On Digital Drumming: Collaborative, Dyadic, Co-Located, Coordinated Interaction

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(ABSTRACT)

The use of digital technology can be seen in many aspects of daily lives. Once a symbol of business and the corporate world, digital devices such as computers and cell phones are now common artifacts to adults and children alike. While these devices become more practical and common, questions of their impact on behavior and interactions begin to arise. Digital Drumming is a series of three experiments that examined the impact of known computer participation as a partner in a dyadic creative, experience-driven task. The subjective processes associated with the task of rhythmic music production by inexperienced and experienced participants working collaboratively either with a human or computer partner to produce complex poly-rhythm sounds were investigated. Specifically, the research question asked is: *How do inexperienced versus experienced drummers solve problems of what to produce when they have a human partner, versus a computer partner?* This is a problem of cooperation, synchronization, and microcoordination(Lee, Tatar, & Harrison, 2010). Data was collected through self-reported questionnaires and audio transcriptions of the actual sessions. Behavioral data and subjective experience responses suggested that participants viewed a computer's role differently depending on their experience level. Participants demonstrated a propensity to simultaneous interaction, often sharing a common tempo with variable rhythmic patterns. The importance of partner, as well as the perception of leader were influenced by the partner type, and the experience level of the participant. This work identifies different perceptions and expectations that humans of varying prior experience levels have when interacting with and responding to technology, and suggests deeper investigation into how people view technology in creative activities.

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Chapter 1

Introduction

The production of music is an intriguing form of human expression. It can exist for different purposes and take various forms, such as music used in celebratory events, communication, entertainment, and spiritual rituals (Beaton, Harrison, & Tatar, 2010). Music production can be a self-rewarding task, where the activity itself is the reason for task engagement. Other, non-music production tasks often are engaged because of a need for goal completion. As such, music production is a rich task environment for the purposes of human-centric research (Schober, 2006).

Technology and Interactions

As culture continues to adopt new technologies, music and music interaction take on new forms. An emerging trend is using commonplace electronic devices to create analog-sounding music. The widespread availability and use of new electronic instrumentation has redefined the notion of a novice musician. New instruments are expanding the limits of musicians and their creative processes (Beaton et al., 2010; Gurevich, 2006; Weinberg, Driscoll, & Thatcher, 2006) . The interpersonal relationships experienced between musicians of various experience-levels changes, as well.

In collaborative rhythmic music production activities, the idea of leadership is important. While chaotic behavior can be meaningful, so can the stability provided by strong leadership. Leadership in a collaborative environment has been shown to be an important factor (Nijholt, Reidsma, Van Welbergen, Op Den Akker, & Ruttkay, 2008). Leadership can be established and asserted with verbal communication, visual cues, or auditory signals. The flow of leadership between members of a group can be intentionally or unintentionally controlled depending on the needs of the group. Yet, the role of leadership when the task is as highly coordinated as digital drumming requires exploration.

Human-centric Research Through Music

Research in the areas of music and music interaction present a rich medium for studying human creativity and cognition (Chew, 2010). By its nature, music is rooted in temporal acoustical patterns, timings, frequencies, and amplitudes. Relationships exist in the form of polyrhythmic patterns and scalar/modal tonal progressions. Each of these facets of music can be expressed in mathematical terms and quantified for comparison.

HCI issues are present in music research; examples include cue response, group dynamics, workflow design, and experiential design (Blaine & Perkins, 2000; Chew, 2010; Crick, Munz, & Scassellati, 2006; Jennings, 2003; Reeves & Nass, 1996). Thus, engineering-based problem solving methodologies are available for research in the music production field. Approaches rooted in computational methodologies may help to develop a better understanding of the cognition processes, limitations, and capabilities present in music perception and production. Additionally, the in-the-moment actions, present in collaborative music production tasks (Beaton et al., 2010), provide a different framing to problem solving in terms of task motivation and help develop deeper insights into engineering research.

Musical Characteristics

When discussing music and music production, two characteristics should be considered. The first characteristic is tonality, which is the character a piece of music has from being composed in a particular key. Depending on the starting key, or tonic of the pattern, a different set of unique pitches can be used to build harmonies and shape the piece. The second characteristic is rhythm. Instead of focusing on unique pitches, rhythm is based around dynamic arrangement of the notes. Tempo, intensity, duration, and variance collectively effect rhythm. Prior research in Human-Computer Interaction (HCI) and cognitive psychology related to music production and coordinated activity has focused primarily on the tonality aspect of music (Blaine & Perkins, 2000; Blaine & Fels, 2003; Blane & Forlines, 2002; Downling, 2002; Drake, Jones, & Baruch, 2000; Gurevich, 2006).

Summary

The focus of this thesis is on the experience of working on the collaborative task of producing rhythmic music using a handheld interface to a drum-like synthesizer. Specifically, the research question investigated through this work is: *How do inexperienced versus experienced drummers solve problems of what to produce when they have a human partner, versus a computer partner?* Collaborative activities have the capacity to be better than the sum of their parts, yet making music is a classic example of a task that is at times associative; that is, a task in which the performance of the whole is gated by the least competent performer. The subjective processes associated with the task of rhythmic music production by inexperienced and experienced participants working collaboratively either with a human or computer partner to produce complex polyrhythm sounds are investigated. Specifically, the subjective experience of music production and the behavioral interactions between activity participants are assessed. Correlations to previous work in cooperation and synchronization, human-computer cue response, and action-driven behavior are presented as a framing (Crick et al., 2006; Nijholt et al., 2008; Reeves & Nass, 1996; Schmidt, 1994; Shechtman & Horowitz, 2003). Previous work from cognitive psychology and human-interaction research is presented to discuss not only the natural elements of music production in human behavior, but also the specificities of rhythmic-based activities (Beaton et al., 2010; Blaine & Fels, 2003; Chang & Trehub, 1977; Chew, 2010; Gurevich, 2006; Jones, 1981).

Chapter 2

Related Work

2.1 Introduction

Collaborative music has engendered its own literature on cooperation, synchronization, collaboration, and performance that is separate from the computer-supported cooperative work (CSCW) and human-computer interaction (HCI) literature. However, key ideas, not surprisingly, overlap across these research areas. For example, the ways that participants of an activity cooperate through synchronized actions, or the subjective experiences that individual participants of an activity experience, are keystone areas of HCI and CSCW research. This chapter discusses these key ideas and areas, and frames the importance of the study of Digital Drumming, and the elements of interaction that occur within a creative collaborative activity.

Four areas of research are investigated in this chapter. The first is *Orchestration of Human Activity*, which explores various elements of human interaction through collaboration and cooperation. *Orchestration of Language* focuses on how people use language in particular to communicate and get things done. Music is a kind of language, it is an expressive medium that may be used to bring about a state of affairs in the world. The ways in which music resembles and departs from language cast light both on the nature of music and the nature of language. The following section, *Music* explores elements of music and music interaction relevant to collaboration and in-the-moment behavior. The final section, titled*Music For/With Others* investigates the performative nature of music, including both single-musician and collaborative performances.

2.2 Orchestration of Human Activity

Human activity can be thought of as more than the actions of a single person acting alone. Rather, human activity often encompasses the actions and reactions of two or more people reacting in context (Suchman, 1987; Chapin & Stuart, 1974; C. Chen & Rada, 1996; Clancey, 1993; Hutchins, 1995). Chapin (Chapin & Stuart, 1974) describes human actions and activities as contextually tied to time and location. The meaning of the action is rooted in the moment. What influences this moment? This section investigates the impact of cooperation of people and synchronization of activity. What is the impact of prior experience? Does leadership play a role in shaping coordinated experiences?

2.2.1 Cooperation and Synchronization

In Modes and Mechanisms of Cooperative Work, Schmidt states, "The articulation of the distributed activities in a cooperative setting normally requires the continuous formation among the members of the cooperating ensemble of a reciprocal awareness of the activities, concerns, and intentions of the other members of the ensemble." (Schmidt, 1994, p. 60) Cooperation and coordination are at the heart of human activity and interaction. From a heated debate between daughter and parents over curfew on a Friday night, to the culturally prescribed movements of a conversation with a stranger on an elevator, human interactions involve an exchange of action and reaction in the moment. This reciprocal awareness of intention requires crosschecking of current actions with prior information, either in the form of prior knowledge or expressed intent.

Both implicit and explicit cues may provide the information required to create and maintain reciprocal awareness. Implicit cues may be intentional or unintentional but are not conveyed as the primary message between person A and B, for example a mother may smirk when her daughter tells an inappropriate joke, which could provide validation to the daughter of acceptable behavior. Explicit cues are more direct, and have intentional and direct meaning behind their conveyance. Crick (Crick et al., 2006) identifies a partial set of cues that actors use to direct cooperation. Actors may use embedded or symbolic representations to draw attention to a specific piece of information. Ephemeral cues, such as pointing at something, or persistent cues, such as monitoring other actor's actions may be used as well. Obtrusive cues, such as interrupting an activity to redirect action, or unobtrusive cues such as hinting at something are common cues. These cues may be present in co-located and distributed interactions.

