inferences that arise during dynamic situations. The affordances relate the attributes of something in the environment, in this case missing knowledge in the environment, or the need to review previous knowledge, to an interactive activity by the agent participating in the interactive activity. Some agents lack attentional or memory resources, some have better access to communicating with other participants, others are less able to execute technical moves to perform some task. Therefore, when I propose design features, I link each feature description with existential properties they bring to the collaboration. I call these *collaborative affordances* which are articulated in specific terms to justify each design choice. I saw it necessary to explain the decisions in terms of collaborative affordances to link action and needs of real world collaboration, to the precise roles that technology can play in instantiating and developing that link.

10.2 Problem Pathways

My first primary research question was the following: What are the communication patterns of collaborators and how do these patterns affect sensemaking of musicians in the act of creating music? This section addresses the first of these patterns, which is the use pathways to help collaborators move in a stepwise fashion from the beginning of a collaborative task to the completion of a collaborative product.

At the beginning of the collaboration, it was clear that participants experienced gaps in sense from the outset of the collaborative tasks. Under sensemaking theory, this finding amounts to collaborators experiencing situations of unresolved connection between the goal and the current problem state which is specifically described in the collaboration sequence. Gaps occur in how to define goals, before attempting to solve a problem, and collaborators follow a refinement loop of adding and revising related concepts and their properties iteratively. The theoretical view of the creative act of making music in groups is that it is a problem solving process, albeit a process with often ill-defined goals. As confirmed in studies about the creative act of music making, (Collins & Dunn, 2011), there is a "chunking" of the protocol in four stages where the compositional strategies are embedded into a cycle of recursive iteration. Theoretical models of coordinated group work generally recognize that factors such as task type and group dynamics can affect how and to what degree members coordinate with one another in virtual teams (Stebbins, 2013; Schneider et al., 2010). In the case of creative music making, within the first moments of collaborating, participants are concerned with populating what is essentially a working set of ideas around which further modification and elaboration may take place. The tendency is for concepts from the discourse, such as references to their objects or properties, to be instantiated early in the process. (Examples of properties include tone and tempo.) An occurrence of low density, low lifetime references in the early stages of the collaboration was determined (see Section 9.5)

Qualitative Model Diagram Cycle of Generation - Evaluation - Revision of Collaborative Products

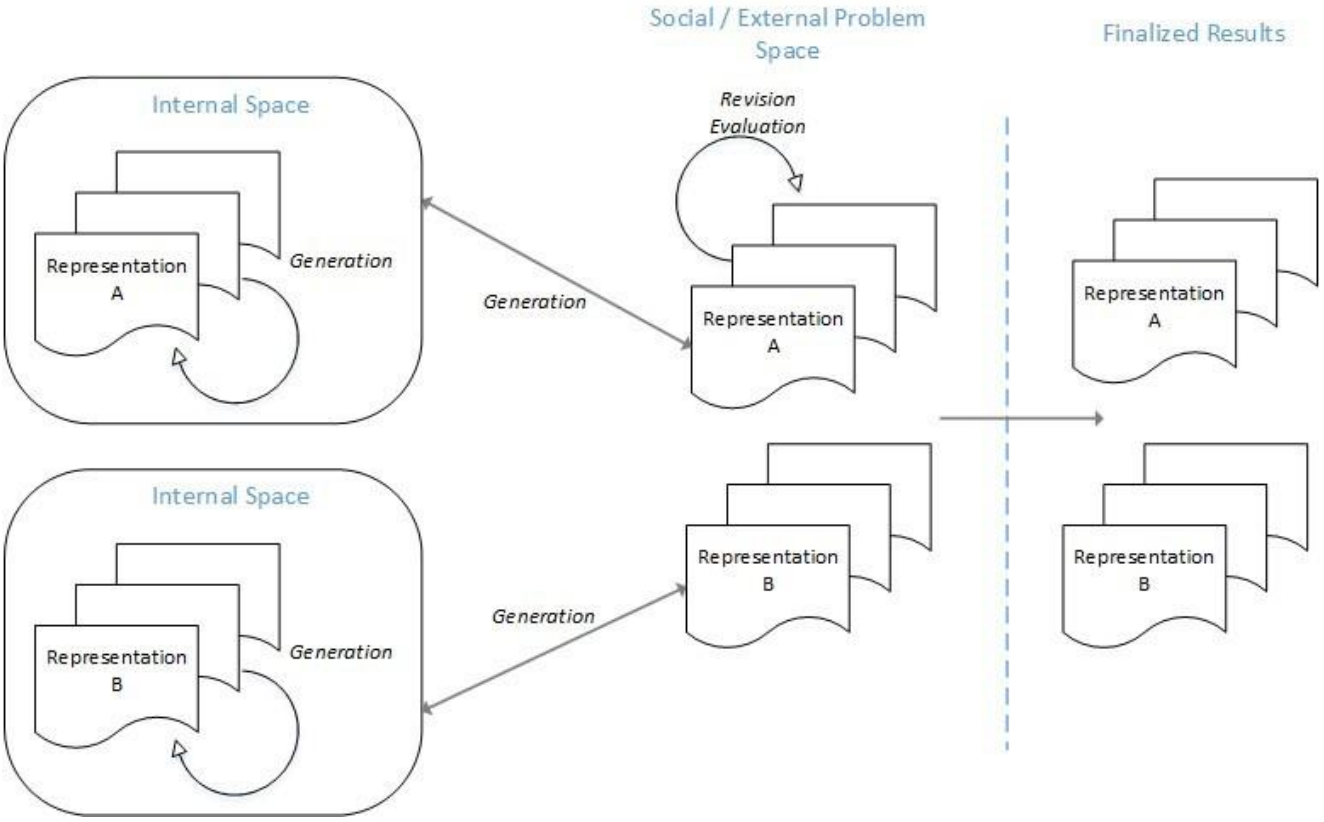

Figure 8: Generation - Evaluation - Cycle of creation during collaboration. Products of generation, represented internally, are translated to the social space where they undergo iterative modification. At some point, external representations form final product.

In the above model (Figure 8) the generation of ideas is performed both internally and externally as ideas are gauged against the existing situation and into the problem space for consideration. Works in progress are assessed by the community and undergo revisions and corrections as the group members deliberate and formulate closure. At some point, competing alternatives are compared and evaluated against a set of criteria. Following the evaluation, the working set of data is transferred to a semi-permanent work set of solutions that meets the group's requirements, and the process then repeats himself. This creative, generative process thus starts at the individual level—one where actors become aware of a current problem situation, and transitions

to the collaborative level are arrived at through generative acts. Problems are resolved through the evaluation and revision cycle, where actors collaboratively make sense of a problem formulation. The processes noticed in this interaction, namely generation, evaluation, and revision are noted as significant task requirements that compose the broader creative endeavour. I use these labels to identify those parts of the conversation which seem to perform these functions and look for patterns in their respective frequencies to draw conclusions about the interactions. Thus the quantitative analysis of language can be a way of illuminating a group aspect in common with other creative group activities.

Evidence in the current study demonstrates a commonality between groups of ongoing, cyclical periods of generation, evaluation, modification (Section 9.3.1, Figure 2). Assessing the utility of the finished product against these goals is equally problematic. I use the definition of a problem solving "pathway" as a cyclical process emanating from the development of plans to begin a composition. Generative talk, or divergent dialogue acts use language and musical actions to create new situations whereby an idea is presented explicitly through the enactment of musical concepts. Subjective accounts of composition identify what seem to be similar procedures with all composers in this study, i.e. first acquiring the germinal idea (or an "inspiration"). As indicated in the Section 9.5 of the RSA Results, a noteworthy trend emerged: several low-density, high-diversity nouns references found within the dialogue, confirming the conjecture. References could be a melodic theme, a rhythm, a chord progression, a texture, a "kind of sound", or a total picture of the work (Collins & Dunn, 2011), which is mirrored empirically in the current findings. A member of group C discusses this loosely defined process as part of an interview response:

> Starting can happen in a few ways. Sometimes I have a song that's been sitting in my head forever... It's good to let others hear my ideas and then let me know what they think so it turns into something new. If I'm in a certain mood, or if I hear something I like, an idea will emerge.

Example 16: Inspiration and starting the creative process

A common method of gap closure is recording an idea, no matter how trivial, and allowing its evolution to develop naturally. Section 9.5 of this research provides a description of the high diversity of nouns which are centred in the early stages of the collaboration, with multiple references posited in a short time. Similarly, previous research describes collaborative development based on generative acts to help to provide working alternatives, subjected to group

deliberation, in, for instance, learning tasks (Noroozi et al., 2013), engineering projects, writing and other creative tasks (Schmidt & Bannon, 2013). In the current context, however, this translates to the use of musical experimentation and repetition, rather than physical sketching, as means of introducing and making these alternatives persistent over time.

Under sensemaking theory, "verbings" are those actions that bring bridges into existence, essentially creating them anew in a metaphorical space that represents the cognitive space of the group (Dervin & Naumer, 2009). Using a quantitative model, other research in collaborative knowledge has been measured by comparing individual utterances with multiple participants, showing how these ideas animate others for collaborative gain through the integration of multiple perspectives. Zones of intense collaboration are identified by comparing maximums of collaborative gain with utterances that have their own gain greater than the chat's average (Trausan-Matu et al., 2012). Extending this idea, I found that zones can be gauged from those timeframes which centre around specific topics, involving multiple participants and higher than average density scores. Terms are introduced over the course of collaboration, repeated and revisited in a characteristic recursivity occurring between the revision (elaborative dialogue acts) and evaluation (convergent dialogue acts) following the introduction of the germinal idea (see Section 9.3.1, Figure 2).

Constructivist models of collaboration point to the building of shared knowledge towards a common goal. Goals on the micro level are indicated by the presence of plan references in the discourse. As indicated in the Section 9.5.1, plan references fall in two general categories: short-term and long-term. Short-term plans are immediate tasks, i.e., infrequently mentioned, low lifetime nouns which indicate courses of action, and therefore do not demand memory resources or persistent naming to aid this. On the other hand, long-term plans, were types marked by frequent references and required names to be utilized throughout more extensive timelines in the collaboration. For example, the task of creating a song ending involves multiple sub-tasks of creating its constituent parts, modulating properties of the music, and eventually refining the composition to a finished product.

> Rhythm: Ok let's get through the last chorus
> Drum: The last chorus was when it goes like this(plays a beat) And then me and you will go (sings for emphasis)
> Drum: Then you have to go right from that part to (plays) RG: Ok, your call

Lead: So after the build-up, we can go (plays one chord, strummed repeatedly) Rhythm: Ok lets begin from that riff.

Example 17: Initiating a problem solving pathway

Example 17 from Group A illustrates a few important elements occurring with regards to problem-solving pathways. Communicating the initial plan first required using music to reference the chorus, and then outline a schedule of tasks, illustrating excerpts by way of singing the phrase, or otherwise verbalizing the rhythm between members. This process is an instance of modification, one which takes place in the context of moving the problem forward: the persistence of these concepts and their attributes is important to make sense of points later on. Products are passed on verbally or through musical actions, and collaborative knowledge building occurs among the participants involved.

Advances in computational natural language processing have been applied to the learning sciences, such as the mapping of words in vector spaces to discover use of concepts through clustering (Gupta & Lehal, 2010). In task-oriented dialogue, a micro-event is a segment of discourse connected to the organization and achievement of the collaborative task-related events. An example is the use of micro-language analysis to predict student progress through collaborative work, and how parts of speech, such as verb markers, can be used to determine planning and resourcing of the task (Thompson et al., 2014). The speaker needs to influence their collaborators or express an imagined event which better matches the desired outcome.

In the current study, cues marked dialogue categories. The beginning of the cycle is marked by high occurrences of all 4 reflexive dialogue categories, a determination which described how the participants developed plans in the early stages (i.e. first 30 minutes) The early stages are marked by a consistent presence of grounding and regulation talk and high occurrences of divergent, generative discussion, combined with relatively low levels of what might be regarded as anti-divergent dialogue, or premature closure of discussion without evaluation (see Table 4).

Each plan may be roughly measured in terms of its complexity, that is, the degree of co-occurrence of plan concepts with other objects or properties over the plan's lifetime. The findings reveal that plan concepts are hierarchically arranged and, through the use of generative dialogue, are populated and made more complex with an aggregation of musical concepts, relating to how a plan may be enacted. This finding supports research in CSCW which indicates that within an

ambiguous problem solving environment it is often a problem that multiple acceptable solutions are considered correct (Kaplan 2001). Interaction within the group allows the pooling of information and the fixing of errors through a process of both aggregation and synergy, critique and checking solutions in quick succession. Section 9.5.4 (Table 7 and Figure 5) illustrates how property concepts are described according to their dominance in the transcript. Most frequently referenced properties such as order (the chronological sequencing of excerpts), tempo (the speed of the music), duration (the length of time to play a section), and quality (a general description of any tonal characteristics) were found to occur in the discourse in a way which mirrored the tonal structure of music. In other words, these properties were concentrated in short lifetimes in the discourse. In a similar fashion this discovery reflects the dispersion of musical object concepts across two categories: short and long lifetimes (Figure 6). This aspect of solution structure is described in more detail in the following section, 10.2.1.