The following sections discuss the impact of three influences of interaction with respect to cooperation and synchronization. Experience-driven behavior and micro-coordination describe types of coordinated action. Experience-driven behavior describes actions that do not focus on attaining an end goal. This behavior is focused on the experience of the process of the activity. Micro-coordination (Lee et al., 2010) describes coordinated actions that take place very quickly from moment to moment and their impact on the progression of the activity. An example would be two people clapping together, their action must take place at the same time with a similar rhythm and tempo. Prior experience, expertise, and leadership are elements of interaction that can impact the overall experience of the actor. Prior experience influences the expectations and experiences that participants in an activity have of themselves, the activity, and the other participants in the activity. The expertise and prior experience a person possesses that relate to an activity can impact their actions and the experience they have in said activity. Leadership often manifests in the form of experienced humans helping less experienced humans complete an objective (Fullan, 1998). This help can come in the form of guidance about actions to take in completing a task, or support in decision making.

Experience-Driven Behavior and Micro-coordination

When discussing activities and coordinated action, questions arise about how people decide what to do, and when. Behavior and decision-making can be predicated by the type of activity the person is involved in(Crick et al., 2006; Schmidt, 1994). Activities can be described by the intention of the person in participation, for example as goal-based or experiential-based. Goal-based activities can be described as being motivated by or seen as important by the participant because of a desired end state. To get to the end state, people must engage in activities (Suchman, 1987).

We call an activity goal-based if the end state is our object of interest. For example, Lucy Suchman's research area focused on goal-based activities and the engagement in those activities (Suchman, 1987). We may be interested in success or failure in making ten copies of a document, and may look at the action required to make those copies as secondary. From this perspective, efficiency and optimization of production may be the lens through which we examine the actions required to achieve the production. Experiential-based activities may or may not have a focused end state. The purpose of participation in an experiential-based activity is to experience the elements of the activity process. From this perspective, subjective experiences and interactions between participants and acting agents of coordination (such as responsive systems) may be the lens through which we examine the actions required to complete the activity.

But, importantly, not all activities are focused on an end state. They may be centered in the moment. These kinds of activities draw our attention to other qualities that may make actions interesting. An example of an experiential-based activity is playing the drums with a friend. The experience in the moment is often more important than the product. Although experiential-based and goal-based tasks differ in their approach, they share similar decision making techniques during the task.

Decisions and actions are made in the moment, within the context of the events that occurred just fractions of a second prior (Lee et al., 2010; Downling, 2002; Drake et al., 2000). In many types of coordinated activities, the interactions that occur are influenced by the moment to moment actions that take place during the progression of the activity. Lee et al. (Lee et al., 2010) investigated micro-coordinated activity among players of a joint problem-solving game using laptops.

Micro-coordination is the study of the phenomena of human coordination in the small (Lee et al., 2010). Particular focus is placed on variation. Lee et al. (Lee et al., 2010) discuss the importance of focusing on the particulars of collaborative actions, and note that the relationship between outcomes and actions has been under-explored within the Human-Computer Interaction and Computer Supported Collaborative Work communities. They focus design on how participants decide who goes next in interaction, and how they regulate attention and understanding. This is oriented at the moment to moment actions of an activity, not the overall task.

Not all activities focus on the end goal. There are times when the purpose of participation in an activity is to experience the elements of the activity process. From this perspective, subjective experiences and interactions between participants and acting agents of coordination (such as responsive systems) may be the lens through which we examine the actions required to complete the activity. At the same time, decisions and actions are made in the moment, within the context of the events that occurred just fractions of a second prior.

Prior Experience

The prior experiences a person brings to an activity have impact on others as well as the individual when they influence the person's participation in an activity. Internet technologies build on this truism often. For example, friend recommendations(Lehto, O'Leary, & Morrison, 2004; Crick et al., 2006) such as Google +1 recommendation tool and Bing Social Search tool use other people's knowledge to infer a person's likely interests. In fact, these tools implement a different filtering algorithm that displays information search results dynamically, based off of the opinions of users or friends thought to be like-minded.

Spontaneous crowd sourcing can be a way for individuals to seek out the prior experiences of others as a way to guide their own experiences. Within the online microblogging service, Twitter, users will often post questions publicly in search of other's prior experiences. "Where is the best place in downtown Baltimore to get fresh crabs?" Other users will respond in a private message or publicly-directed message with their opinions. In this way, the prior experience of the group shapes the experience of a searcher.

Cognitive science literature refers to these prior experiences as elements of self-memory (Eysenck & Keane, 2010; Conway & Pleydell-Pearce, 2000). According to Conway and Pleydell-Pearce (Conway & Pleydell-Pearce, 2000), self-memory can be categorized into two types: Autobiographical memory, and the working self. In the autobiographical memory, images, sounds, and emotions are stored about general activities, such as getting ice cream while vacationing in Madrid. This knowledge is usually stored and recalled with respect to temporal characteristics. Information in this group is often linked within a hash web of other general events memories pertaining to a repeated activity, such as going to Grandmother's house for the holidays.

While autobiographic memory can be thought of as personal experiences in the past, the working self memory (Eysenck & Keane, 2010; Conway & Pleydell-Pearce, 2000) is a reflection of self in the current and future states. The working self refers to memories that are a perception of self. These are how we see ourselves within a short time frame. What are a person's hopes and dreams? How do they feel about their current activities? What are their goals? These goals and feelings act as sparks for the autobiographical memories we recall. Conway writes, "Autobiographical memories are primarily records of success or failure in goal attainment" (Conway & Pleydell-Pearce, 2000, p. 266). The working self acts as a constructor to point to memory types through direct retrieval. As Crick described (Crick et al., 2006), various visual, auditory, haptic, or other sensory cues are used by humans as interaction modes. These cues can trigger specific memories to be recalled, like the smell of perfume your wife wore on your first date.

The prior experiences of an actor have a direct impact on the expectations and interactions used during a task. Lehto et al; (Lehto et al., 2004) investigated the effects of prior experience on tourists' vacation behaviors. According to their study, prior experience had an effect on the spending habits and activity participation of the tourists. Tourists' recommendations of activities also influenced the behaviors of new tourists without prior experience. These changes in behavior indicate a change in the goals of a task as well, with tasks being influenced by positive or negative prior experiences. New experiences must now be as good or better in the eyes of the human to maintain a positive rating.

These prior experiences can manifest as feelings and opinions as generic as "those four years at college" or as specific as "that man selling smoothies on the beach in the rain during our last trip." All of these memories can affect the actions a person makes, and the influence of opinion they have on the other people they interact with. What happens when the prior experiences are related to an activity, but parts of the activity have been changed?

Expertise and Leadership

The expertise and prior experiences a person has in regard to an activity can impact their actions and the experience they have in the activity. One of the seminal findings about experienced-novice (for the purposes of this thesis, experienced refers to prior experience relating to a task, while novice refers to very limited prior experience) differences is that experienced users tend to have "compiled" knowledge; that is, knowledge that is hard to break up into small pieces (Hoffman, 1992). On the other hand, in studies of experienced-novice behavior in resolving spatial location references, experienced users were able to adjust to the limited knowledge of novices in describing places in New York City within two utterances

(Isaacs & Clark, 1987). Because the skills involved in describing places in New York City from pictures are relatively simple (e.g., if your partner does not recognize the picture of "Rockefeller Center", it is easy to look at the picture and describe it as "the building with the flags" they are not precisely parallel to the skills associated with "compiled" expertise, such as chess playing.

There is an old saying, "Too many cooks in the kitchen." It refers to too many people trying to give direction, and not enough willing to take it. Just as expertise impacts the behavior and decision making of people in action, it can also impact the leadership exhibited within the activity. Leadership often manifests in the form of experienced humans helping less experienced humans complete an objective (Fullan, 1998). This help can come in the form of guidance about actions to take in completing a task, or support in decision making. Nijholt et al; (Nijholt et al., 2008) describe explicit and implicit leadership in the context of an orchestra. The role of the conductor is to be the leader of the orchestra. That entails monitoring the output of the various compartments of the group, and changing their actions on the fly. While they do not change the scalar progression of the piece, they do have control over the tempo and dynamic voicing in real time.

Implicit leadership can also exist within a group. This type of leadership can occur when one person is providing feedback to another without being on purpose. This could be done through the use of various cues. Typically, people with less experience in a task would look to someone with more experience for guidance(Isaacs & Clark, 1987; Fullan, 1998). In the example of a father and daughter playing catch, the father would be the leader and the daughter would be a dependent. The father may explicitly offer guidance such as, "stand here" or "move back" but there are other messages that are conveyed as well. How the little girl stands in relation to her father before a throw can be a representation of how she views him behaving in the activity. Yammarino (Yammarino, Bass, & Avolio, 1994) investigates the performance of individuals who do not report directly to the leader they are receiving guidance from. This idea, coined "leadership at a distance" found that by freeing the individual of responsibility of reporting to a single leader, intended task completion outcomes were steady with those where the individual reported to a specific leader. The presence of a leader with adequate expertise could be linked to successful task completion outcomes, regardless of any further relationships between the leader and individual(Isaacs & Clark, 1987; Fullan, 1998).

The expertise and prior experience a person has can impact their actions and the experience they have in an activity. Questions remain about how novices adjust to experts in skilled, "compiled" activities. Furthermore, questions remain about how novices adjust to experts when the nature of the expertise is itself about coordination. The impact that these differences in expertise have on the subjective behavioral interactions of pair collaborations is relevant to the HCI community because, as cited above (Isaacs & Clark, 1987; Fullan, 1998; Yammarino et al., 1994) as technology continues to develop, it is important to understand technology's impact on task and objective completion.

2.2.2 How Things Get Done: Situated Action

n section-2.2.1, micro-coordination was defined as the study of the phenomena of human coordination in the small. There are times when the task activity needs to be studied at a higher level. Situated actions describe the process of the activity. Lucy Suchman first introduced *Situated Action* in her 1987 work,

> "I have proposed an alternative approach drawn from recent developments in the social sciences, principally anthropology and sociology. The aim of research, according to this approach, is not to produce formal models of knowledge and action, but to explore the relation of knowledge and action to the particular circumstances in which knowing and acting invariably occur."(Suchman, 1987, p. 176)

This new research direction focused on exploring the relationship of knowledge and action and specific environments. Drawing from anthropological and sociological techniques (as well as other social sciences), the context that an activity process occured in can be as important as the outcome of the activity. Suchman goes on to say,

> "To designate the alternative that ethnomethodology suggests more a reformulation of the problem of purposeful action, and a research programme, than an accomplished theory I have introduced the term situated action."(Suchman, 1987, p. 70)

Purposeful action can be goal oriented behavior or action-driven behavior, depending on the intended task. Suchman's work focused on goal-driven behavior, specific to workplace environments. As discussed in the earlier sections of this chapter, some actions are not driven by a specific goal, but rather are context dependent and focused rather on an experience. Further investigation is needed to examine how experience-driven behavior occurs within the context of an activity.

The interrelationships between an action and the context of the action are referred to as situated action (C. Chen & Rada, 1996). The focus of importance is not on the actual performance, but instead on the influencing actors. While people may begin a task with a specific protocol of what they think or want to happen, actions may deviate from the intended plan as the scenario develops in real time.

Although countless hours may be put towards planning and appropriate actions, the in-the-moment action of the activity eventually turns to the embodied skills available to the person at that time. Suchman states,

> "In planning to run a series of rapids in a canoe, one is very likely to sit for a while above the falls and plan one's decent. The plan might go something like

> I'll get as far over to the left as possible, try to make it between those two large rocks, then backferry hard to the right to make it around that next bunch. A great deal of deliberation, discussion, simulation, and reconstruction may go into such a plan. But, however detailed, the plan stops short of the actual business of getting your canoe through the falls.(Suchman, 1987)."

In Suchman's example of traversing a section of white water rapids, the details of responding to the currents and how the canoe is handled in the moment of action is dependent on the action canoe in the water, and reaction of the person paddling at that moment.

The deviation from an original plan is dependent on the person's embodied skills and prior experiences, People often have plans of action mapped out in their heads, but may need to change that plan depending on what is actually happening in a specific situation. They use their embodied skills or past experiences to get them through the situation(Suchman, 1987). This lays the foundation as to how plans are constructed prior to beginning to perform a task. A macro, or high level plan is constructed prior to beginning a task, and small adjustments are made as the task progresses, with next actions being created and altered based off of what just happened.

Clancey (Clancey, 1993, p. 51) has a modified definition of situated action. Clancey defines situated action as,

> "Situated activity is not a kind of action, but the nature of animal interaction at all times, in contrast with most machines we know. This is not merely a claim that context is important, but what constitutes the context, how you categorize the world, arises together with processes that are coordinating physical activity. To be perceiving the world is to be acting in it–not in a linear input-output relation (actobservechange)–but dialectically, so that what I am perceiving and how I am moving co-determine each other."

Clancey views situation as the nature of animal interactions in contrast with what we expect machine interactions to be. It is the contrast of human interactions to computer interactions. Categorization of the world around us grows simultaneously with the moment coordinated with the physical actions. It is not a procedural occurrence, but rather a balanced relationship between a person's perception of the world around them and the actions they make.

Clancey's work raises the question, how do the actions that a person takes compare to another person's actions in the same task, but with a different perception of the world around them? What impact do these differences have on the subjective behavioral interactions of a pair collaborating within a task? Suchman's work focuses on goal-driven behavior, but what types of actions occur within the context of an experiential-driven activity?

2.2.3 Human Response To Technology is Like...

It is difficult to find a task in today's world that does not involve digital technology in some way. From the construction workers warning oncoming traffic of their presence with electronic road signs, to the stock broker on the floor of Wall-Street depending on information from their iPad, Blackberry and iPhone to make things happen in real time. "The confusion of mediated life and real life is rare and inconsequential, and it can be corrected with age, education, or thought."(Reeves & Nass, 1996; Nass & Moon, 2000) Reeves and Nass posit, "Equating mediated and real life is neither rare nor unreasonable. It is very common, it is easy to foster, it does not depend on fancy media equipment, and thinking will not make it go away."(Reeves & Nass, 1996) How humans perceive technology, as a tool or as a collaborative agent capable of active contribution to a task, can affect how terms such as real life and natural are embodied.

In The Media Equation (Reeves & Nass, 1996), Reeves and Nass found that media equals real life. "Individuals interactions with computers, television, and new media are fundamentally social and natural, just like interactions in real life."(Reeves & Nass, 1996) Nass and Moon (Nass & Moon, 2000) found that humans respond to social cues in the same way, whether the source is human or some piece of technology behaving as a human. Their study was grounded in social psychology, in which previous interaction studies of human-human pairs were replicated with human-computer pairing.

Shechtman and Horowitz (Shechtman & Horowitz, 2003) found contradictory results to the work of Nass and Moon (Nass & Moon, 2000). Their study (Shechtman & Horowitz, 2003) was grounded in the principles of Interpersonal Theory. The main variable was whether participants were informed whether they were communicating with a computer or human partner in the room next door. Participants had a structured text-based conversation with a computer that gave scripted conversational responses. Contrary to The Media Equation (Reeves & Nass, 1996), Shechtman and Horowitz found that when participants believed they were communicating with a human, their behavior was more indicative of attempting to establish an interpersonal relationship. Discourse analyses revealed a key difference in participants behavior when participants believed they were talking to a person, they showed many more of the kinds of behaviors associated with establishing the interpersonal nature of a relationship.

While previous studies (Nass & Moon, 2000; Reeves & Nass, 1996) have examined the existence of differences interpersonal relationships depending on interacting with a human or computer partner (from social science and interpersonal theory perspectives), others have questioned the longevity of the media equation, and the durability of its effect over time (Pfeifer & Bickmore, 2011). "Research on social responses to computers often assesses only first-impression reactions during a single experimental session, providing limited knowledge about the lasting effects of the results."(Pfeifer & Bickmore, 2011, p. 777) Laura's study assessed the lasting strength and of biasing effects on an interface designed to track exercise, with personalization as the manipulated variable. Their work found that "Social responses to computers change over time, and moreover, that this change varies depending upon the personalization of the interface."(Pfeifer & Bickmore, 2011, p. 777) This claim was based on a study with a small population size and ran for less than a year. The longevity of the behavioral change is still unknown, but the study showed that for a brief period of time a semi-lasting impact was made.

This synthesis of the Shectman and Horowitz work and the Nass and Reeves/Moon work raises several questions. What is the impact on the subjective experience of a person when collaborating with a computer partner? In what ways are behaviors similar or different when people complete the same type of task, but with either a human or computer partner? This thesis does not side intentionally with Nass and Reeves (Reeves & Nass, 1996) or Shechtman and Horowitz(Shechtman & Horowitz, 2003). The purpose is rather to investigate this interesting gap of human response posed.

2.3 Orchestration of Language

Language is used for doing things. In the previous sections we have discussed approaches used to decide what to do, whether driven by goals or driven by experience. Language is a tool for collaboration, used to synchronize coordination. Clark said that Language use is really a form of joint action. A joint action is a group of people acting in a coordinated way with one another. This could be a musical act on a stage, a crowd of people applauding a play, or a server taking an order at a restaurant. There are moments of synchronization in the activity that delegate whose turn it is, and what to do. Telling your order to a server before they have asked what you would like can create an awkward situation, in the same way that certain music doesn't sound pleasant to the ear when played out of order. In this way, the structure that develops from the joint action embodies both individual and societal processes. There is a rhythm within the structure that establishes a sense of flow to how language is used.