Drums: I don't know where to come in
Rhythm: I don't know, just give us the intro
Bass: Maybe you should try it with some big bar chords
Rhythm: Yeah. But also longer, play it maybe two times through Bass: We also have to figure out the last chord there
Drums: Oh ok. We did the build up when we shouldn't do the build up Rhythm: Well we really didn't do it. Let's go through that build up

Example 18: Negotiating blockages and reformulating plans

The situation demonstrated above in Example 18 resolves only when the individual achieves a sense of comfort or coherence. Here we witness a form of negotiation within the group, and a form of knowledge-based output where the individual has made temporary sense or coherence from a discontinuity of experience (Spink & Cole, 2005). In Example 18 from a Group 2 session, a single player requires group consensus about when to come in, how long to play, and which section of the musical piece the group is in fact working on at the moment. The topic of discussion is about the intro of the song, and how its performance should transpire, creating an overlap in the discussion of song objects and properties in increasing complexity. A plan is developed from the point where the drummer lacks sufficient understanding of the current state. The drummer, inquiring to the group, needs to understand "where to come in" with the rhythm responding to the request with an alternative of playing the intro. The response initiates a suggestion from a third member, as well as the rhythm, to change the way the intro is played: altering its properties through an acts of newly contributed content and divergent dialogue. The

initial inquiry posed by the drummer is resolved somewhat, as he achieves some individual understanding and knowledge about what went wrong. The resolution here is a temporary solution, a momentary "product" of the collaboration which consists of the intro, as well as performance characteristics, including when instruments will begin, and how they should be played (e.g., with big bar chords). As a micro-event of the collaborative work, it illustrates a common pattern of taking a broad topical item and modifying it in necessary detail through dialogue. In sensemaking terms, the individuals become aware of the problem following a process of enacting work activities. The problem occurs when a gap occurs that prevents task completion (Weick, 1995). A plan is initiated through the introduction of missing information about identifying what instruments are being introduced, and how loud and how long they should be played. Feedback is provided when the group actually plays the solution through, essentially enacting the plan that was laid out prior to the emergence of the problem.

Collaborative sensemaking in music creation is evidenced in a strong temporal aspect (Lessaffre et al., 2008). The sense that was made earlier of a particular situation by one member of the group tended to influence the sense made later of the same intuition by others. Although the sensemaking process is the focus, understanding the persistence of the temporary products of sensemaking is important to that process; products are passed on not only across time, but also across group members. Knowing the "path" that a group member had followed to make sense during the emergence of a particular information task helped other group members. This phenomenon of developing *sensemaking pathway* is the steps in the sensemaking process and the 'sense' made at each step (Paul & Reddy, 2010). In the current study, the exception was that they were internal to the immediate group so less effort was expended to communicate the contextual properties of the problem, and the focus was on the solution or resolution. A "pathway," therefore, is seen as any concept whose lifetime spans a salient and traceable process of acceptance, of refinement and of development, and evaluation towards a completed form. Transcripts consistently revealed many instances such as that shown in Example 18 where tentative solutions or "products" of defined musical ideas in fact existed over time Those items which represented solutions existed across its lifetime of relevance to the group discussion. Further movement in the problem space necessitated revisiting these items and re-establishing new plans, properties or performance details. In other words, the prevalence of *checking* and other evaluation-type codes does not eliminate the particular concept from the problem set if it is

mentioned again later in the discourse.

Another pattern were cases where the resolution of plans was interrupted, as shown in Example 19 below, where a breakdown in the information flow is the result of mistranslation of properties from one point in the collaboration to the next. The problem is compounded when properties such as duration, affect and ordering, and multiple musical layers, such as solos and the thematic variations of the problem, are being addressed simultaneously.

> (Band is playing second song from the start after their discussion. Sound is improving and they are continuing through in its entirety, not stopping to discuss at any point) Rhythm: Wait a sec, was that right? (Questioning to everyone)
> Drum: Sounded good to me. (Nodding)
> Bass: Yeah, we (messed up). We were supposed to go to the solo after 4 times, but I like it like that.
> Rhythm: I can never remember if we change it every time. I just want to keep everything the same.
> Bass: Ok, lets try it again and you go right to the solo when I look at you. (Bass nodding to lead player)
>
> **Example 19: Maintaining persistent knowledge of musical layers.**

There is an implicit hierarchal grammar used in the understanding of music, consisting of successive levels of detail and refinement of sonic content. This hierarchy becomes more salient as the group refers to structure continuously as a kind of guiding principle for the organization of discussion content. Studies in the Generative Theory of Tonal Music (Lerdahl & Jackendoff, 1983) describe the mental procedures under which the listener constructs an unconscious understanding of music, and uses these tools to illuminate the structure of individual compositions. In Example 19, the rhythm states the difficulty in transferring between the recurring high-level pattern, to the more low-level tonal characteristics. A plan indicating an agreed-upon song structure and its duration of a section were not adhered to in the trial for one reason or another — seemingly because of a failure to record or memorize details of the temporary solution, and may actually constitute modification that was implicitly accepted by the group at the time. For this member, it is a problem in maintaining the knowledge of multiple layers of the group. However, accidental mistakes can sometimes create more favourable solutions. The bass justifies a new solution when he corrects the mistake with explicit knowledge of what the correct sequence should be, but then offers his approval of how the mistake seemed to sound better. Various reasons within the setting may account for this, such as some alteration

of the musical context that necessitated the change. We see yet again the need for group reference and namable objects and persistent properties, which serve as low-level details of the arrangement. When they are not intuitive to the group, a system representation should make these dominant according to priority in the real time collaborative process. Conversely "accidental" property modifications can benefit the process since they serve to provide candidates for evaluation. To track and facilitate the collaboration, the group should enjoy these options in real-time as well. Sensemaking trajectories highlight the fact that, in collaborative information tasks, both the products and process of sensemaking persist, and remain nameable over time and across multiple participants.

10.2.1 Solution and Plan Structures

This section discusses how specific patterns in language, in the form of numeric reference occurrence and density, mirror the structure of the solution. These are the products of sensemaking and are the ways information is used as the outcome of a sensemaking process. Section 9.5.4 introduces the relationship between lifetime and density of object and property references, and the ordering which is an intrinsic to music itself. Transcripts describing musical objects such as notes, phrases, chords, melodies, verses and so forth, are analyzed. From studies in the psychology of music, musical understanding arises in a top-down fashion, from a hierarchy of successive layers which pertain to the organized structure of the sonic signal (Lerdahl & Jackendoff, 1983). Likewise, the distribution of reference categories is significant in the respect that mirrors this structure. In conversational terms, the references with higher average density correspond to the lower level of this hierarchical structure. This includes object references which are distributed between 60 - 90% density scores, namely *note*, *melody*, *chord*, and *phrase*. Those with a lower average density, that is those references which have high lifetimes and are less concentrated (20 - 40% density) and classified as medium layer objects. This includes *verse*, *chorus*, *intro*, *ending*, etc. The nouns serve as the subject of revision dialogue acts as they evolve, and therefore function as the topic of sensemaking pathways for the group.

Plan structures operate in a similar fashion: work is more concentrated towards the end of the collaboration as details become more pressing. Discussion of high-level structural components are more prominent towards the early stages when they are the topic of generative, divergent

dialogue (see Figure 2, Table 3). In a typical scenario it is safe to conclude that task detail is a highly operative variable in the course of collaborating and the topics of concern in sensemaking. At the same time that more general goals are being both evaluated and collectively critiqued and accepted, the scope of the task is narrowed to resolve details.

Depending on the roles within the group, plans assume varying degree of priority regarding the ability for each member to perform his or her respective activity. Plan reference findings (see Section 9.5.7, Table 9) show there is often not an even distribution of lifetime values for concepts. Instead they are distributed in two categories. The first category comprises long, sparse referents, such as arrangement, excerpt, and version. The second category comprises secondary, short-lived musical plan referents, such as tone, affect, and harmony; these can be thought of as lower-level components of musical structural planning.

10.2.2 Design for Problem Solving: Notations & Information Extraction

My second research question in Section 6.0 reads: *How can the determination of these patterns inform the design of an effective Computer Supported Collaborative Work (CSCW) system?* In this section I address this issue by proposing the first of several design features which capture and facilitate the communication patterns exhibited during creative collaboration.

As they are being developed, segments of an original collaborative product can be described according to their purpose, provisionality and level of confidence, and these arise from the interaction between the resource and its user. What emerged in the qualitative and quantitative investigation is the importance of saliency of lead conversational elements, and the persistence of solutions across time. The lifetime of an information object undergoes periods of modification, as products are passed along verbally or through musical action. In the current study, instances of divergence represented a problem in individual memory, and as a result, difficulty in coordinating the musical activity.

Natural Language Processing (NLP) methods include ways of domain-independent extractive summaries of naturally occurring texts, and consists of selecting important sentences, paragraphs etc. from the original document and concatenating them into shorter form. The importance of sentences is decided based on statistical and linguistic features of sentences (Gupta & Lehal,

2010). Certain text tools such as information extraction (IE), and annotation functionality such as meta- notations (Rahman & Siddiqi, 2011), structure solutions by promoting divergent discussion and work to offload memory. Information Extraction is an NLP-type technology, one which identifies key information from natural language such as the subject of a sentence, and associates it with a set of corresponding properties. Properties may be inherited according to the semantic category of the entity, and thus create rich descriptions of entities by populating relevant fields. A shared representation of the problem is a key issue for identifying problem pathways. When understanding is more reliant on unaided interpretation of working ideas, more effective communicative objects are needed. The use of reusable semantic structures improves the process of orientating awareness of problem components, and enhances communication in some important design processes. In addition to auto-filling entity properties, customizable meta-notations can be used to represent explicitly degrees of provisionality, importance, and precision of what state the solution might be in. Communicating provisionality and confidence through notation or annotation, or both, is an important issue, one which has been explored only to a limited extent in collaborative technology design. For example, in the technical design of knitwear (Eckert & Stacey, 2003), technical sketches fail to convey different degrees of commitment, as well as different degrees of precision. Often certain aspects of the technical sketches are included only to provide a context in which the important elements of the design make sense, yet it is hard to distinguish between an exactly specified part of the design and unimportant details. Nilan extends the spatial metaphors of sensemaking (gaps, bridges) to system design by describing the human-computer setting as oriented around a problem space (1992). The correspondence between the persistence of objects and solution structure is an important property of collaboration and should be reflected in a virtual space. Language exchanged by group members can identify values of concept persistence ranked from metrics derived from the discourse.

NLP technology can facilitate collaboration in scenario-based multi-user virtual environments (MUVE) and has recently been utilized in long-term collaborative design tasks (Thomson, 2014). It allows for the identification of the types of micro-event that learners enact and the determination of whether learners complete the transactional functions crucial to task success (e.g., reporting, determining rules, planning, implementing or resolving). Content items which are persistent and relevant to collaboration should be represented as namable entities, with

dedicated screen area, preserve the presence of information which emphasizes the temporal structure of information seeking and sensemaking.

The increased access to shared content through annotation is postulated to help facilitate the production of divergent input. This shift would mean creating explicit notations for the content of problem space as it develops over the course of interaction. Divergent dialogue is solution generating communication designed to generate insight and manufacture new ideas. Views which support virtual meetings help to create a sense of shared space and support verbal and non-verbal forms of communication, thus allowing a easier creation of different versions and solutions by more than one member (Shah, 2010). At the same time, they serve a valuable function of coordinating the activities of geographically distributed composers.

10.2.3 Summary of Problem Pathways

This section includes a summary of Section 10.2 with a description of sensemaking barriers, the associated cues which indicate the existence of these barriers, and the related design features to support sensemaking.

Table 10: In summary, issues discovered in problem solving during group collaboration translates to a set of observable language cues. Solutions in the form of design features offers affordances specific to each issue.

Issue	Language Cues	Feature Support	Collaborative Affordance
Problem Solving Trajectories Solution Structure	Micro-events Long vs short-lived tasks and objects reflect song structure	Persistent, namable Items Dedicated screen area Meta-notations	Represent problem Space Promote divergent discussion and offload memory

10.3 Awareness and Sensemaking

In my first corollary research question in Section 6.0, I introduced the need for investigating how can we make visible the process of collaboration activities. Klein et al. (2006) proposed that situation awareness can be considered a state-of-knowledge, or mental model representation of the state of the world. Sensemaking is related since it is the means of achieving that outcome. The transition from individual sensemaking to the collaborative level happens because of a set of

triggers (Karunakaran et al., 2013). In sensemaking, this set includes the moment-to-moment situation that occurs during collaboration. Knowledge of the situation involves the awareness of the activities —what are collaborators doing? In a musical context, as in many creative domains, awareness is difficult to measure normatively. I began from assuming situation awareness as the extent to how actions are casually observed without requiring intentional awareness generating actions. This approach is founded in the "spatial model" (Gross, 2013) which considers a computer environment as a space or a set of spaces, through which users can move and interact with other users or with objects. It reflects users' everyday experience in the real world, where proximity and distance influence and constrain the possibilities for interaction with each other and with artefacts. Awareness is the means of supporting ad-hoc as well as planned interaction; the use of body language, orientation and movement, and other social conventions in conversation management.