The following sections discuss how language is used, and what is needed to facilitate it's synchronization. Within the coordinated actions is an underlying rhythmic characteristic. Music is presented as a form of language, as it can be characterized by joint action, being rooted in rhythmic pattern, and as a collaborative activity. With respect to the HCI community, framing music as a language affords opportunities to investigate collaboration and coordination within a creative domain that can be less focused on goal outcome, instead focusing on experience. the section.

2.3.1 Conversation and Signaling

When talking about how people get things done, languge use and conversation go hand in hand. Conversation is an exchange of information between two or more actors though verbal or other communicative streams. Conversation is a joint activity, where actors work together simultaneously to facilitate understanding of meaning, and flow of the conversation. Conversational partners use similar words and utterances, sounds, body language, and facial expressions to align themselves in the conversation. Smith et al; (Smith, Ramsay, Garrod, Jackson, & Musizza, 2007; Garrod & Pickering, 2004) refer to this as interactive alignment. Clark refers to a similar process as establishing common ground (Clark, 1996). The process of interactive alignment usually consists of: speakers A and B use similar representations and language of one another in conversation, so when speaker B describes something to speaker A, they are already operating with a similar understanding. The common understandings are defined and redefined as the conversation progresses. This rhythmic trade of message and confirmation between partners continues throughout the exchange.

Signs and signals are used by humans as a way to synchronize communication and mental models. It has been said that language use could not actually happen without signs and signals, as they are determine how communication is actually structured (Clark, 1996; Garrod & Pickering, 2004). Signals can be either linguistic or nonlinguistic. For example, a woman in a coffee shop may confirm her order or a double espresso by verbally saying, "yes" or by nodding her head. Both of these actions are methods of communicating a signal. Non-linguistic and linguistic methods of signaling may be used at different times independently, but may also be combined to create multi-modal methods of signaling. These multi-modal methods may reflect different stages in a conversation. For example, a wife may repeatedly attempt to make eye contact with her partner at a business meeting as a way to get their attention, at which time she may silently mouth the word "GO." Both of these methods of signaling combine to convey the meaning that she is ready to leave.

When investigating ways in which humans construct coordinated activity, the methods used for synchronization of action are important to note. This thesis recognized the types of signals and cues used, but does not focus on their usage structure specifically. Instead, this thesis was designed with metrics that focus investigating the subjective experience of an experience-based activity and the behavioral interactions between activity participants. Future work may investigate deeper meanings of cue usage structure in experience-driven behavior.

2.3.2 Music and Language Use

In a similar way to what Clark describes as conversational language use (Clark, 1996), music can be used to convey meaning(Seifter & Economy, 2003; Crick et al., 2006; Blaine & Perkins, 2000). When producing music, dynamic inflections can be placed at the end of measures to convey emotions, such as sadness or whimsey. Rhythmically, some genres of music correlate with exotic lands, or other environmental locations. Specific scales, or progressions of tones, often reflect parts of the world, such as the Hungarian Minor Scale. In a conversation, person A might whisper to person B to suggest something about the message is secret. Musicians can convey the same idea by mimicking the nuances of speech, and playing in lighter touch and in a quieter volume.

Multiple musicians coordinate timing, tempo, key, and rhythms to create a multi-layer sound that changes over time. As in linguistic conversations, musicians adapt their playing style to the proficiency of their partner(Seifter & Economy, 2003). Drake (Drake et al., 2000) describes how musicians will subconsciously orient their play to the least talented musician in the group. That subject ranking is done through a judgment similar to Clark's common ground (Clark, 1996). It is a way that musicians are able to communicate in a self-synchronizing process. Within the first measures of playing together, musicians are able to assess the competency of the other musicians with respect to staying on beat, staying in key, etc.

While up until this point music has been described as being similar to spoken language, there are ways in which they are different. Earlier, Clark said that language is used for doing things(Clark, 1996). Language and music can both at times be is utilitarian. Music can also be experiential. An example of this would be tapping out a rhythm on your knee while listening to music. This common habit isn't done to convey a message, but rather to pass time. At times tapping is even done without intention. Walking down the street, a person might find themselves humming or singing a melodic pattern. It might be a song that they know, but it could also be a random grouping of notes in a rhythm. Sacks (Sacks, 2008) talks about "infinite loop melodies" which are melodies that can get stuck in a person's mind and play over and over again for weeks or months. There is no correlation to the rhythm or key of the piece, but it can be quite bothersome to the patient. A person can develop internal connections to a piece of music, at a level where just the sound of it can evoke physical responses, such as smiling or goosebumps (Blaine & Perkins, 2000; Seifter & Economy, 2003).

It is more than a personal response to music, in fact a study by Patel(Patel & Daniele, 2003) demonstrated that music is influenced by the native language of the musician or composer. "Musicologists and linguists have often suggested that the prosody of a culture's spoken language can influence the structure of it's instrumental music."(Patel & Daniele, 2003, p. B.35) Through quantitatively measuring and comparing the melodic structure and rhythmic pattern of music from the United States to the syllabic structure and intonation of United States English, Patel found that the rhythmic patterns were quite similar. Patel claimed that, "the spoken prosody leaves an imprint on the music of a culture."(Patel & Daniele, 2003, p. B.35) Similar results were found when investigating the cultural music and language of France. Interestingly enough when comparing two countries music characteristics, as well as their language characteristics, the music and language differed in similar ways.

Clark describes language use as conversational(Clark, 1996), having the ability to convey meaning and ideas though exchanges. Music can also exchange ideas (Seifter & Economy, 2003; Crick et al., 2006; Blaine & Perkins, 2000; Sacks, 2008) (such as emotion through the use of modes and scales) through similar turn-taking techniques. The domain of this thesis focuses on non-verbal music, specifically rhythmic and melodic compositions. Conversations in music can be constructed through exchanges or shared melodies and rhythms among many different musicians.

2.3.3 Crossing into HCI

While there have been several pieces of work focusing on language and HCI(Patel & Daniele, 2003; Clark, 1996; Kaptelinin et al., 2003; Green.T., Davies, & Gilmore, 1996; Blaine & Perkins, 2000; Seifter & Economy, 2003), there is a lack of research investigating the co-ordinated behaviors of humans in creative tasks such as music and art(Orio, Schnell, & Wanderley, 2001; Alty, Rigas, & Vickers, 1997). As discussed in upcoming sections, music (specifically rhythmic music) production tasks present a rich research area. A combination of different mediums (such as visual, haptic, and auditory) may be used to convey signals and coordinate actions.

The domain of music and music production is often thought of as not a place for human-centric research. It is important to recognize that is not the case. Music is a relevant and important area of work in relation to HCI research. The ways in which humans process music involves many different aspects of the self. Music processing is a natural skill present at birth that continues to develop through life (Downling, 2002; Shepard, 2002). The production of music requires humans to use skill sets of coordinated actions. These actions may be coordinated by turn-taking, or they could be simultaneous actions produced by multiple people at the same time. The next behavior may be dependent on the moment immediately before it, or it maybe be oriented towards completion of a larger goal. As discussed in previous sections, music can also follow a script, in which the skill set of the music is imperative to the completion of a piece.

As Crick writes, "In order to develop computer systems that provide adequate and effective support for cooperative work in contemporary flexible work organizations, it is crucial to advance our understanding of cooperative work and its articulation."(Crick et al., 2006, p. 77) In order to develop articulate computer systems that support cooperative work, more research must be focused around understanding how cooperation and coordination occur. It is also necessary to understand the affects of technology on task completion. The introduction of technology into a task process affects the ways in which a system operates. This has been one of the cornerstones of systems engineering and systems research (Carol, 2003). Within a known system, with known actors, what modes of interaction occur at a given time? What methods of signaling are a person exposed to, and how do they react during a task?

The auditory medium has not been extensively investigated in comparison to visual or haptic mediums(Bly, 1982; Gaver, 1986). Those studies that have focused on audio have done so in a primitive fashion. Audio has been used in user interface design to act as auditory icons, or "earcons" (Gaver, 1986; Blattner, Greenberg, & Kamegai, 1992). Spatial sound has been used in projects such as SonicFinder (Gaver, 1989), which conveys environmental information through the auditory channel. Audio has also been used as a supplemental medium in visualizing algorithms (Brown & Herchberger, 1992). All of these studies have used primitive types of audio, acting as signals by beeping or holding a simple tone and oscillating amplitude. The area of using music (one of the more sophisticated forms of auditory media) within the context of language use and signaling has seen little investigation (Alty et al., 1997).