I draw a distinction between two types of awareness in the current study, both critical to collaborative sensemaking. The first is *affect awareness*, which I define as awareness about the collaborative environment, a reaction which elicits converging subjective experience described in affective terms, and translates it to positive social action. It is distinct from a second type, *activity awareness*, drawn from Activity Theory, and emphasizes the need to maintain awareness about the sequence of actions, directed towards a goal or object (Farooq et al., 2007; Vygotsky, 1978). The current analysis has examined evidence for the correspondence between awareness and language patterns. I looked to interpret patterns of conversations over time and discovered how frequency, concentration, reference types, and conversational cues indicate these two forms of awareness. Concentrations and repetition of topics in the discussion represent breakdowns of awareness, and opportunities for sensemaking. The content of topics, the plans formed by groups, and the use of prosocial communications all reflect the importance of affect in the collaboration and were typically influential in the success of collaborative sensemaking. Properties of an activity and how it is communicated to the group is the action that translates individual knowledge—in the current case a subjective idea or sense and the tools member use, to social knowledge which initiates action.

> Just start playing. I hear something that makes me love it. Sometimes there's those deep ideas that are just a part of you, like a deep secret part. There's something in you that you didn't even know what's there and it comes out automatically. It's not like you can just sit down and plan everything out and say, like ok we're going to write a song

like the Beatles. It doesn't work like that, at least not for me.

Example 20: Interview response about how to begin the group composing process.

This interview response from a group C member describes a typical process of initiating activity: commencing the creative act. As indicated in the qualitative model (Figure 8), despite a strongly subjective and individual orientation of making music, at some point artists require tools to translate ideas outside themselves, beyond the use of music itself, into a comprehensive language no matter how inexact it may be. The participants in the current study required accurate constructions of reality—whether about group membership, group activities, the state of work, current goals, or current priorities—to respond accordingly, through their assessment and evaluation.

10.3.1 Affect Awareness

Dialogue moves that express positive team-directed affect or emotion are intrinsically functional to the task at hand, and demonstrates consulting and valuing the partner's perspective and contribution (e.g., referencing others, acknowledgment, polite markers, encouragement, addressing the group). Planning dialogic acts were supported with concentrated occurrences of a number of prosocial dialogue acts, namely, mutual grounding and cohesive-talk. This situation was true for all three groups. The reasons for this co-occurrence between task-related and social related talk is accounted for in subjective responses from group members. In an interview response, a member from Group B describes the importance of a positive social component and of a familiarity which helps to create mutual amicability within the group.

My friend, who's a great songwriter, will come to me with a folk song where that sounds great when he plays it. I can tell him how I hear it, what vibe I get from it. I doubt I would react the same way if I heard it on the radio or something. He doesn't mind my ideas, and when you go through the process of changing it for a band, it becomes a whole new experience.

Example 21: Positive social emotion and acceptance to divergent ideas.

Here, the member relates the importance of familiarity and trust from previous experience in order to change another member's idea and adapt it to a band scenario. Without the common familiarity and trust, negative reactions can sometimes ensue when a group member feels his or her contributions being marginalized. This finding ran, with some exceptions, in accordance to the postulations computer supported collaborative problem-solving and decision making in group

scenarios (Feinman, 2006).

Musical awareness depends on the participants' real time, and instantaneous knowledge of the topics of deliberation when they are expressed in musical form. Subtle variations of musical properties demand personal effort. Attention must be divided to incorporate the activities of others. As band members worked to advance the state of the composition, cohesive and positive group management dialogue instances were often deemed to be determining factors in the occurrence of breakthroughs. Sometimes just taking time away from a problematic situation and focusing on a past success can aid in moving the collaboration forward.

> When something's not working I stop. What I won't do is play something I know doesn't sound good, just for the sake of putting something down or getting my energy out. If it's not working, you move on and go to something you know. Maybe later when everyone's looser you can pick back up and fix what's not working.

Example 22: Interview response about how to being the group composing process.

Making connections in sense are distinguished from the regular course of collaboration by deducing that a topic of importance in the collaboration—a musical excerpt, an idea, or a plan, would also diminish in density between two points in time once a resolution occurs. When a topic of discussion features less prominently following a period of importance, an agreement about a solution is reached, and the collaboration can move forward. When I looked at concentrations of critique and checking dialogue, I also saw these as clues to specific knowledge gaps which had blocked the interchange.

As addressed previously in 10.2.1, density measures reflect the moment-to-moment importance to the conversation. As part of this finding, both performance directions and plans regarding the affective quality of the composition tend to play a significant role. Considering the totality of references across all groups and sessions, they form the majority of plan references (20.5% of the overall plan references, Table 9), performance references (35% of the overall performance references, Table 6), and enjoy a relatively larger average lifetime (22). In the current study, participants of Group A and B tended not to rely not on verbalizing plans explicitly, but rather on a process of experimentation with sonic output. When compared to others, these groups relied on tactile musical activities, that is sporadic experimentation to play ideas out rather than use verbal discussion, regardless of whether they were used as part of a final product. It is a kind of collective rehearsing where parts are played and replayed with added development. This process

allowed users not only to follow the actions of others, but also to understand and make changes in the working environment. Under the spatial model of awareness which stresses the importance of place, orientation and movement to group learning, we see how instances of musical communication work to perform group knowledge construction. In contrast, the members of Group C reported laying out plans in a verbal manner. This points to the importance of mixed modes of communication, where verbalizing details followed by musical demonstration are used together to create shared knowledge.

> I find that spontaneous jamming is good for a time, to have fun and get some ideas out there. But at some point you need to plan out when everyone comes in as a group and individually so everyone isn't playing all the time and it becomes muddled and just noisy. That's the tricky part: arranging all the different pieces but when it works. Right dynamics, or how busy and loud, or how sparse and quiet and how you move between the two, can take make a good song into a great song.
>
> **Example 23: The importance of planning and arranging rather than pure improvisation**

Maintaining states of positive affect was important throughout the collaboration. At other times, a shift in density of object references was determined, suggesting the presence of reflexive dialogue and affective talk. New topics which caused problematic group understanding, a shift which forced repetitive discussion. Instances of these problems were often alleviated through positive affect. Conversely, the presence of negative affect showed density shift in the opposite direction whereby the collaboration is hindered with the co-occurrence of less positively charged dialogue. Data from conversational trends, (see Figure 2 Section 9.3.1) indicate that divergent conversational patterns, including positive affect dialogic acts, spike at certain points in the collaboration which is common across all three sessions and groups. Sporadic concentrations of dialogic acts invite investigation concerning how the presence of statements, and the affective properties which form the subject, may translate to collaboration success, and whether subsequent statements indicate evidence of positive knowledge construction and learning occurring at these moments. The relatively short lifetime, high density characteristics of affective performance, and affective driven plans (63.3% and 51.3% respectively, Table 6 and Table 9) coupled with high occurrence counts (103 and 62) when averaged across all groups, indicate that this dimension is an ongoing element of concern and relevant for directing the collaboration. Examination of specific instances in the transcript show that even though discussion may be "off topic" with regards to the specific goals of the problem, the presence of affective dialogue

communicates an increase in cohesive awareness and represent completion of "small victories" surrounding the completion of previous tasks. In an excerpt from a Group A transcript (Example 24) we see an incident following a period of collaborative stagnation where a particular reference is repeated both in the verbal dialogue and musical actions of the group as they decide on how to choose a chord to transition between two sections: a verse and a bridge. Positive affect created by cohesive interjection served to motivate members around common goals.

Bass: Yeah that was cool music, and you know... we're going to win!
All: yeah we're going to win (muffled, laughing banter)
Rhythm: That was awesome.
Lead: Yeah
Rhythm: So all the people will be like oh yeah? So if I have to sing a couple of songs it will be just me, I want to tell you guys, but it will be sweet.
Lead: Let's go from the top. I think we agree it sounds all right.

Example 24: Use of positive affect to overcome blockages in collaboration

Rather than revisiting the same problematic topic, the group in this case continued rehearsing the established new content which were collectively agreed upon. The use of group management discourse, such as grounding questioning and cohesive talk—e.g., "that was awesome," "It sounds all right," "we're going to win!" —and similar social management use of language served to create positive encouragement for the group, and was helpful in establishing and justifying the context and priority of plans. However, the relationship between positive affect and the occurrence of breakthroughs is not always a straightforward one.

Olsson, in his study of sensemaking with theatre professionals made note of this complex dynamic between successful work and emotion. He notes that apparently "negative" emotion may play a positive role in a participants' sensemaking, and that "'emotional truth' is both the subject and the generator of discourse" (2010). While the few examples of direct negative affect were clearly not associated with breakthroughs noticed in the groups currently studied, the example below (Example 25) highlights that authenticity, rather that mere positive emotion can also be a fruitful source of sensemaking. It was not surprising that instances of successful sensemaking were marked by periods of higher occurrences of (1) all group management and evaluation categories, in particular planning and regulation talk (see Section 9.3.1, Table 3), (2) divergent dialogue, especially solution generation talk, and (3) a number of prosocial dialogue categories, namely, grounding, affective and cohesive-task talk.

Example 25 shows one of the instances found of successful collaboration at points where the group engaged less frequently in cohesive-playful talk, while reporting using forms of disaffective talk as a way to motivate change or abandon the current solution.

> Drum: I'll just hold the beat like a drum track then you guys can play around Bass: That's not 4/4 time but it's making me excited (Bass tries to count out the time)
> Rhythm: I don't want this Math Punk or whatever that is, too complicated. Drum: Ok then, I'll keep it fun and easy. Just like last time I guess.
> Rhythm: (Takes lead, plays chords to provide emphasis on the beat
> This seems to be a key idea the Lead adds a minor 4-chord that allows the group to continue playing longer. Then they stop.)
> Bass: (enthusiastically) Alright! Sounds' like Para-chill or the Fall!

Example 25: Strategic use and utility of negative affect and disagreement

Although this form of communication represents the minority of management occurrences for every group, it was not necessarily detrimental to constructive progress and motivating members to focus on the task at hand. In the above example, an affective response is often being sought, as musicians propose disjointed ideas which may be quickly discarded and not discussed. A plan is not necessarily forged ahead of time, but is the natural response from an experimentation of tones and techniques that participants use to form what may be described as a jumping off point. In *Music and Imagination,* Michael Copland describes one possible tendency for musicians to "form a desire" through free and unfiltered generation of ideas. The objective of this process seems to be affective in nature, where the musicians try to enter a state of emotion which is effectively manufactured until it "feels correct" (Copland, 1952).

> Bass: Is that cool or is it too nuts?
> Rhythm: (stops after second song is played) We'll try it one more time then we'll lay it to rest.
> Bass: It's like watching two windshield wipers

Example 26 - Trial and error: beginning and experimenting begins the collaboration.

The problem-solving approach to music begins with, and is influenced by, many learned examples, and allusions to outside references, for example to specific bands or songs (e.g., "we sound like Para-chill or the Fall"). Similar instances of using this technique involve the use of allusions and exemplars as a way positive endorsement, when used as the subject of checking-type dialogic acts. Similar cases, which were particularly common in Group B, help to confirm the composition, and functions to refine a target goal that remains relevant throughout the

collaboration scenario. They are made explicit through labeling so that they are referred to at a later time. Pointing to the importance of persistent labels and names over time, plans were often reaffirmed repeatedly to satisfy implicit tasks, and co-occurred with properties of the music, such as the affective quality, the duration, sequencing or tone used in the composition. Such occurrence can be viewed as short, highly-relevant strategies or attempts to resolve a current unknown or ambiguity within the group. Referents for planning excerpts, and versions of the current solution, are identifiable by their relatively higher average lifetime (33.1 and 33.7% lines of text respectively) (see Section 9.5.7- Table 9); co-occurrence and overlap of density and lifetime (see Figure 7) worked together in preventing disruptions in collaboration.

> We're all clear that there's music ... we would never want to listen to. I play music I WANT to listen to. We can all hear what's cool and what's trying too hard, or trying to be too interesting and too original. I just play it out and not think. We're not beginners here, so it's not like we're trying to be something we're not.

Example 27: Developing common grounding and evaluation criteria

The transmission of music served a similar purpose of communicating a group's affective states without detailed forethought. The account describes how music itself is often a highly efficient and effective means of establishing an overall "feel" in the environment, and was marked a grounding communicative act, and a type of performance intention to create music based on a genre. Leman (2008) has referred to this as the connection between musical empathy and sensemaking. A sense emerges that gestures indicate a combination of positive intention to "agree" with various ideas, and are attempts to understand the intention and emotion of the subjective experience of others. Embodied empathy with music draws on shared and distinct representations of perception and action. A key finding is the trend in conversational references to form a separation between concept nouns of high-variance, short-lifetimes versus concept nouns with low variance, high lifetime. With regards to conversational codes, I discovered that *cohesive talk* and *talking off topic* are instrumental in supporting collaboration At the same time, high concentration of these codes may be an indicative language cue used to approve, and to acknowledge socially, recently successful knowledge formation amongst the group. If the spatial model of awareness holds, cues can come in the form of findings that do indicate that expressive behaviour is indeed vital to building mutual grounding for collaborative sensemaking. Conversely, a lack of movement indicated indifference, disinterest and passive disagreement. The use of gestures and the corporeal link to musical activities are discussed further next, in Section

10.3.2.

10.3.2 Activity Awareness

Awareness is an understanding of the activities of others, which provides a context for personal activity. Dissenting opinions form an important role in group decision making (Wiggins, 2007), since they help the group to move away from overly structured behaviour patterns and the collective thinking which might not be most conducive to success. The context of work activities is used to ensure that individual contributions are relevant to the group's activity as a whole, and to evaluate individual actions with respect to group goals and progress (Gross, 2013). Apparent in the current environment of study, collaborative activity is based on the sharing of activities. The high degree of group activity awareness in two ways serves as a catalyst to successful knowledge construction, sensemaking, and coordination rather than blockage. First, high-level awareness of the character of others' actions allows participants to structure their activities and avoid interference. Second, lower-level awareness of the content of others' actions allows fine-grained, synergistic group behaviour.

Monitoring progress of "solutions" was a challenge. From a design analysis perspective, the difficulty is similar to the technical challenge of an intelligent system design which relies on quantifying the dynamic variability in language. A pitfall of design is the temptation to address low-hanging fruit contextual services through computation without first addressing higher priority challenges. The reason for the difficulty is the transitive quality of tentative "solutions," which are defined as the moment-to-moment topic of the collaboration. In a collaborative process of creation, there are non-trivial relationships between topics which form the substance of the solutions. The complexity of activity awareness was the fact that participants often did not have one, but multiple topics to attend to. Demands of group creativity required participants to shift, in real time, focus (attentional resources) between individual awareness (playing of individual instrument), awareness to others' work (stream of sonic output), and awareness of the group as a whole (memory resources about articulated and agreed-upon plans).

Quantitatively, the problem is defined as the as a time-dependent analysis of natural language of conversational segments. The complexity, the demand on attentional resources of the group as a whole, was gauged loosely as the number of distinct topic values (cardinality, i.e. nouns) (Noy &

McGuiness, 2000) associated to a duration of time. It is a value that is potentially cumulative over time. An inexact heuristic is the set of working, active concepts which were always falling in and out of relevance. The problem space includes relationships among an overlapping lifetime of simultaneous concepts. It represents the structure of work, and includes musical objects, performance properties and tasks which form the current state of the shared work. The example Group C excerpt below illustrates the issue of actively attending to concepts. Certain participants had little difficulty in recalling, while others could not manage the series of concurrent running tasks which, because of their complexity, ran the risk of bogging down attentional resources of participants.

> Bass: The first riff, and then we don't do the full chorus - only once through. Then the solo, then we go back to the F like the beginning.
> Rhythm: (playing and repeating a pattern on the guitar. It is falling in and out of time with the drummer who had begun playing)
> Rhythm: I'll think of something. I can't remember what I'm supposed to do. Drum: Sorry I made a mistake. It' 8 on the build right?
> Bass: It's ok
> Drum: You didn't cue us in right. You didn't give us some indication what we're all supposed to.

Example 28: Activity awareness as a function of cardinality

This example provides some hidden yet important clues about activity awareness. One player is struggling to perform an individual part by responding to the sonic output of other members. The bass lists a series of concurrent details that summarize the solution to that point, yet this level of understanding is not shared likely because it was a recently invented solution. Numerous concepts are mentioned: "riff," "chorus," "once through," "the F," etc., all of which are important to play the piece successfully. The remark, "I'll think of something" shows not only the requirements to comprehend the summary given, but also the need to create something suitable, in real-time, to the series of sections which was then the topic of the collaboration. Meanwhile, another player halts the playing from an error of another type. The drum failed to recall the length of section ("8 on build") forcing an apology. This breakdown may have been prevented by offloading memory into some other format, or by resources to aid prioritization, to minimize clashing of multiple, high-effort tasks simultaneously. Scheduling affords developing goals in succession, rather than in parallel. Co-ordination was clearly of value in sensemaking, since processes of coordination (information exchange and ranking) were required to make the environmental conditions conducive to group sensemaking. Participants attempt to negotiate

their own duties in playing while mentally maintaining what had transpired at early points in the collaborative session. Evidence of breakdowns—which are seen as spikes in convergent dialogue patterns (questioning, justifying and critiquing) —also involved points where the working concept set is particularly large.

> Bass: (attempts singing a riff against a beat the drummer is trying) Lead: I'm not hearing that. Did you play that before?
> Bass: Let's do New Metal, this has to be fast
> Rhythm: Is it how I was doing bar chords before? (rhythm guitar tries a set of chords as if trying to come up with a theme)
> Bass: Don't try to do too much, but keep it busy, and swift
> Lead: (Lead enters the playing but the notes he tries inserting does not materialize and the band stops for a moment)
>
> **Example 29: Group A - Spikes in convergent talk mark sensemaking breakdowns**

The episode in Example 29 occurred 20 minutes into group A's second session, during what was the early stages of planning and structuring the piece. The bass's action of proposing an idea vocally starts off the compositional action. His initiative brings the composition on track and leads members to communicate via references to persistent objects and their (sonic) properties and performance qualities. We could describe these as "trying out parts" of the piece. As the bass succeeds in directing group action he now finds himself in a position with potential of controlling and producing music. It is not resolved, however, as the complexity increases as other members try to establish what the bass has proposed. This represents a dense concentration of plan reference type and divergent action.

In an interview response by one of the Group A members, the bass described the process more explicitly, and a distinction is made between a deductive approach which uses a logical approach of composing based on a specific genre or style, and spontaneous action which does not depend on a specific musical structure.

> Sometimes there's disagreement and you can only argue for so long before it's like, "ok this isn't working" Lets go listen to it and figure it out. You hear it. But I think you got to get away from it. When you're playing and then something clicks, even if it's not for long, you remember it. When something's sounds off you hear that too. We always record what we do and then go take breaks, really listen to it, and you hear what's good.
>
> **Example 30: Deduction versus spontaneity in composing.**

In his study of groups engaging in collaborative, creative work, Olsson found that embodiment was a key feature in sensemaking since it helped the participants to understand the problem and

experiment with solutions (2013). The awareness of each member was influenced by more than words, but by gestures as well. Musical gestures and bodily movements of musicians are associated with the act of making music to work as vehicles of meaning. Although the current study deals with a different subject of creation, namely music, the use of gesture was a tool often employed to communicate to fellow members as a way of signaling understanding or agreement. Such bodily communications have significance in the HCI context, since gestures can serve as a form of control to interact with a system (Leman, 2008).

> (Rhythm guitarist moves the most, hopping up and down and kneeling while playing. Bass guitarist kicks the air when they succeed in playing a transition correctly.)
>
> **Example 31: Bodily gestures during performance (from transcript notes)**

Musicological research has often pointed to the importance of corporeal aspect of music, and a tight coupling between perception and action in music (Sloboda & Juslin, 2001). A central idea of this model is that the human body supports action causation and perception from a musical goal to haptic, sonic, and visual energy. This proceeds back and forth via corporeal articulations (Leman, 2008). A range of gestural communication codes noted the importance of "embodying the music," as evidenced by instances of physical movements ranging from head nodding, knee lifts, sitting or standing, jumping, or subtler acts that were meant for the group to comprehend, and thus served to move the collaboration forward.

10.3.3 Design for Awareness: Scripts and Timelines

Awareness is a key concept, one where a tension operates between the user's attendance to the foreground and the background of the activity. Information technology in this view lies in its ability to disrupt or destabilize the regulation of boundaries (Dourish, 2006). Persistence of solutions and related topics of discussion were evidenced to be important to maintaining high activity awareness and successful knowledge construction during collaboration. Users need a way of flagging how the current state of the solution has been evaluated. Through a representation of the "process so far", users can view information in time-dependent transactions by group member (e.g., all actions performed by member X to member Y) or by type of information (e.g., all sections created by member X). A "timeline" is a method of visualizing a single musical piece from the parametric window based feature and typically include Mel-Frequency Cepstral Coefficients (MFCCs), and spectral features from the Short-Time Fourier Transform (STFT) for example. Beat spectrum and spectrograms represent the periodicity and

relative strength of rhythmic structure and can be derived from the similarity matrix (Cooper et al, 2006). Other implementations use colour effectively to represent different parts of the musical texture, or gesture to represent performance data (Isaacson, 2005). Timeline animations are able to show semantic similarities using similar labels, such as the overall song structures and arrangement. The complexity of a formal diagram is based on the complexity of the music and the desired level of granularity. Parallelism in these visual representations can use content extraction with characteristics of dialogue based on reference lifetimes and frequency values to represent their importance within the discussion, and their connection to a spectral segments of solutions. Timelines can also help users to deal with the challenges of role based distribution of information by allowing information to be filtered based on roles (Noroozi et al., 2013). The presentation is therefore all important, if this representation is to translate effectively to an appropriate mental image. In the current context, tools should support persistence of the process and products of sensemaking by visualizing such pathways through timelines which show, chronologically, the evolution of how members make sense. Representations of the collaboration should, therefore, reflect this relevance. Persistent, task-relevant items, are a function of their frequency at various points along the collaboration. Concepts that have been proposed at the beginning of the discussion must be persistent and namable since they are subject to continual revision and subsequent evaluation. Some designs work at embedding various representational structures to facilitate knowledge sharing. These structures can be represented graphically (e.g., digital maps or awareness tools) or textually (e.g., scripts) to guide learners' interactions and to co-construct shared knowledge. I discovered that during efforts to support learning tasks, fellow group members become important learning resources when they contribute unshared prior knowledge to the discussion, which may eventually be shared after collaboration. As with findings for similar learning studies, through interacting with one another in Computer Supported Collaborative Learning (CSCL) and being involved in various social, epistemic, and argumentative activities, learners could co-construct knowledge that can also be applied to solve complex and ill-defined problems (Noroozi, et al. 2013).

Generally speaking, as ideas are generated they go through a lifecycle of refinement and discussion by the group as a way to facilitate their evaluation and inclusion in the finished solution. It is vital to allow users to manipulate these tentative solutions, and make explicit their content details as a way of offloading memory efforts that impeded production in the face-to-face

environment (Cockburn & Jones, 1995). Providing visual representation of prominent discussion topics provides feedback, and makes more explicit the history of the interaction, products beneficial for capturing articulation work employed in a shared workspace. A common work area facilitates group sensemaking through the authorship of common material resources.

10.3.4 Summary of Awareness and Sensemaking

This section includes a summary of Section 10.3 with a description of sensemaking barriers, the associated cues which indicate the existence of these barriers, and the related design features to support sensemaking.

Table 11: Affect and Activity Awareness are impacted by disaffective talk, topic cardinality. Solutions in the form of design features offers affordances specific to each issue.

Sensemaking barrier	Language Cues	Feature Support	Collaborative Affordance
Affect Awareness Activity Awareness	Positive semantic sense correlate to positive collaboration Social knowledge depends on visceral, positional and verbal, communication	Cohesive talk Talking off topic Time-dependent topic cardinality	Visualize Timelines Scripts Exemplars

10.4 Language and Sensemaking

I investigated sensemaking in terms of emergent knowledge gaps, and the efforts of group members to bridge these gaps through their creative efforts. Dervin's view of information is one of subjective construction by human observers, which is modified repeatedly according to the situation, rooting in the constraints of space and time (1999). One goal of the research is to identify how system features can support collaboration, and this involves identifying points where activeness may be modulated across a spectrum, between the absence and necessity of user control. Language and musical activities communicated critical pieces of information between group members, and provided indications of what group members *knew to be true* about their environment. One major challenge in collaborative sensemaking was for the group to

communicate efficiently high priority information relevant to understanding a particular situation or fulfilling a shared need. Ambiguity of information formed challenges because different group members, based on their particular roles and current level of familiarity, might assign different labels to information. As a strategy to overcome inefficiency in communication, bracketing of solutions promoted the reuse of solutions, and made available knowledge constructed at prior points in the collaboration. The creation of new language structures to facilitate sensemaking is indeed a natural outcome of creative collaboration. This section describes a system recommendation which utilizes ontology for reifying the normally invisible structure of the discourse, and therefore provides a ways of structuring the domain and talking about the micro-world of the composition.

10.4.1 Ambiguity

The use of spoken language, creating temporary works in progress, and gestures were all important elements in the repertoire of creators when employed as a means of negotiations, indicating future process, and avoiding conflict. I sought to include how group members understood the goal at hand, or at minimum, the degree to which the group sought to define the ideal outcome of the music at the outset. The investigation addressed how satisfied were groups in keeping the goal ill-defined, and granting this, how were fresh musical ideas evaluated such that the goals were satisfied. This includes not only the final collaborative product, but intermittent contributions of each individual. Knowledge gaps formed around the state of member participation, and state of completion of persistent goals, and were directly affected by ambiguity.

Three forms of language and correspondence ambiguity were discovered:

1. *Ambiguity of output.* Provisionality of temporary works and partial "solutions" were found to be incomplete "works in progress" that participants added to and reused during the collaboration

2. *Ambiguity of language.* Terms were found to be confused when multiple meanings were assigned to words, requiring ad-hoc labelling as part of group communication.

3. *Ambiguity of goals.* Initiating the problem was often a problem in itself. The open-

ended nature of the composition meant that participants had to investigate limitations and possibilities.