The cognitive requirements of creative tasks, such as music production and performance are demanding on the listener, as well as the musician (Zatorre, Chen, & Penhune, 2007; Janata & Grafton, 2003; J. Chen, Penhune, & Zatorre, 2008). Auditory-motor interactions in music production raise questions of what the brain does when a person plays music. "Music performance is both a natural human activity, present in all societies, and one of the most complex an demanding cognitive challenges that human minds can undertake."(Zatorre et al., 2007, p. 547) Because of the close coupling between perception and action, music provides a rich domain for investigating coordinated activities and cooperation. Within the domain of music production, do cooperation and synchronization play out?

2.4 Music

The domains of music processing and music production represent a type of non-verbal communication. Emotions and meaning can be communicated by a composer to thousands of listening people through music. At the same time, a thousand people can hear the same piece of music, and may all experience something different from it (Sacks, 2008). Music may be tied to memories and prior experiences, and can trigger different recollections depending on the listener. Though, music does not need a partner to exist. A person might hum a song to themselves as they walk down a hallway, or drum on their knee while waiting for a bus. This section frames music as being foundational through cognitive psychology. Rhythm, a foundational characteristic of music and language, is outlined specifically.

2.4.1 Rhythm: Foundation of Music

There are three main characteristics to any piece of music; *melody, tempo, and rhythm* (Zatorre et al., 2007). *Melody*, is the "catchy" part of a piece of music. It is the a linear grouping of pitches that follow some progression and sound like a single piece to the listener(Sacks, 2008). People often find themselves humming melodies on elevators. If a person is trying to remember a song but doesn't know the name, they most likely remember the melody to it. The second characteristic, *tempo* is the speed of the music as it progresses. It is a combination of how quickly the rhythmic pattern of a piece repeats. Composers often correlate slower tempos with darker emotions, such as sadness and anger, while quicker tempos are used for excitement and happiness. American punk rock music from as early as the early 1960s performed pieces with quick tempos as a way to keep energy levels high at their shows.

Rhythm is one of the fundamental elements of music as we know it today. Rhythm has been an underlying piece to many of the previous sections of this literature review. There are rhythmic qualities to language use, and to coordination of action in activities(Clark, 1996; Lee et al., 2010; Beaton et al., 2010). While there are many different definitions of what rhythm is(Sacks, 2008; Jones, 1981; Chang & Trehub, 1977; Chew, 2010), this thesis defines rhythm as the pattern of either regular or irregular pulses caused by the occurrence of dynamic beats. Rhythm does not have to be a steady stream of beats in the same time, although it has been found that regular rhythms are more pleasurable to humans (Sacks, 2008). The rhythm of a piece of music impacts the melody of a piece as well. Without rhythm, a melody is simply a progression of predefined pitches relating to a specific scale. But while melody needs a rhythm to exist, a rhythm can exist without a melody. To pull from a previous example, a person drumming on their lap at a bus stop may have no notion of an accompanying melody. A rhythmic structure and tempo may exist to support other components of music, but they are not required. Rhythm and tempo combine to become the timeline of a piece of music, in a similar way to how coordination has a rhythmic component that develops over time.

2.4.2 Music and Human Behavior

Music recognition and performance are natural human activities that are present in some form in all human societies (Zatorre et al., 2007). Music production and music recognition are intrinsic characteristics of human behavior. Humans possess an understanding of music and music interaction from the early stages of development (Chew, 2010; Downling, 2002; Shepard, 2002). In a study on infant response to pitch, infants tended to respond to melodies with similar melodic contours as the same melody. Their behavior changes were similar when exposed to similar melodic contours, meaning that some melodies would evoke smiles while others would evoke giggles and body contortions. Similarly, in studies investigating infant response to rhythm, infants' behavioral response to similar rhythmic patterns was found to also be similar. Interestingly, changes to the tempo of the rhythm did not have an effect on the infant's behavioral response (Downling, 2002; Shepard, 2002).

While spoken language and music are similar in many ways, the responses they evoke from humans are different. In 2002, a study investigating singing activities (Shepard, 2002) found that infants' speech production patterns were distinguishable from their singing patterns. There are tonal, rhythmic, intonation and inflection differences between singing and speaking a piece (Shepard, 2002). The study also found that the infants did no respond physically to the same utterance when it was spoken or sung to them.

Rhythm and melody production develops early in the life of a child. Rhythmic grouping and melodic contour recognition are present in early communicative tasks; for example, when a child is babbling either alone or to another child (Chang & Trehub, 1977). Childrens cognition for musical patterns is present from birth, and is the groundwork for adult cognition. Although there have been several studies that have outlined the relationship between perception and action within the domain of music (J. Chen et al., 2008; Janata & Grafton, 2003), their focus was on the neurological affects and associations. The use of neuroimaging allowed for claims to be made about physical components of the brain. While this thesis recognizes the importance of such work, the focus of this work is on the behavioral and experiential phenomena that occur within the domain of such a fundamental activity.

2.4.3 Fundamental Rhythmic Processing

Music is comprised of three main elements, and it is important to treat them as three separate things. Rhythm processing and melody processing are important elements of music production. Investigation of music component processing (melody and rhythm specifically) need to be investigated independently.

With regard to rhythmic processing, Chang and Trehub (Chang & Trehub, 1977) demonstrated that infants could distinguish among different rhythmic patterns without the aid of pitch as an auditory cue. Jones found that adults are able to separate rhythm from tonal melodies, "Adults in listening to speech and music are able to use their experience with similar patterns to focus their attention on critical moments in the on going stream of stimuli to pick up important information."(Jones, 1981, p. 557) From an early age humans have the capacity to distinguish among different rhythmic patterns, a skill which does not diminish as they get older. As a child, humans can identify a specific rhythm among a set of rhythms, and as an adult humans develop the ability further to the point they are able to recognize the specific rhythms in melodic constructs.

While melody is comprised of an arrangement of individual pitches, rhythm deals with intensity and arrangement of silence and sound. To recognize and produce a specific pitch requires a certain level of priming. For example, the C-Major scale consists of 7 unique pitches (C-D-E-F-G-A-B), to recognize any of those tones individually requires training in perfect pitch, a skill which can take years to become proficient at. While many musicians claim to have perfect pitch, few actually do (Sacks, 2008; Chang & Trehub, 1977). Similarly, to recognize a scale played in a specific tempo requires familiarization with the melody. In other words, melodies are linked to previous memories. That is why 10 people can hear the same melody, and have 10 different reactions to it. Their mind maps the melody to other similar melodies, which recall prior experiences(Jones, 1981; Chang & Trehub, 1977). Rhythms are processed differently, and do not cause the same type of response. Rhythm recognition and replication, or the generation of new rhythms is a natural activity that does not require the same type of training as melody recognition or perfect pitch(Chew, 2010; Downling, 2002).

Rhythm production and processing are skills that are present at birth, and continue to develop as the we age. Melody and rhythm processing each have their own distinct characteristics. This thesis focuses work within the domain of rhythm production and processing. How do drummers of different experience levels interact within the domain? What kind of impact does digital technology play?

2.5 Music For/With Others

Music performance, whether for or with others, can be seen as a type of human activity. It may be a joint activity, in which case coordinated actions of music production are dependent on the context of what was previously played, and the direction the musicians wish to go with the piece(Crick et al., 2006). It may also be a single human acting alone, generating rhythms and melodies without a specific goal, but instead for the experience of creating music(Schmidt, 1994). This section focuses on different elements of music performance. What influences performance? How does prior experience of a performer influence their experience? How does it influence the experience of other musicians they are performing with?

2.5.1 Performance

As discussed earlier, music performance may take the form of a singular musician, or a form of joint activity in which two or more people coordinate to create a singular piece of music. For the purposes of this thesis, we will focus on multiple musicians playing together. For these groups of musicians performing together, there are many different personal elements that may impact the individual musician's experience and the overall performance. The performance is the joint activity, where the music is the outcome.

Anxiety about performing, expectation of the performance, and ability of the performer in comparison to other musicians can all influence a performance. Two characteristics of performance that can influence a performance are: *self esteem* and *interaction with others*. Feelings of self may impact not how a performer behaves, as well as how they view the performance (Gurevich, 2006; Downling, 2002). These may come from prior experience with performance, but may also come from feelings of inadequacy in comparison to others. Interaction with others focuses on the interactions between musicians instead of the individual needs of the musicians. This can be described as a form of situated action, but rooted in experience-driven behavior, rather than goal-driven behavior.