Ambiguous information is information that is unclear or that can be interpreted to have multiple meanings (Weick, 1995). It was during instances where the participants interpreted information differently that gave rise to breakdowns, and occasions for sensemaking. Ambiguity in a problem-solving environment can be seen as a beneficial construct, so long as the intent to deal with ambiguous parameters is communicated to the rest of the group. Ambiguous communications provide an opportunity for designers to project and reflect (Eckert & Stacey, 2003). Ambiguity in communication arises, not only from explicit communications, but also from those matters left unsaid. This interpretation is useful in viewing what were breakdowns in sensemaking associated with concentration of deliberation type communications, coupled with lack of assessment and verification. Such moments represent collaboration which is essentially "stuck," without any clear progress in terms of useful decisions to move the collaboration forward.

A trend was detected that reveals that the presence of evaluation (convergent) dialogue corresponds to points where the group contends with disruptions in the clarification of the problem. Section 9.3.1 describes how, on average, convergent dialogic acts are most prevalent midway through the session so that there is a spike in frequency of the conversational codes. Investigation of these segments in the dialogue shows there is a tendency to converse about the concepts which were introduced at prior points in the collaborative session. In all cases, groups reach a point of needing to discuss and filter the existing original concept set. In musical terms, this point may consist of a "seed" or "germinal idea" (Collins & Dunn, 2011), such as for a melody, or a choice of a chord progression that was introduced prior. References to these prominent solutions were frequent (Section 9.5.4 - Table 10) and so necessitated assigning easy-to-remember tags without the use of burdensome, detailed musical descriptions. This process amounted to establishing an ad-hoc labelling system to reference parts of the problem space, and is explained in more empirical detail in Section 10.4.2., Bracketing of Cues.

As divergent production dialogue transpires, it is necessary for the participants to work out a unique set of references to denote both high-level and low-level structural elements of the music. Ambiguity in language creates potential gaps in knowledge, and breakthroughs happen when

ambiguity is resolved. Describing his thoughts on the evolution of the composing task, a member of Group A hints at the need for resolution of competing ideas and clarification of misinformation:

> I was worried at first, how is this going to work. I mean we don't know anything about each other, how we play or anything, but you find your groove quick. I found that at different points there has to be a leader who says, "Ok this is wrong and this is right" and people just take their cue from that. Of course you have to kind of fall into that level of comfort.

Example 32: The need for disambiguation

Occurrences of resolving unclear information through group consensus were instances of "invisible work" (Schmidt & Bannon, 2013) in group collaboration for two reasons. First, participants were required to determine the instances and degrees of ambiguous goals and outcomes, requiring extra communication for consensus. Second, resolving ambiguous terms again instigated new language requirements to form linguistic labels or a "secondary structure" to reference working concepts common within the group. This component of collaboration represents an additional level of activeness required from the participants. Effort which is not necessarily articulated outwardly is reason to explore these processes further, and provides potential points of system intervention.

The vignette from the transcript below illustrates an instance where collaborative sensemaking occurred because of a trigger that invited the need to discuss and resolve ambiguous information. In the following occurrence from Group B, a combination of musical objects was employed in a sequenced fashion: starting and stopping a musical phrase or an using an articulation device against a musical backdrop. However, certain problems arose from confusion around labels. To confirm his understanding, the rhythm player asks for clarification. However, one piece of information, namely the duration of the section, was ambiguous because it did not fit with his understanding of the goal.

> Drum: I think we should do that build up for the second part Rhythm: What do you mean "build up"?
> Drum: Ya, do it 4 times. Do that build up thing. Play B on the 4 Rhythm: But, we've already done that build up twice, right?
> Drum: You should only play that part one time
> Rhythm: I think I get it. Can we try it once just to hear me?

Example 33: Ambiguity blockages give rise to sensemaking

In sensemaking terms, *constructing* refers to what is involved in information sharing and the successive modifications of internal pictures of reality. These loosely-defined strategies are repetitions of ideas used in the past, or sometimes newly-created because of how the individual defines the new situation. The individual will implement his or her pictures using behavioural tactics which are responsive to the individual's ideas of the situation (Savolainen, 2006). Ambiguity of information arose because information was spread out across different participants who might each have a different understanding of the "big picture." To deal with such ambiguity, fragments of information needed to be synthesized across different group members to create a shared understanding of the information available.

10.4.2 Bracketing of Cues

The act of bracketing involved secondary structures: temporary linguistic labels which serve to organize participant behaviour. Research shows that participants in a recurring activity habitually create and participate in conversations which simplify interaction by creating expectations in other participants (Hargreaves et al., 2012; Paul & Reddy, 2010). Faced with a difficult problem, users often attempt to generate this secondary structure in their interaction to address the problem. The improvised language is an ad-hoc naming convention, a form of authorship, and a set of terms to improve group sensemaking in the face of articulation problems.

The process of creating the song demanded that participants continually shift between using broad information about long-term tasks, and more detailed-oriented knowledge. For instance, a participant may require information about the overall structure of the song in terms of constituent parts, to more intricate knowledge of how to execute a melody with another player. Participants were forced to alternate between attending to their own role and the roles of others, while coordinating how other members were interpreting the flow of ideas. The following example from Group B highlights a typical instance of such an interaction:

> Drum: You guys want to do four (bars), and then like four and then I come in on the last one? Rhythm: You can come in, I think
> Bass: Wait! I think you know four (points to lead) and then us.
> Rhythm: I don't want to make it anymore complicated than that. (long silence) you could try your high hat though, what's going on with that?
> Drum: You want to try it? I know this is bugging you.
>
> **Example 34: Relying on cues as communication tools**

Participants seemed to extract familiar structures form ongoing experiences as "cues" and these

cues become seeds from which they developed a sense of what might be occurring. Cues used by the group posed a challenge during data analysis when the same musical concept was referred to in a variety of ways. Once cues are extracted, sensemakers categorize or "bracket", which is to say, temporarily store these cues such that action may be taken. Individual sensemaking was aided by noticing and bracketing of cues from a stream of continual experience in the form of musical, verbal and gestural communication. As time progressed, participants created unique, ad-hoc labels to describe these temporary solutions which were referred to at a later time. I found that prioritization of information during the composing activities was akin to noticing and bracketing of cues during individual sensemaking Each individual group member made relevance judgments on an ongoing basis: deciding which musical ideas were important enough to share, for example, or which mistake was significant enough to attempt to correct. Bracketing of cues was also a social process and it was important for group members to reach agreement on priorities which were shifted and reorganized. Hence, the structure of the conversation was based on information and learning needs, and assembling information available across multiple participants. The distinction between individual and social sensemaking, led to important design implications for sensemaking tasks.

Bass: It's just the wrong part. Sorry.
Drum: Let's try and then get the whole ending.
Bass: The whole last chorus right?
Drum: Yes the chorus and then the stop before the ending. We'll start it from the chorus
Bass: Aren't we starting from the D minor ending on the E chord?
Drum: Ok

Example 35: Breakdown without clearly defined naming convention

Example 35 from Group A above shows a frustrated communication attempt, where a breakdown occurs from a lack of clearly-defined naming convention: the label used, "ending," is confused with the "last chorus" and it is not clear from the language that the two are, in fact, separate. A reference is made to the beginning of the point of departure, "the E part" and one member has confused it with the chorus. Clearly, the repetition of music object labels evident in this interchange indicates a struggle on behalf of some group members to reorient the group around a plan of playing a particular section. In an RSA analysis framework used in the current study these appear as two labels used for the same concept. In system design terms, this is a feature of the dialogue which should be flagged. As the members work to establish common ground, their efforts failed from an inability to communicate complex musical ideas verbally, coupled with the

fact that the state of the composition was dynamic, changing on the fly based on what was most recently played and what instructions were last articulated between group members.

> (As playing occurs, the tempo is not correct, off synch and out of key. They then stop.)
> Rhythm: But, it would be great if we all came in on the B and the F like (sings)
> Bass: Yeah
> Lead: Like what?
> Rhythm: Like (sings, but much more clear and intentional emphasizing an extended bar)
> Bass: Yeah Ok, got ya.

Example 36: Social knowledge creation is dependent on resolution of ambiguity.

In example 36 from Group C, the lack of common language and ambiguity in the terms selected forced the band to rely on their best state of knowledge, however poor it might be, when the moment came to execute the plan and carry forward. In essence, the band was forced to act despite holding only inadequate, fragmented information across group members, with too much time and attention was being drawn to establishing conventions of reference to what were, it would seem, relatively short sections of the music.

10.4.3 Design for Language: Ontology

This section describes a system recommendation which utilizes ontology for reifying the normally invisible structure of the discourse, and therefore provides a way of structuring the domain, and talking about the micro-world of the composition. Socio-technical systems in the case of innovation require many detailed design decisions to be made, with respect to links between constraints on workflows, role authorization, and configurations (Feinman, 2006).

Technologies for distributed environments use the actions of others to be casually observed without requiring explicit or intentional awareness generating actions (Blomberg & Karasti, 2013). To be able to represent and automatically reason about patterns, ontologies are needed. An ontology is a explicit specification of a conceptualization. At the very least, an ontology contains the main concepts and relationships agreed upon by key stakeholders in a particular domain, arranged in a hierarchy. It is quite common for the same representation to present information which can be used in a variety of ways at once, although these alternate uses might be difficult to understand without thorough domain analysis.

Knowledge-based processing techniques and lexical ontology are used for the identification, delimination, and visualization of the interaction of the voices of collaborators and learners

(Ferrara et al., 2006). Two major benefits of ontology design are found in the context of this study. The first benefit is to provide disambiguation to improve communication. In an ontology design, concepts are capable of being combined with other concepts or parts of concepts, which means a fairly flexible knowledge representation system is required. Ontologies, by definition, require consensus on what should be included and how it should be structured, and the identification of the concepts and relations considered as fundamental. For example, in the current context, semantic disambiguation was an issue across all groups. Commonly referenced musical objects are understood conceptually but may be referred to variably: a verse may be called "section," "drop out part," "second part," "REM thing," or any variety of labels which seem to be relevant to the verse at the time. A reference to a desired meter or beat target which is to be played, in addition to pronoun linking, may also take on different names over the course of a collaboration without specific disambiguation by group members; the commonality of references may or may not be understood within the group. The connection between these two concepts: beat and meter, is implicit in their proximity within the language and are inextricable from each other in a structural musical understanding.

The second benefit of ontology design is to model the domain as a way of reifying solutions using an explicit secondary structure. Using concept relationships such as taxonomic inheritance (which describes general to specific), part-whole, synonym, antonym, and others (Trausan-Matu et al., 2007) semantics can be applied to content of collaborative discussion. External language ontologies (WordNet, EDR, etc.) have been used for further "semantic expansion" within domains which have been modelled for reuse (Lambert & Yu, 2010). Once in place, the ontology may serve to control interpretation with the goal of formally defining the practice of the community, and allow for users to create naming conventions and relationships that are applicable to the problem setting (Malone & Crowston, 1994). The fact that an ontology's purpose is to make transparent the conceptual categories and relationships that are deemed important by a community opens them up for negotiations, thus distinguishing them from more obscure representations, such as tags.

This abstraction provides a way to apply metrics derived from referential structure analysis and conversational analysis. The objective is to identify the information pathways within a system and match the reference types to them. Dialogue characteristics such as references to musical

objects, plans, and performance-type concepts are deemed vital aspects of the interaction as seen in their prominence in collaborative discourse and sensemaking tasks. The ontology conveys underlying patterns derived from group members, as they undergo realistic scenarios of the problems and design directions experienced in the collaborative work situation. Since conceptual graphs have a well-established linguistic foundation, they can be automatically translated into controlled-language sentences, creating main stores that community members can validate without having to interpret graphic forms (Ferrara et al., 2006). Content or desired socio-technical designs of particular collaborative communities can be modelled as collaboration patterns, which is the aim here.

10.4.4 Design for Language: Inferred Topics

The ability of the system to shift control between the user and system is an extension of findings that determine moments in the collaboration where participants are impeded by the invisible work of managing ongoing states of the creation. This research works to identify how system features can support collaboration, identifying points where activeness may be modulated on a spectrum both away from and towards user control. In one sense, a continuous level of system monitoring is required to keep track of the communication state in a distributed collaborative environment. In another sense, a system should be responsive to identify moments where summarization and disambiguation can serve as collaborative aids, and require a shift in activeness towards the system side.

The creation of new language structures to facilitate sensemaking is indeed a natural outcome of creative collaboration. Dervin's view of information is one of subjective construction by human observers, which is modified repeatedly according to the situation (1999). However, the added work required to first identify ambiguity and manage new structures can impede the collaboration, and indicates a point of intervention, and increased system activeness. This aspect is a stark example of invisible work which extends beyond the current context of music creation, and into domains where factoring and managing resources is critical. A successful system design therefore depends on accounting for this effort. As an example, examining the content of discourse reveals that high concentrations of deliberation as a potential cue, and system control should shift. Inputs such as people, tasks, and technology have a dual impact on group effectiveness, and to focus on the system as a way to advance understanding is

counterproductive—the user should take precedence (Dalrymple, 2001). Technology can influence outcomes directly, by changing the ways that group members interact with each other. For example, groups are generally better able to complete a well-defined task, because it is easier for them to figure out and evaluate solutions based on strict criteria (Avouris et al., 2003).