The process of understanding music may be carried out automatically, as opposed to conscious analysis, when the elements of information arrive to the listener in rapid succession (Chew, 2010). Musicians do not need to consciously process music, instead focusing on responding to it. Nijholt et al; (Nijholt et al., 2008) focus on human and virtual human interaction. In their work, they discuss the implementation requirements of a virtual conductor. The virtual conductor assumes the leader role over a human orchestra. In order for the virtual conductor to effectively lead the humans, it must have prior knowledge and reciprocal awareness, as discussed by Schmidt (Schmidt, 1994). It is not enough for the virtual conductor to recognize an erroneous tempo from one of the human musicians and immediately start playing the correct tempo, because the human musician will be lost. Instead, the virtual conductor must make small incremental adjustments, based off of reciprocal awareness as well as anticipated action

Orchestras provide guidance through predefined pieces of music. The goal of the musicians is to play the piece with high representation of it's original composition. How does the presence of a computer agent in the collaborative process influence the performance or activity?

2.5.2 Prior Experience

Similar to the discussion of prior experience in the *Cooperation and Synchronization* section, this section discusses the relationship of prior experiences to current and anticipated actions and activities. As noted before, prior experiences can manifest as feelings and opinions as generic as "those four years at college" or as specific as "that man selling smoothies on the beach in the rain during our last trip." All of these memories can affect the actions a person makes, and the influence of opinion they have on the other people they interact with. Within the domain of music performance, this means differences in both the experience and performance.

Differences in the prior experience of players can have a profound impact on the performance and the subjective experience. People bring different kinds of skills to tasks, and have different expectations for how the task will go. Crick (Crick et al., 2006) notes that humans are particularly good at anticipating and harmonizing with rapidly changing environments in real time. Drake(Drake et al., 2000) emphasizes the importance of these skills in relation to rhythm attention. Blaine notes that mixed abilities among the musicians can cause group dynamic difficulties that lead to the exclusion of less proficient players (Blaine & Perkins, 2000).

Perhaps because they anticipate exclusion, inexperienced musicians often have fears about performing with other musicians or in front of others. Gurevich((Gurevich, 2006; Downling, 2002), p. 822) refers to this anxiety as the Amateur Musicians Paradox. "I want to play with other people, but I dont want to be embarrassed." Tools such as Jamspace (Gurevich, 2006) address this anxiety by allowing inexperienced drummers to collaborate anonymously over the Internet with other various skilled drummers. This anonimity, at least in the Jamspace situation, helped drummers overcome issues of inhibition and intimidation.

Seifter and Economy (Seifter & Economy, 2003) discuss responsibility in performance. In their orchestra experience, the buy-in to the experience is directly related to the responsibility of the performance as a whole, "...individual member is directly and personally responsible for the quality of our performance. Theres no one to hid behind or to pass the buck to."(Seifter & Economy, 2003) One musician was quoted, "I feel responsible for ensuring that our concerts arent just good, or even great, but that theyre as close to perfection as possible."(Seifter & Economy, 2003) The responsibility a person feels to perform a certain way will affect the experience they have in the activity.

Drumming itself is thought to alleviate some of these concerns, "By attributing less relevance to the importance of traditional music metrics based on melody, more emphasis can be placed on metrics that involve the players experience."(Blaine & Fels, 2003, p. 129) Gurevich's work also alleviates some of the stress by reducing the amateur musicians paradox. Does Guervich's phenomena hold true when experienced musicians are performing with technology? As discussed before, more than proficiency with an instrument can cause affect performance expectations. How does the performance change for the musician when their partner is a piece of technology?

Collaborative Drumming

There are many different types of collaborative music production environments. Orchestras are an example of a group of musicians coming together to play a predefined structured piece of music, with changes made on the fly by a conductor (Seifter & Economy, 2003). Often orchestras are comprised of members that meet a relatively high threshold of proficiency. This can be daunting to less experienced musicians. The drum circle is an example of a collaborative music creation task that facilitates both inexperienced and experienced musicians. The drum circle is like brainstorming, in that it attempts to create an ethos in which everyone is invited to participate without criticism. Weinberg praises drumming circles for their rhythmic, improvisatory and collaborative nature. Drum circles offer participants the ability to freely switch from a follower to a leader role (Blaine & Fels, 2003). There does not need to be a defined leader though, as this free-flowing collaboration is more focused on the joint activity and interactions than the roles of the participants. In the realm of spontaneous flow in collaborative musical environments, musical complexity is not limited to the use of highly skilled instruments. Projects such as Machovers Toy Symphony (Jennings, 2003) demonstrate the sophistication that can occur with even simple instruments.

Previous experience is thought to be helpful when participating in a drum circle, but it's relevance is dependent on the skill type. Blaine notes that physical mastery and musicality are partially separate attributes of the musician (Blaine & Perkins, 2000; Blane & Forlines, 2002). Just as a classically trained pianist, however musical, may have difficulty performing on the French horn, so too will she have difficulty performing on a digital French horn. Blaine found that limiting the number of notes or sounds an action triggers is related directly to the ease with which a new interface can be learned. The relevance of the physical skill developed on other instruments may have have positive impact on theory and how a musician approaches a task, but technical proficiency is still a skill that must be learned through practice.

The fact that the drum circle offers the opportunity for a collaborative music creation task that facilitates both inexperienced and experienced musicians makes it the ideal testbed for this thesis. The environment allows participants of varying experience levels to collaborate in an experience-driven activity, focusing on the improvisatory and collaborative nature of the event.

2.6 Summary

This chapter investigated cross-cutting themes of research in collaborative music, CSCW and HCI literature. From these areas, four areas of research were identified for investigation. The first was *Orchestration of Human Activity*, which explored various elements of human interaction through collaboration and cooperation. This section investigated how people interact through joint activities, and the different types of behaviors that can influence action in an activity. While there has been a large body of work investigating situate action, there has been little work investigating the domain of activities that are not goal-driven. How do people act when their task isn't about reaching a final goal, but about the experience of the task itself?

The section, *Orchestration of Language* focused on how people use language, in particular to communicate and get things done. Music production and perception was presented as a kind of language use, as it has the capacity to allow people to communicate emotion and meaning. It is an expressive medium that may be used to bring about a state of affairs in the world. The ways in which music resembles and departs from language cast light both on the nature of music and the nature of language. Signals were discussed as a way to synchronize behavior and coordinate actions. The relevance of music as a research area to HCI and CSCW was outlined.

The third section, titled *Music* explored elements of music and music interaction relevant to collaboration and in-the-moment behavior. The relationship of music and human development was outlined through cognitive psychology literature. How humans process music was discussed from infants to adulthood. It is important to draw a distinction between this work and related studies in other fields. While there is strong connection between perception and action within the neuro-science and cognitive science domains, the focus of this work is on the behavioral and experiential phenomena that occur within the domain of such a fundamental activity. Rhythm is an underlying theme throughout language use and synchronized collaborative tasks. Because of that, investigation into rhythm through music was a natural research direction.

The final section, *Music For/With Others* investigated the performative nature of music, including both single-musician and collaborative performances. This section elaborated on the prior experience work from earlier sections, focusing on prior experience in reference to music production and perception. Although it has been acknowledged that music performance can take place without others, this work is scoped in a way to focus on dyadic, collaborative performances. These performances do not necessarily need to be between two humans. As discussed in this section, interactions may take place between humans and other humans, or humans and computers. This gives situational context to earlier work discussed in the first two sections.

The focus of this thesis is on the experience of working on the collaborative task of producing rhythmic music using a hand-held interface to a drum-like synthesizer. Collaborative activities have the capacity to be better than the sum of their parts, yet making music is a classic example of a task that is at times associative; that is, a task in which the performance of the whole is gated by the least competent performer. The subjective processes associated with the task of rhythmic music production by inexperienced and experienced participants working collaboratively either with a human or computer partner to produce complex polyrhythmic sounds are investigated. Specifically, the subjective experience of music production and the behavioral interactions between activity participants and partners were assessed. Specific details of the experimental setup are given in the next chapter.

Chapter 3

Experimental Design

3.1 Introduction

The Digital Drumming study was designed to investigate creative task collaboration with respect to coordination. Associated subjective processes of experienced and inexperienced drummer participants when paired with an experienced partner (human or computer agent) were also evaluated.

In total, three individual experiments were developed as part of Digital Drumming. Each experiment is addressed in detail below. To highlight, experiment one was developed as a two-by-two factorial study. The experiment paired human participants of varying experience levels with an experienced partner that was either human or computer. The independent variables in experiment one were: experience level of participant (experienced or inexperienced) and type of partner (human or computer).

Experiments two and three were supplementary studies that provided grounding to the results of experiment one. Experiment two was developed as a single independent variable study: experience of participant (experienced or inexperienced). This experiment paired human participants of varying experience levels with an experienced partner that was human, and replaced the iPhone instruments with analog hand drums. Experiment three was developed as a single independent variable study as well: experience of participant (experienced or inexperienced). This experiment paired human participants of varying experience levels with an experienced partner that was a computer playing back a human-generated drum track.

Across all 3 experiments, each session began with a self-reported pre-session questionnaire, a tool used to evoke participant opinion through multiple choice and short answer responses. Participants were asked to complete a second self-reported post-session questionnaire at the end of each session.

This chapter describes the experiment protocol that was developed, as well as details of the three experiments that were conducted for this thesis. Details regarding population type and size are discussed in each experiment's description. The self-reported pre-session questionnaire and self-reported post-session questionnaire are described separately from the experiments, because they were a common tool used regardless of experiment type. Hardware and software implementation details are described in individual sections as well. Behavior interaction coding, inter-rater reliability and statistical measures are discussed at the end of the chapter.

3.2 Experiment Protocol

As part of Digital Drumming, a strict experiment protocol was developed to help mitigate variability between sessions. Each session began by greeting the participant(s) outside the laboratory. For the purposes of coherency, the term participants will be used to describe the participant and partner in this section. Participants and partners were unaware of their unique role in each dyad. Once inside, each participant was presented a copy of the VT-IRB approved IRB consent form. Upon reading and agreeing to the terms of the experiment, each participant was asked to complete a self-reported pre-session questionnaire. Each participant completed the questionnaire on an individual computer located in the same room of the laboratory. It is important to note that at no point was the topic of prior experience level of each participant discussed, although it was referenced in the self-reported pre-session questionnaire.

Upon completion of the questionnaire, the participants were lead to a separate area of the laboratory where the hardware for the experiment had been set up. The specific setup varied based on the type of experiment (1, 2, or 3) and the participant:partner dyad (human:human or human:computer) for that specific session. Specific setup details are discussed in upcoming subsections.

After the self-reported pre-session questionnaires were completed, the primary investigator verbally summarized the details of the experiment to the participant and partner (if applicable). The primary investigator explained that their (the participant and partner) task was to, "collaborate with your partner to create a poly-rhythm that sounds good to you." This key-phrase was used to align purpose of the experiment to a self-assessment, in an attempt to mitigate the anxiety amateur musicians experience through the Amateur Musicians Paradox (Gurevich, 2006).

For the drumming activity, participants paired with human partners were positioned in chairs initially facing each other 3 feet apart. Participants paired with a computer partner were initially positioned facing the computer 3 feet away at the opposite side of a desk. Initially in front of each participant on the desk was an Apple iPhone or iPod Touch and a set of computer speakers at their feet.

The actual task of drumming took place in three phases: training/orientation, session 1, and session 2. The training/orientation portion of the experiment involved a 5 minute tutorial about the instrument, either the iPhone or the analog hand drum. Participants were told to freely explore the instrument during this time, to better understand the possibilities of sound production. This time was also used by the principal investigator to perform last minute configurations and volume adjustments.

After the training phase, participants started session 1, in which they performed for 5 minutes. In order to normalize the human-human and human-computer pairings, each pair was presented with an example drum loop prior to the beginning of each session. Instructions were given that the example drum loop was meant only as possible inspiration, and not an instructional piece. Participants who drummed with the computer partner were seated slightly angled toward the computer screen to facilitate possible visual cues from watching the display of the computers progression through the loop on Garageband. This was not stated to the participants. Upon completion of the session, participants were asked if they felt comfortable continuing the experiment, or if they would like to take a short recess. Session 2 then began, consisting of another 5 minute performance.

Upon completion of the three drumming phases, participants were escorted back to the computer area of the laboratory, where they were asked to complete a self-reported post-session questionnaire. Each participant completed the questionnaire on an individual computer located in the same room of the laboratory. There was no talking among participants and partners after the drumming session and before the questionnaire. After questionnaire completion, the principal investigator asked the participants if there were any additional comments they would like to make about the experience that were not addressed in the self-reported post-questionnaire. Participants were thanked for their time and excused from the laboratory.

3.3 Self-Reported Pre-Session questionnaire

At the beginning of each session, participants were asked to complete a self-reported pre-session questionnaire. The questionnaire was the same regardless of experiment type. The questionnaire was hosted on survey.vt.edu, and each participant was given a unique identification code that denoted no categorical data to the participant. Answering any or all of the questions was voluntary, and could be left unanswered at the discretion of the participant without voiding the remainder of the questionnaire.

The purpose of the questionnaire was to collect demographic data on the participant population. Participants were asked to provide their age and gender. Participants were then asked a series of 4 questions, each requiring a "'yes" or "no" answer. After each question, a large text area was provided for a more detailed answer. Three questions were chosen to evaluate participant rhythm abilities across analog and digital technologies. Participants were categorized as experienced drummers if they had professional experience in response to any of the three questions, or if they were had experience with any of activities in question for over 3 years. The computer was classified as experienced status, because of its structured playback.

It should be noted that the group inexperienced human participant paired with inexperienced human partner was intentionally avoided. This was only applicable in experiments one and two, where human participant and human partner dyads were used exclusively. The rationale was that in collaborative drumming events, such as drumming circles, a drummers individual playing style would be influenced by the sounds around them (Weinberg et al., 2006; Shepard, 2002). To provide structure to the experiment activities, as experienced entity was present in every group.

The questions were written to scope from no experience or general musical experience (*Do you have any experience playing musical instruments?*), to rhythmic orientated tasks (*Do you have any experience drumming?*), to specific drum circle experience (*Have you ever listened to/been involved in a drum circle before?*). Finally, participants were asked if they had prior experience interacting with a touch screen device before, such as an Apple iPhone/iPod Touch. As a probe to understand the musical background of the participant, one question asked participants to list specific artists and genres of the kind of music they "liked to listen to" (specific wording from questionnaire). This information was collected to build a deeper understanding of the background each participant was influenced by.

3.4 Experiment Summaries

3.4.1 Experiment 1: Human Participant and (Human or Computer) Partner Digital Drum Dyad

This experiment was the primary study of the set. In experiment 1, human participants were paired with a partner, and asked to, "collaborate with your partner to create a polyrhythm that sounds good to you." Participants were given an Apple iPhone or iPod Touch device running a drum machine simulator as an instrument, and collaborate with a human or computer partner. If the partner was a computer, it played a pre-defined set of looped computer-generated drum beats. If the partner was a human, they were given the same instrumentation as the participant. The experience level of the partner was always experienced.

This experiment consisted of two independent variables: experience level of participant (experienced or inexperienced) and type of partner (human or computer).A total of 20 participants were recruited from the Research in Gaming list server, an undergraduate CyberArts class, and through word of mouth via a local drum circle for a total of 20 dyads. Twenty-one males and nine females participated in the experiment. The average age of participants was

Figure 3.1: Experiment 1: Human Participant and Human Partner Dyad

19.9 years, with a standard deviation of 0.85 years.

Participants were divided equally into one of four types of pairings: inexperienced human participant paired with experienced human partner, experienced human participant paired with experienced human partner , inexperienced human participant paired with computer partner, or experienced human participant paired with computer partner. Each participants experience level was assessed during recruitment and scheduling.

3.4.2 Experiment 2: Human Participant and Human Partner Analog Hand drum Dyad

This experiment was developed as a comparison study to examine the effects of drumming without digital technology. In Experiment 2, human participants were paired with a human partner, and asked to, "collaborate with your partner to create a polyrhythm that sounds good to you." Participants and partners were given individual analog hand drums as an instruments. The experience level of the partner was always experienced.

This study consisted of one independent variables: experience level of participant (experienced or inexperienced). A total of 20 participants were recruited from the Virginia Tech Psychology Experiment Management System, an undergraduate CyberArts class, and through word of mouth via local drum circles and musicians for a total of 20 dyads. Twelve(12) males and 8 females participated in the experiment. The average age of participants was 21.7 years, with a standard deviation of 2.19 years.

Participants were divided equally into one of two types of pairings: inexperienced human paired with experienced human, experienced human paired with experienced human. Each

Figure 3.2: Experiment 2: Human Participant and Human Partner Analog Drum Dyad

participants experience level was assessed during recruitment and scheduling. [Elaborate on what the point of this study was.]

3.4.3 Experiment 3: Human Participant and Computer Partner with Human Playback Track Dyad

Similar to experiment 2, this study was developed as a comparison study to examine the effects of drumming with a computer playing a human-generated drum track. In experiment 3, human participants were paired with a computer partner, and asked to, The experience level of the partner was always experienced. Participants were given an Apple iPhone or iPod Touch device running a drum machine simulator as an instrument, and collaborated with a computer partner. The computer played a pre-defined track of human-generated drum beats.

In experiment 1, the computer played back a pre-recorded, computer-generated drum track that was based on a metronome track, or click track. The human-generated drum track for this study was chosen out of 5 possible tracks by a group of graduate students. The track was described as having the most *natural* feel. The term *natural* was not specifically defined.

This study consisted of one independent variable: experience level of participant (experienced or inexperienced).A total of 20 participants were recruited from the Virginia Tech Psychology Experiment Management System, an undergraduate CyberArts class, and through word of mouth via local drum circles and musicians for a total of 20 dyads. Thirteen (13) males and 7 females participated in the experiment. The average age of participants was 20.95 years, with a standard deviation of 3.62 years.