In the computer supported collaborative work (CSCW) domain, researchers have developed technologies to reduce interruption among team members which may impede effective traversal through the problem space. Identifying intense collaboration zones works by extrapolating the concepts of personal and social knowledge-building to a finer grained dimension of individual utterances. Cohesion is the bridge between utterances, enabling information transfer and cumulative knowledge-building from personal and social perspectives (Trausan-Matu et al., 2012). Techniques like scheduling conventions, which distinguish between quiet times when communication is discouraged, and interaction times, when communication within the group is permitted (Pickens et al., 2008), is a cohesion-building process. A collaborative scenario contains verbal communication in the form of either text or speech, and holds clues to topics of interest, extracted from the discourse in the form of concentration metrics. Language processing on the snapshots from the content feeds—including summarization techniques, hypernym augmentation, or generalizing words into more generic terms, and classification based on machine learning (Uthus, 2013)—may take into account such referential dimensions as lifetime, frequency and density, listed in increasing order of importance. Such processing is useful to identify concepts of value to the collaborative session. Concepts from content feeds may be assigned importance based on the computed. Technologies for theme identification and text mining architectures (Semeraro et al., 2009) operate as a "sniffer," examining messages sent between participants in the chat. It is responsible for identifying them against terms present in a domain ontology.

In the current case, the study applied manual methods to determine topics which were persistent and instrumental to the collaborative performance at various points. Automated methods may mimic this process through subject/topic detection, term weighting, and features describing broad and narrow segments of the collaboration. These techniques are akin to the indexing, summarization, and similarity algorithms which are applied to static documents (Trausan-Matu et al., 2012). Similarly, relationships between text and concept utilize similarity function based on existing semantic hierarchies, such as WordNet, and unsupervised clustering based on feature,

Rocchio's and Bayes's scores, prototype-like vectors to represent texts and concepts (Lew, 2006). In the current design, the dynamic characteristic of group discourse introduces a variability of topics and hence topical priority in reference to their relevance to the group's goals. Modifications to automation may therefore depend on training classifiers within time specific segments. This particular form of discourse-based automation utilizes the concept of "segment vectors," which includes variation of term-based classification with an additional feature to describe the chronology of the context. Hence, data structures represent a time frame of the discourse. The benefits of this model is that, given a training set of discourse data, including features described RSA features, multi-label classifiers may predict topics and critical points in the collaboration. This output allows users to adjust the work accordingly.

10.4.5 Summary of Language and Sensemaking

This section includes a summary of Section 10.4 with a description of sensemaking barriers, the associated cues which indicate the existence of these barriers, and the related design features to support sensemaking.

Table 12: In summary, ambiguity and bracketing were language issues discovered in problem solving during group collaboration which map to a set of observable cues. Solutions are achieved with ontology, NLP and knowledge networks.

Sensemaking Barriers		Language Cues	Design Feature	Collaborative Affordance
Ambiguity	Work to resolve references	Non-normalized Self-labelling	Ontology knowledge net	Disambiguation of natural language
Bracketing	Maintaining beneficial "chunks" of collaboration	Persistence of unique Items	Inferred topics with NLP	Reifying a community's perceptions of a piece of work Capturing solution context rationale

10.5 Collaborative Learning and Sensemaking

The first corollary question proposed in Section 6.0 is the following: *How can we make visible the process of collaboration activities to facilitate learning, and to track ownership of media items through metadata?* This current section looks at the phenomenon of learning processes which take place, both in the individual and between peers. From this, technology features are discussed which aim to support key aspects of learning that is so integral in the collaborative creation of music.

Studies of information seeking and sensemaking have found that group members' roles are important for how information is found and shared in creative problem solving (Campbell, 1995). At various times, members displayed differing levels of expertise to help the collaboration progress. The definition of "domain experts" can be regarded as those who have specialized domain knowledge, and can help those lacking expertise in that particular setting (Pickens et al., 2008; Prigoda & McKenzie, 2007). In a study assessing learning outcomes of school pupils, Rosen (2014) identified key tools to gauge computer-supported collaborative learning (CSCL) outcomes, and the relation to collaborative problem-solving abilities, namely outcomes of establishing and maintaining shared understanding, of taking appropriate action, and of establishing team organization. Findings in the current study, point to how collaborative work and problem solving depend on team organization based on well established task roles. Group members coordinated work, developed and designated tasks, assumed individual initiative and navigated the problem space.

The current study has added to everyday information behaviour findings which shows how experts prevail: experienced members of the group served as valuable information sources for those with less experience (Kostagiolas et al., 2015). They encouraged group management conversations by including subjects of their own: friends, books, films, current events, community information. In the musical context, role names can fluctuate, being either based on the instrument (guitar, drums, bass, rhythm) or on the implied structural hierarchy of the music itself (lead, groove, rhythm, background), with each member focusing on needs in relation to performing a particular song segment. Hence, each member had a different understanding of the situation, or current plan, at any given point. This layering of knowledge complicated the situation since in addition to concurrent, relevant plans, different levels of internal

representations of those plans exist. Experiential differences and background knowledge therefore necessitate an uneven demand on resource requirements within the group. I translated these particular knowledge gaps to a lack of expertise.

Together with fragmentation, and lack of immediately accessible resources, the lack of expertise has been found to be an important trigger for collaboration during information-seeking and sensemaking activities (Karunakaran et al., 2013; Paul & Reddy, 2010). While role-based information led to lack of adequate information being available, sometimes adequate information was, in fact, accessible, but also hard to understand because of the lack of a particular skill set. Such instances triggered a common response of instruction between members. This instruction took the form of critiquing and group management dialogue. A member might not understand what the others were asking, or comprehend the requirements but not be able to technically execute the required music. At this point effective collaborative cooperation was required through functional dialogue. Someone would need to either volunteer time to help the others understand the problem in more detail, or more rarely, the group was willing to change their ideas because of the difficulty in actually playing it. Thus, the group could make transitions between stages of the collaboration without mismanagement. Example 37 below illustrates how even role-based distribution of information led to an occasion for collaborative sensemaking.

> Rhythm: We do a stop right? And then we all riff back together. And then we all riff with you and then go to the ending.
> Lead: Oh no I can’t. I don't know that one.
> Drum: Me neither
> Bass: It’s because you didn't cue us in right, you didn't give us some indication that we're all supposed to end.

Example 37: Assumed leadership

This short excerpt shows where the members are willing to take direction from a member (rhythm player) assuming a temporary role in the group as an unofficial leader. In this case, a blockage occurs as a result of not being able to continue without instruction from a particular team member, who was not apparently aware of his or her instructional duty. Instances of peer instruction were often associated to performance reference types, where conversation consisted of grounding type dialogue between two members. Power relations and their connections to knowledge were identified by noticing how blockages were overcome through dialogue and its use in transferring performance knowledge. These issues were decisive for the speed of composition, since collaboration came to a halt from lack of performance knowledge, and also

inability to recall prior plans. The next episode, Example 38, demonstrates again how knowledge roles influence compositional processes. In this particular episode are illustrations of a number of the phenomena presented: compositional and personal actions, leadership, and peer teaching, all of which depend on responsibilities.

> Rhythm: can you play something less frantic? (Everyone is playing a little bit now. Drum responds and plays the "big E song" rhythm. Lead has turned away from the rest of the group, seemingly uninterested in what is going on.)
> Bass: I think you can go like this. (He vocalizes the rhythm three times) and not very hard.
> Drum: With the floor tom?
> Bass: You have to play it in twos. (Drum plays)
> Rhythm: That's it, a little softer. You have to stop complaining (Lead turns towards the group)
> Bass: Complaining? (questioningly).
> Rhythm: Come on, play it Drums: ...two times?
> Lead: Yeeees! (shouts, he has been watching with increasing impatience) Rhythm: Let's try everything again. Never mind him.

Example 38: Assumed leadership

In the episode in Example 38 from Group C, it is evident that the rhythm is trying to exert leadership. He acts according to a plan: playing something less frantic. The others accept and support the rhythm's leadership, even though the bass seems a little confused and uncomfortable as he is restricted between the power exchanges. The situation turns negative, and frustrating for the lead player who shouts in frustration. It is simple to point to bass as the "villain" here as he appears to interfere with directed learning. But then again, to this point, he has taken the lead as the expert in the composition, given that he had been directing the group and creating the prominent solutions to this point in the session. The power aspect of this act of producing knowledge, i.e., making progress in the creation of a piece of music, is evident in the relationship between the drum and the drum and rhythm. To a large extent, it is the dynamics of the relationship between group members which defines what happens and what does not happen. The power relation between the lead and rhythm in this episode prevents efficient peer teaching from taking place with regards to playing. As seen in early sections, peer teaching can be observed recurrently in compositional processes. But it is a delicate thing, in the sense that personal actions and power issues can prevent it from happening.

Work groups that are functionally diverse have a large stock of ideas to draw upon and they have differences in assumptions that allow them to generate more creative solutions. A

disadvantage to this approach is that it is difficult for individuals of divergent groups to share a common enough language to communicate different values and beliefs about what is important (Paul & Reddy, 2010). On average, groups do better than their individual members on many tasks. But the extent to which they exceed the capabilities of individuals, and the processes by which they achieve this success, depend upon the characteristics of the task. Concentrations of solution generation dialogic acts can uncover tasks facing the group. Successful sensemaking is demonstrated through highly proportionate occurrences of the mutual grounding type acts such as questioning and responding. This dialogic feature points to healthy levels of reciprocity during instances of successful sensemaking—standing in sharp contrast to unsuccessful instances. In the latter case, these cases were marked by lower occurrences of questioning talk (i.e., approximately half), the implication here being that unsuccessful sensemaking between group members was because of nonreciprocal interactions throughout the process.
Researchers developing collaborative learning tools have emphasized that there can be several kinds of roles in collaborative learning tasks (Paul & Reddy, 2010). In LIS, the concept of learning is situated around the acquisition of knowledge, ways of organizing and storing knowledge—and helping others learn from knowledge. Resolving information needs in a sensemaking problem involves building a bridge through probing and testing information as possible solutions (Dervin, 1999). The process of encoding retrieved information to answer task-specific questions, forms a learning loop complex: a multistage process in which the user can gather found information and encode it to a representation or frames (Weinberger et al., 2013). One or two group members were often tasked with routinely reminding the rest of the group about decisions regarding these properties, which were apt to become lost within sideline discussions.

> Lead: “Ok, let us try the beginning again, I start” (two guitarists watch carefully what happens)
> (Drums have started to play the rhythm softly while lead is playing. He plays slightly louder when the bass comes in, and now it seems to work, but the lead raises his hand to signal he should stop or wait.)

Example 39: Top-down task delegation

Peer teaching occurs in this excerpt from Group A. The drum senses the lead needs support with the rhythm and acts accordingly without using any verbal instruction, just supporting of the lead’s melody. The rhythm does not yet understand what contribution is required, and his way of

evaluating the situation likely has to do with whose turn it is to play, rather than what is needed to help. Lead then acts skillfully in the sense he has a degree of authority over the work and social competence to reject the rhythm's reaction as misguided. It is interesting to notice that this communication process happens mainly through musical and kinetic dialogue rather than verbal discourse and interaction.

10.5.1 Design for Learning: Frame-based Communication

The third corollary question posed in section 6 reads*: How can we make the products of collaboration reusable for collaborators*? Here in section 10.5.1 I discuss how design features can mirror the way knowledge frames are constructed and reshaped during collaboration. Sensemaking stresses that representations are important for integrating new incoming information into existing categories in a top-down process. Conversely new data can work to expand knowledge frames in a bottom-up, data-driven process. From the data/frame notion of collaborative sensemaking which I use in my analysis, describes the primary function of frames is recognition, to guide attention to fill in missing parts of the frame, to test a frame by searching for diagnostic information.

In studies in collaborative information seeking and collaborative learning systems where the users' information needs may be adjusted based on the group to which he or she belongs (Erkens et al., 2005). In the data/frame theory, frames are things that you think with but also things you think about (Pirolli & Russell, 2011). A goal of the collaboration tool is to examine discourse, and this aspect of the tool has broader application in learning environments. As described in Section 10.2.2, extraction of key dialogue features is an advantage of NLP tools to achieve this goal, and to implement services that aid the group processes. Technology can play a variety of roles in collaboration and learning, by chunking useful portions of the collaboration, providing a visual representation of the task or the product on which the participants are working. Making these salient to the group, i.e., improving awareness, increases participation in an argumentative discourse; to make defensible claims and to test the claims of others, provoke mental activities social interactions (Dillenbourg & Traum, 2006; Fischer, 2011; Goodyear et al., 2014). Discourse structuring technologies, such as frame-based communication, take as their point of departure the fact that the collective interoperation of an artefact or idea is invariably accomplished through discourse, or the exchange and conversation around a subject (Feinman, 2006). The belief is that

discourse as the basis for computational support is intuitive to end users in two respects: as the means of data capture, and in subsequent reuse of solutions, given predictable problems.

Qualitative findings regarding leadership and learning have important implications for the design of collaborative information retrieval tools for supporting collaborative sensemaking. Information must be distributed based on roles. The learning process is an intrinsic part of the collaboration, since feedback from others and musical refinement occurs continually following its assessment against prototypes. Studies about the connection between learning and sensemaking have proposed methods to understand the degree that individuals retain and form new knowledge (Copland, 1952). Wilson & Wilson (2013) analyzed the degree of learning through simple fact and statement counting, and breadth and depth of topic coverage comparing low and high prior knowledge. Likewise, the current study relied on summarizing verbal cues to identify concepts that form the description of knowledge gaps and targets how group members work to resolve them.

Sensemaking structures which simplify the coordination of a conventional behaviour can be codified into artifacts, whether conversional, procedural, or instantiated as physical objects (Shum & Selvig, 2000). There is evidence that a discourse structuring scheme can work to reduce the complexity to help participants to tackle an ill-structured problem systematically. As framing the problem is witnessed to be important to prioritization and group learning, processes should allow interaction to make this activity explicit through the use of communication-based frames. Coordinating artefacts presents a way for participants to organize their behaviour, by expectations of roles and actions, through partially structuring actions. Effort required to perform a collaborative task is reduced by the introduction of conventions for conversation, teaching, and action. Using a system analog of the sensemaking space allows any representation of these literal elements which form the components of the problem.

An example of frame-structure is itinerary data that represents content of the dialogue as an external record offloaded onto the system (Klügel et al., 2011). Free-form text columns correspond to reference type. For example, a *task* field can organize task referents; the *properties* column gives users a place to put instance information, separated out to encourage users to enter information in a structured fashion, or to be populated automatically from

communicated dialogue. Structuring dialogue based on present participants and directed communication can be made explicit through a structured interface widget (Trausan-Matu et al., 2007). The role of external artifacts in coordination interaction is to simplify the team work of participants, rather than to directly affect the task (Feinman, 2006). Coordinative structures such as these function as community-specific solutions to recurring problems in coordination of talk or action, for example who is permitted to speak next, what to do when welcoming a new participant, a person, or other common situations (Malone & Crowston, 1994). This situation creates expectations in the participants of a joint activity but does not determine the activity completely. By organizing task behaviour and providing expectations about the behaviour of others, conventions can form a strong basis for establishing common ground and reduce the articulation work necessary to perform a tasks.

Another frame application is situation-oriented/prototype frames (Weinberger et al., 2013). Similar to using exemplars as way of invoking emotion, musicians referenced terms such as familiar bands, or other allusions, to communicate goals and increase affect awareness. For instance, when they referenced tonal properties “Joy Division all the way” (Example 2) they were identifying a prototype of equivalence, and connecting it with prior knowledge. Situating-oriented frames are designed to help to understand information both during routine and problematic situations—though it was those “problematic situations” which gave rise to sensemaking. The persistence of provisional/temporary solutions over time could serve as templates for reuse, which rely on bracketing to denote key pieces of group dialogue. Each group demonstrated a behavioural pattern of repeating predictable problem-solving strategies arising from routine situations, for instance, deciding on certain repeatable elements song structure, a progression of chords, or a melodic line. In the same way, communicating suggestions often involved invoking terms or labelling used in previous points in the collaboration. Whether a piece of information was relevant and hence important enough to share was often a crucial decision made by each member. For this reason, an important aspect of collaborative sensemaking was the prioritizing of certain shared pieces of information as relevant. However, it was often challenging to judge what those pieces were.

10.5.2 Design for Learning: User Profiles

As outlined by this investigation of CSCW, one key component of the awareness dimension described in Section 10.3 is the knowledge participants have of members, as well as key abilities and properties that serve important functions in their participation. As Koh (2013) asserts in her conclusions of studying youth information creation behaviour, information professionals should meet youths' needs by providing education to create reliable information, to build upon others' work creatively but legally, and to help others to disseminate their own creations through an appropriate path.

Users' expertise, appropriate roles, and experience can be answered through public musical profiles stored within the system and made available to co-collaborators. This user data, in the form of hierarchical data of expertise, background, interests, behaviour, provides explicit information for each user, and tracked in order to associate ownership of particular media with a user (i.e., improve data provenance) (Li et al, 2011). Also, it allows data of past conversations and contributions to be captured, and improves informational awareness from other participants (Paul & Reddy, 2010). When members of a learning group are not fully aware of other members' expertise, they may exhibit a lack of trust, for example, by ignoring or disregarding information submitted by their learning partners. Portfolios can be used to represent one's own and learning partners' expertise in the encoding process, coupled with interaction between group members. In turn, sharing one's own knowledge and externalizing others' knowledge allows group members to judge and evaluate the trustworthiness, accuracy, and credibility of their learning partners' knowledge (Noroozi et al., 2013). Collaborative music software design, as with environments used for any joint authorship of creative works, should strive to negotiate the existence of privacy boundaries as well, and reflect privacy requirements as communication within the group.

10.5.3 Summary of Learning & Sensemaking

This section includes a summary of Section 10.5 with a description of sensemaking barriers, the associated cues which indicate the existence of these barriers, and the related design features to support sensemaking.

Table 13: In summary, learning and sensemaking can be improved with features to support the use of secondary language structures through frame based communication and user profiles. In addition to improving awareness, these features organize solutions.

Sensemaking Barrier	Language Cues	Feature Support	Collaborative Affordance
Roles assume expertise Learning key to collaboration	Secondary language structures Cohesive talk: grounding and checking	Frame based communication User Profiles	Reuse of solutions given predictable problems Make expertise of other collaborators explicit

10.6 Discussion Summary

This study offers important contributions to the conceptual understating of collaborative sensemaking by providing insight into the occasions and characteristics of collaborative sensemaking. In summary:

1. Creative work can be understood in terms of ill-defined problem-solving. It follows predictable pathways where the persistence of namable objects is key for collaborative sensemaking. Capturing dialogic data based on what concepts are most pertinent for the user could help to focus on production and generation of ideas, rather than group management goals.

2. Meta-notations should be robust enough to capture discussions for subsequent reuse, yet plastic enough to allow negotiation over the meaning of ambiguous or controversial elements (Buckingham, 2001).

3. Awareness both of affective understanding and ongoing activities should be accurate and prompt for collaboration to run smoothly

4. Ambiguity of information, marked by ambiguous labelling of solution instances taxes users. One reference type takes on a series of different labels, and misunderstanding of short-term plans create knowledge gaps which trigger searching for appropriate knowledge representations.

5. Resolving ambiguity can be accomplished by integrating domain ontology in the system. Chat sniffers and other language tools can model the domain, and automation offloads the work that impedes collaboration

6. Secondary language structures and bracketing are formulations which achieve collaborative breakthroughs, and serve as knowledge representations to make prior solutions reusable.

7. Uneven distribution of expertise leads to certain members contributing more than other members do. This means collaborative systems should support communication structures which facilitate peer-learning.

8. Information distribution and awareness, in particular, knowledge of peer expertise and collaboration roles can be very helpful to group collaboration. Users of collaborative technology should be allowed access to this through user profiles to store prior work and publish annotations on created resources.

Chapter 11

11 Conclusion

This thesis examined collaborative sensemaking as part of collaborative activities. As articulated in my original research questions, the goals were to provide a conceptual understanding of sensemaking, and inform insights about design features that can support sensemaking in CSCW systems. Sensemaking has been a useful model for understanding information behaviour in a variety of domains, including the creation of music. The study of non-work collaborative information behaviour is a relevant area of study, from the point of view of designing systems for supporting collaboration and communication across virtual spaces. Appropriation and control schemes for the authorship of shared artefacts, and the compositionality of objects in collaboration allow group members to organize a common document corpus. The current study addressed the lack of a general understanding of how leisure activities, reside along the continuum of user control versus system control.

Three innovative outcomes were achieved from this research. First, it was theorized that in addition to general models of collaboration, this study could expand the state of knowledge by relating how language patterns provide insights into sensemaking, and function in the co-construction of knowledge. Second, quantitative models which target language using dialogue features could further refine the exploration of music making. This study bridged patterns of language usage with the products of sensemaking by focusing on a niche, non-work environment and user type. Third, given the inherent problems with indexing and searching for music content online, the thesis followed the recommendations of existing research, which has forwarded the idea of intervening at the creation stage as way to harness useful metadata. The detailed use of conversation data was found to provide solutions to that problem, giving fine-grained description of musical data itself, and the functional contributions of the creators at various points in the development of collaborative products.

Sensemaking difficulties and breakdowns in face-to-face collaborative work are indeed manifest when considering the demonstrable patterns of communication, and the propensity to adopt predictable cycles of generating and deliberating about solutions. Identification of important factors in this process: problem-solving, awareness, language and learning were findings used to

propose system designs. These design features aimed to integrate existing insights and technologies from the HCI domain, and employ them to address the problems gleaned from the empirical data. User-oriented design was a priority in the experimental design, which included examining the users' natural behaviours in an environment unencumbered and unmediated by technology. The results of the study make important contributions to the theoretical and technical understanding of collaborative sensemaking. This section lists these contributions and discusses ideas for future work.

11.1 Contributions

The first question I set out to answer in my thesis was the following:

1. *What are the communication patterns of collaborators and how do these patterns affect sensemaking of musicians in the act of creating music?*

People collaborate to find, retrieve, and share information to fulfill a shared information need. Understanding the information found can be a challenge for collaborators due to various reasons. My study of the non-work practices of experienced musicians in a informal composing environment found that ambiguity of information, role-based distribution of information, and lack of expertise influenced the ability of users to collaborate. Ambiguous information is information that is unclear both in terms of specific word sense, but also in terms of the goals, evaluation criteria, and anticipated outcomes of an ill-structured problem.

Three important characteristics of collaborative sensemaking emerged from my study, specifically concerning the prioritization of relevant information, following problem-solving pathways, and relying on activity and affect awareness. First, an important aspect of group sensemaking is prioritizing of incoming information was way of reshaping representations and useful for organizing new data. Difficulties arose in collaborative activities because different group members have access to different pieces of information, and might understand the information differently based on their roles and expertise. Information is uncovered in the course of generation, evaluation, and revision, and being able to assign priorities to information pieces according to the changing context of the problem is challenging. Second, problem-solving pathways emphasize the temporal nature of collaborative sensemaking. The products of group collaboration are passed on across time and individuals need to be exposed to the methods and

products of others' work to traverse this space successfully. Finally, making sense of the connections between the actions of various group members with respect to long-term activities is important for sensemaking outcomes.

The second question posed at the outset was,

2. *How can the determination of these patterns inform the design of an effective Computer Supported Collaborative Work (CSCW) system?*

I hypothesize that various views of information presented to users in the course of using information tools can provide support for sensemaking during different parts of a collaborative task. Problem-solving pathways can be supported by making temporary solutions persistent and visible in the form of timelines and features from chat discussions. Ambiguous information that transpires during group interaction can also impede problem solving. This problem necessitates the need for natural language processing techniques to summarize discussion segments, disambiguate terms, and help define and describe the domain. Prioritization of information can be supported by allowing users to comment on, organize and annotate segments of the collaboration. Furthermore, tracking and storing user contributions via profiling is a useful solution, since it makes details about the users, level of expertise, interest and specialties available to peers who wish to collaborate. However, preserving security privacy are two critical considerations that should always be addressed in any information system which seeks to regulate how personal data is gathered and disseminated between users. There is a considerable tradeoff and many inherent risks involved in using such profiling data, and design solutions should always be made with the users' best interests and safety in mind.

This research contributes to three academic research communities: computer-supported collaborative work (CSCW), musical instruction and learning, and information sciences. The CSCW community has been concerned with understanding and supporting people's collaborative activities in both professional and personal domains. This research extends the current understanding of sensemaking in collaborative activities by highlighting its social and interactional aspects. However, these results need not be tied to only one domain. Indeed, open-ended, creative problem solving is a factor in many creative fields and areas of learning. Sensemaking has been an implicit aspect of information seeking studies for many years;

however, few studies have explicitly examined the interactions of musical creators in order to extend these findings to other non-work domains. I chose combined methods: referential structure analysis and conversation analysis, both of which have proven to be successful tools to aid in the design of groupware. In the present case, they were useful in assessing patterns of information behaviour in a direct way, and may be useful in subsequent design studies.

I also presented a conceptual framework for collaborative sensemaking that focuses on the occasions and characteristics of collaborative work as part of a cyclical process loop, where maintaining states of temporal solutions is integral. The study extends important CSCW concepts like problem-solving pathways and awareness by focusing on the role these play in sensemaking. This thesis moves forward the research in a broad range of domains by emphasizing design features that can be used to support sensemaking in collaborative information retrieval tools. It also brings to light the design challenges that developers face when supporting sensemaking-enhancing features in such tools.

Finally, this research makes an important contribution to the information sciences community. Understanding information behaviour has been a long-running theme in the LIS field. Music as a form of non-text information, imparts challenges regarding how to describe its many semantic and content-based features. As part of MIB and other forms of life information studies, this work reinforces the idea of intervening at the creation stage as a way to provide detailed, rich descriptions of content, thus making it traceable and searchable in a digital environment.

11.2 Study Limitations & Future Work

Throughout the description of my Research Methods (Chapter 7) and Data Analysis (Chapter 8), I noted several key decisions which necessarily limited the work in several respects. These decisions made the work partial in the sense that they restricted the scope of the study to the content of the data being analyzed, the type of variables introduced in the task and environment, and the target population of the study. These limitations are reviewed here.

First, there was the decision of made to study amateur rock bands, rather than more professional groups of musicians. This choice of course restricts the outcomes in various ways. The genre of music, rock, tends to undergo a compositional process which is distinct from other forms, such as ethnic folk music, jazz music, or classical. At the same time, it is a genre which tends to

welcome collaboration. Although the findings described here may not be generalizable across musical forms, they do present ways of considering collaboration of other creative acts not necessarily music related. The convenience and opportunity of examining amateur rock musicians has produced rich outcomes for further exploration into the phenomenon.

Next, there were limitations regarding the type of communication being analyzed. Again the decision to limit the research to studying verbal natural language over other modalities, such as gestures or musical output, meant that important factors were excluded in place of those more easily traceable. Since the focus of the study was on language specifically, language-based technologies, and the relationship to sensemaking routines meant that other communication forms were set aside for the time being. However, in subsequent research more focus may be placed on analyzing those communications which did hint at being significant factors in collaborative work. These include gestures and non-verbal communication such as music that seemed to indicate ways that participants could establish common ground and translate complex ideas efficiently to one another.

As mentioned in Section 8.5, a shortcoming of the current study was that I was not able to perform inter-coder reliability and thus had no way of confirming that the instances of RSA reference and conversation codes I identified would be the same as those noticed by other coders. This shortcoming could be alleviated through coding a small subsection of the transcript, rather than the entire data, to achieve an satisfactory inter-coder agreement rate between multiple coders. I did perform the coding process to a point of saturation on the data, meaning no new categories, references or examples emerged from the raw data.

Follow up research will involve implementation of the system. Certain areas of difficulty, addressed in the data analysis require modification in a practical application. The problems inherent in processing natural language is the first of these issues. My approach of manually examining conversational data provided the human reasoning that is not fully replicable in automated tools. The goal of automation is a system able to identify and classify parts of the discourse according to their concept category, property and type.

Conclusions about information complexity and simultaneity were difficult to demonstrate quantitatively. The co-occurrence of relevant topics in the participants' discussion could not

easily be ascertained from the clustering charts or by metrics, but only by attending to chunks of the collaboration as a whole. This was an important finding, addressed in Section 10.3.2 as "cardinality", which is the existence of concurrent, relevant discussion topics in a particular time segment. More sophisticated automated language processing techniques could address this is in future system development, which could aim to map overlapping lifetimes, taking into account a representation of the entire chat content. Analysis of overlapping features, for example, through cluster analysis of RSA references that share common lifetime and density ratios, make it possible to draw conclusions about the commonalities of language features. Ratio values seemed to loosely correspond to the structural hierarchy inherent in the products of collaboration. The method may generalize to other domains as well, so that summarization of natural language in a collaborative chat can be used to draw conclusions about the content of work and which concept groups were assigned to the content of the solution, and at which times. Highly concentrated, but briefly relevant (high lifetime to density ratio) form clusters, and inspection of these data reveal other semantic commonalities as they pertain to domains outside of music. Making these groupings salient in use-case scenarios is important as a real-time feedback output stream for collaborators, as they seek to understand the legacy verbal problem solving process and its role in generating solutions.

At a higher level of abstraction, I was also able to identify conversational types such as elaboration, evaluation, and deliberation. Automating the categorization of conversation types in an actual implementation would require the assistance of sophisticated language tools, scaled back to a certain degree to allow for a basic prototype system to be developed. Another major area not addressed in the current research is that of user evaluation. The system proposal is based on a single-pass assessment of user needs. What remains is feedback from the target users to determine both the level of acceptance of the system, and how best to improve the design. The task of coordinating user input in the form of both talk and musical communication in a single system, while at the same time managing an on-screen interface, poses difficulty over and above the problem of managing standard synchronous interaction. Addressing this issue would be the primary focus of a future user study.

A final drawback of the current study was the absence of statistical linkage between the data collected, the conversation codes and reference types, and a measure of their utility in

overcoming blockages in collaboration. Although classifying sensemaking instances as either successes or failures is a difficult and ill-defined target, such an effort would nevertheless strengthen the findings, and help avoid conflating anticipated observations with actual empirical evidence. Several previous studies which have analyzed group collaboration for design (Tan et al., 2014; Rosen, 2014; Collins & Dunn, 2011; Paul & Reddy, 2010) have employed assessment as their point of departure for research. This is promising since it frames observational results along a positive/negative continuum regarding the facilitation of sensemaking. My future work in this area will build on these studies by employing similar methods of statistical analysis.

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Appendices

13.1 Group A Dialogic Acts

Table: Group A dialogic acts for totalled over Sessions 1, 2 and 3. Data based on transcript text and field observations to categorize speech and behaviours according to Generation, Evaluation, Management and Revision Instances, and their subtypes.

Group A Dialogic Acts Frequency by Time									
Time (min)	**15**	**30**	**45**	**60**	**75**	**90**	**105**	**120**	
Generation (Divergent Production Dialogue & Action)									
Epistemic	3	8	5	16	5	7	14	4	**58**
Concrete	9	7	3	7	6	3	8	8	**51**
Total	12	15	8	23	11	10	22	8	**109**
Evaluation (Convergent Production Dialogue & Action)									
Critique	2	8	3	4	14	4	3	13	**51**
Justification	4	2	2	5	12	6	8	15	**54**
Checking	2	6	5	11	7	12	10	7	**60**
Total	8	16	10	20	33	22	21	35	**165**
Management (Reflexive Dialogue & Action)									
Regulation	9	8	7	5	8	15	8	7	**67**
Grounding	6	10	12	10	7	4	7	7	**63**
Affective	3	12	5	9	5	7	17	5	**63**
Disaffective	3	2	6	2	8	8	3	14	**46**
Total	21	32	30	26	28	34	35	33	**239**
Revision (Elaborative Dialogue & Action)									
High level	8	19	14	3	12	10	12	4	**82**
Low level	14	3	6	5	15	16	17	14	**90**
TOTAL	22	22	20	8	27	26	29	18	**172**
All	**63**	**85**	**68**	**77**	**99**	**92**	**107**	**94**	685

13.2 Group B Dialogic Acts

Table: Group B dialogic acts for totalled over Sessions 1, 2 and 3. Data based on transcript text and field observations to categorize speech and behaviours according to Generation, Evaluation, Management and Revision Instances, and their subtypes.

Group B Dialogic Acts Frequency by Time									
Time (min)	**15**	**30**	**45**	**60**	**75**	**90**	**105**	**120**	
Generation (Divergent Production Dialogue & Action)									
Epistemic	3	2	5	6	11	7	8	3	**45**
Concrete	10	12	14	15	3	12	8	8	**82**
Total	13	14	19	21	14	19	16	11	**127**
Evaluation (Convergent Production Dialogue & Action)									
Critique	2	0	7	4	8	9	3	7	**40**
Justification	4	3	4	5	12	6	5	8	**47**
Checking	2	6	5	8	5	4	5	4	**39**
Total	8	9	16	17	25	19	13	19	**126**
Management (Reflexive Dialogue & Action)									
Regulation	9	3	3	4	2	7	5	9	**42**
Grounding	2	7	10	7	2	8	7	2	**45**
Affective	8	6	6	7	5	4	3	2	**35**
Disaffective	2	0	3	4	4	0	2	3	**16**
Total	21	16	16	22	13	19	15	16	**138**
Revision (Elaborative Dialogue & Action)									
High level	3	12	4	2	12	6	10	6	**55**
Low level	2	5	6	15	2	32	20	7	**89**
TOTAL	5	17	10	17	14	38	30	13	**144**
All	**47**	**56**	**61**	**77**	**66**	**95**	**74**	**59**	535

13.3 Group C Dialogic Acts

Table: Group C: dialogic acts for totalled over Sessions 1, 2 and 3. Data based on transcript text and field observations to categorize speech and behaviours according to Generation, Evaluation, Management and Revision Instances, and their subtypes

Group C Dialogic Acts Frequency by Time									
Time (min)	**15**	**30**	**45**	**60**	**75**	**90**	**105**	**120**	
Generation (Divergent Production Dialogue & Action)									
Epistemic	2	2	7	1	17	4	4	1	**38**
Concrete	1	2	14	15	3	3	10	8	**56**
Total	3	4	21	16	20	7	14	9	**94**
Evaluation (Convergent Production Dialogue & Action)									
Critique	2	12	3	7	10	2	4	4	**44**
Justification	4	4	9	10	16	8	8	7	**66**
Checking	2	2	6	16	12	8	8	4	**58**
Total	8	18	18	33	38	18	20	15	**168**
Management (Reflexive Dialogue & Action)									
Regulation	3	7	8	2	7	9	5	14	**55**
Grounding	6	5	6	8	14	12	5	5	**61**
Affective	5	3	13	2	2	5	9	2	**28**
Disaffective	2	0	2	1	4	8	2	9	**18**
Total	16	15	16	13	27	26	19	30	**162**
Revision (Elaborative Dialogue & Action)									
High level	6	16	0	8	18	3	20	2	**73**
Low level	13	1	16	6	14	4	12	16	**82**
Total	16	17	16	14	32	7	32	18	**155**
All	**43**	**54**	**71**	**76**	**117**	**58**	**85**	**72**	1158

13.4 Interview Questions

1) Can you recall when you first began writing songs? How did it happen?

2) What kind of progression did you experience playing with your bandmates?

3) Please describe in some detail the process by which you write music.

4) To what extent do you use a deductive process in composing, or is a spontaneous process?

5) Are there particular emotional states that motivate you to write?

6) What individuals or experiences have had the greatest impact on your music?

7) What do you do when something is not working right, like when you hit a roadblock? How do you deal with that?

.

13.5 Consent Form

Music creativity support

Niall Conroy (Ph.D. candidate)
Faculty of Information and Media Studies, UWO

The purpose of this letter is to provide you with the information you require to make an informed decision on participating in this research.

Purpose of this Study

You are being invited to participate in a research study looking at Creativity and Music composition at the University of Western Ontario. It is the intention of this study to examine how musicians compose music in a group setting.

Who is eligible to Participate?

You are eligible if you are older than 18 years of age and currently enrolled in an undergraduate program at UWO. Participants should be experienced musicians and have 3+ years performing and playing music as part of a group ensemble.

Research Procedures for this Study

If you agree to participate, you will be observed during 3 rehearsal sessions within a rehearsal venue, as well as one short interview with the primary researcher. Each rehearsal session will be video recorded and the interviews may be audio recorded. The time of the rehearsals will be arranged with other band members in order to not conflict with your current schedule. A total of 15 people will be participating in the study.

Voluntary Participation

Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time. Please note that it will not affect you in any way if you decide that you do not want to participate; or decide to withdraw part way through the study.

Inquiries and Risks

You are free to ask questions about the study or the questionnaire at any time. Contact Niall Conroy at [redacted] or Phone [redacted]. There are no immediate risks involved

from participating in this study. Participation in the present study does not hinder your ability to participate in other concurrent studies or in future studies about creativity and composition. You do not waive any legal rights by signing this consent form.

Benefits from the Study

There are no known benefits to you from participating in this study. However, your participation will help to gain insight on the creative process of group songwriting.

Confidentiality of Information

Information that is collected during the study will be stored securely in the office of (Niall Conroy, [redacted]) and will be destroyed following the completion of the study. The data will be made available from the principal researcher as part of a submitted Phd dissertation, but no individual will be recognized by name. If the results of the study are published, your name will not be used and no information that discloses your identity will be released or published without your specific consent to the disclosure.

Compensation

You will be compensated in the form of a gift certificate for your participation in this study.

Consent to Participate

I have read the Information Letter, have had the nature of the study explained to me and I agree to participate in the study. All questions have been answered to my satisfaction.

_____

Name (please print)

_____ _____

Participant's signature Date

_____

Name of person obtaining informed consent

_____ _____

Signature of person obtaining informed consent Date

Contact

If you have questions about this study, please contact Niall Conroy by phone at 5[redacted] or by email at [redacted].

If you have questions about the conduct of this study or your rights as a research subject you may contact:

Office of Research Ethics
The University of Western Ontario
Phone: [redacted]

13.6 Ethics Approval Form

Western
Faculty of Information and Media Studies

Ethical Review of Research Involving Human Subjects

All non-medical research involving human subjects at the University of Western Ontario is carried out in compliance with the Social Sciences and Humanities Research Council Guidelines (2010). The Faculty of Information Media Studies (FIMS) Research Committee has the mandate to review minimal-risk FIMS research proposals for adherence to these guidelines.

2012 – 2013 FIMS Research Committee Membership

1. R. Babe
2. A. Benoit (alt)
3. J. Burkell (Chair)
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5. A. Hearn (alt)
6. P. McKenzie (alt)
7. H. Hill
8. A. Quan-Haase
9. D. Robinson*
10. C. Whippey*
11. L. Xiao

Research Committee member(s) marked with * have examined the research project **FIMS 2012-13-023** entitled:

Exploring the use of artificial intelligent (AI) conversational agents for library services to specific user groups

as submitted by: Victoria Rubin (Principal Investigator)
Niall Conroy

and consider it to be acceptable on ethical grounds for research involving human subjects under the conditions of the University's Policy on Research Involving Human Subjects. Approval is given for the period to 30 June 2013.

Approval Date: 8 April 2013

Jacquelyn Burkell, Assistant Dean (Research)
FIMS Research Committee Chair

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Publications:

Rubin, V. R., Conroy, N. J., Chen, Y. & Cornwell, S. (2016). Fake News or Truth? Using Satirical Cues to Detect Potentially Misleading News. *Proceedings of the Workshop on Computational Approaches to Deception Detection at the 15th Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies (NAACL-CAADD2016),* San Diego, California, June 17, 2016.

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