Figure 3.3: Experiment 3: Human Participant and Computer Partner Digital Drum Dyad

Participants were divided equally into one of two types of pairings: inexperienced human paired with computer, or experienced human paired with computer. Each participants experience level was assessed during recruitment and scheduling.

3.5 Self-Reported Post Session questionnaire

After the participant completed the two drumming activities, they were asked to complete a self-reported post-session questionnaire (see Appendix A). The questionnaire was the same regardless of study type. The questionnaire was hosted on questionnaire.vt.edu, and each participant used the same unique identification code they were given earlier when completing the self-reported pre-session questionnaire. All questions were voluntary, and could be left unanswered at the discretion of the participant.

The purpose of the self-reported questionnaire was to collect experiential data from the participant's perspective. Participants were asked to rate 4 separate characteristics of the experience individually on a five-point Likert scale. Participants were asked to rate their enjoyment of activity, frustration of activity, the importance of their partner, and how likely they were to recommend the experience to a friend. After each question, a large text area was provided to allow participants to give a detailed response. The rationale for the four Likert-rated questions has been discussed in more detail below.

Besides the four Likert-rated questions, participants were asked to answer six short answer questions related to their actions and specific moments of the sessions. The first question participants were asked was to describe the techniques used to create a drumming sound. This question was intended to be open-ended to act as a probe to get participants thinking about what physical movements, as well as what collaborative techniques were used.

Participant's perceived coordination and coordination with their partner were addressed through several individual questions. Participants were asked to identify moments they felt a loss of cooperation or coordination. A separate question asked how well the participant felt they cooperated or coordinated with their partner. Cooperation and coordination were addressed as separate constructs, resulting in four individual questions on the questionnaire.

Likert-Rated Questions

In the self-reported post session questionnaire, four questions required a 1 to 5 rating of the experience. The questions asked:

- Experience Enjoyability
- Experience Frustration
- Importance of Partner
- Experience Recommendation to Friend

Each question was designed to address a different aspect of the user experience to be compared across experience levels and partner types. Enjoyability was addressed because of it's correlation to repeated use/adoption of a task (Kolko, 2008; Kaasinen, 2005). The idea being that the more enjoyable an activity is, the more positive their perceived experience will be.

It is possible for an experience to be skewed by the prior experience or expectations a participant has. As discussed in the literature review chapter, prior experience of the participant, and of the other agents in the activity can also skew the experience. The expectation of the activity (unrelated to the goal of the activity) can also have an effect on the perceived experience. The frustration measure addressed those issues.

The participant's perceived view of the importance of their partner in the task addressed the view of the participant's partner. One of the independent variables in 2 of the 3 experiments was partner type, asking the participant what their view of the partner was provided incite to the relationship they (the participant) felt they had. The final question was designed to address the overall buy-in a participant felt to the experience. This question came from social media and interrelationship research [cite 3 papers on social circles]. According to the literature [cite 1 paper], participants were more likely to recommend an activity/place/thing if they had a positive experience with it. This is analogous to a person recommending dinner plans to a friend, under normal circumstances they would not recommend a place that they expected to have a bad time going to.

The purpose of these questions (combined with other questions on the self-reported post questionnaire) give perspective to the perceived experience of the participant. In order to get a deeper understanding of what the experience was, these results were corroborated with the categorical session codings (discussed in the following chapter). This provides 2 perspectives of the experience: *what was the perceived experience of the participant during the experiment*, and *what was the participant actually doing during the experiment.*

3.6 Implementation

In order to put the digital drumming experiments into practice, specific hardware and software solutions had to be used. Instrumentation had to be similar in digital and analog forms. The digital instruments had to sound like real drums, not like 8-bit samples from the 1980s. The section outlines the design implementation used for the experiments. Specific hardware and software solutions are discussed, as well as differences between the digital and analog drums (or drum simulator).

3.6.1 Implementing an electronic drumming activity

Experiment 1 and experiment 3 required constructing an electronic drumming dyad. The interplay between participant and partner represented the types of coordinated actions that take place in larger drum circles.

Weinberg points out that electronic drumming circles are limited by the electronic reproduction and amplification of sound through speakers (Weinberg et al., 2006). These cannot fully capture the richness of acoustic sound. This suggests a choice between accepting or fighting this limitation in the current study. Instead of competing with the real world implementation, we synthesized all sounds. Drummers were given a device that triggered sound playback through a set of stereo speakers. The computer also was set to play through a set of stereo speakers. Each partners drum sounds were played through an individual set of stereo speakers as an attempt to simulate real world sound production, and to maintain a sense of individuality.

For the present work, the program Digidrummer on commodity touch screen devices was chosen to enhance the capacity of collaborative flow. The final interface chosen for this study consisted of eight large touch sensitive button icons with a specific sound assigned to each.

3.6.2 Hardware environment

To maximize participant flexibility to move their input device to different positions during the drumming sessions, and to simplify the learning curve, Apple iPod Touch and iPhone devices were used. The basic hardware setup consisted of one Apple MacBook Pro 17" Core 2 Duo 2.33GHz laptop connected to one Apple iPod Touch device and one Apple iPhone device. Each iPhone or iPod Touch was connected to a Mackie 12-channel stereo mixer using 6-foot stereo $\frac{1}{8}$" mini plug to $\frac{1}{4}$" plug cable.

The Mackie stereo mixer had two purposes. Because the Apple devices provided low audio output levels, the Mackie mixer provided the needed additional amplification. It also acted as an A-B-Y line splitter. That is, to maintain a sense of individual contribution and realism during the improvisation sessions, each participant heard their own devices sound, isolated, through a set of speakers sitting at their feet. This simulated the sensation of playing a set of bongo-style drums.

Experiment 2 did not require Apple iPot Touch or iPhone instruments, instead using analog hand drums. Each participant and partner was issued a Latin Percussion LPM198 Mini Tunable Wood Conga Drum. The conga drums were tuned to the same pitch. Each drum was unmounted, and could be positioned at the discretion of the drummer. The drums were recorded using two directional microphones mounted 18-inches off the ground and directed at a specific drum. The microphones were connected to a M-Audio Firewire 410 mobile recording station. No amplification was necessary for the drums.

For the analysis portion of the sessions, each audio track had to be played back simultaneously. The mixer was used to package one participants signal to the left channel and the other participants' signal to the right channel. Four outputs emerged from the mixer; two were speaker outputs for monitor playback during each session, and two were used to relay audio signal to a M-Audio Firewire 410 mobile recording interface. The Firewire 410 converted analog audio to 24bit 96khz quality. Slight signal padding was used to adjust the signal from the mixer. The digital audio signal was transferred through an IEEE 1394 interface to the dedicated laptop.

3.6.3 Software environment

Participants used the drumming simulator software by Magnic, called *Digidrummer*. Digidrummer provided an interface to a drum-like synthesizer that was developed specifically for handheld devices. Digidrummer is compatible across Apples iPod Touch and iPhone platforms, making the two devices interchangeable for the purposes of this study. Digidrummer presented the participant with eight touch sensitive areas on the screen arranged in a two-by-four configuration.

During the drumming sessions, participants were limited to the "Bongo King" preset of drums. This preset featured five bongo drums of varying pitch, two timbales, and a tambourine. The touch sensitive pads were pre-assigned specifics sounds and could not be reassigned. Participants could touch any combination of pads simultaneously to trigger multiple high quality sounds, simulating real-world use of multiple drums.

During a pilot study where we compared several handheld drum-like synthesizers for the iPhone platform, latency was unreported by participants when using Digidrummer. Latency was not dependent on the number of simultaneous sounds triggered. Aside from single pad and simultaneous multi-pad triggers, participants had the ability to slide across any number of pads quickly to play back several sounds repeatedly. This technique also could be used between two pads to simulate a drum roll or similar trill effect.

The laptop was configured with Apple Garageband 09 version 5.0.1 for the study. Garageband is an audio recording suite that can record "real instruments", traditional instruments, or vocal parts that are captured using microphones or direct input. Garageband also records "software instruments", non-traditional input where USB, MIDI devices, or on-screen keyboard are used to create sounds using MIDI files and pre-defined loops. For the purposes of this study, each iPhone or iPod Touch device was assigned to an individual real instrument track. This allowed for simultaneous and individualized playback. Using individual tracks also allowed volume adjustment of each device, which was useful when listening to a human-computer paired session.

Another feature utilized in Garageband 09 in this study was the ability to handle loop creation. Loops are segments of music that are played back to back repeatedly to generate a longer piece of music. Traditionally drum tracks are a popular loop medium because of their rhythmic nature. For this study, two separate sessions were run per participant pairing. The first session consisted of two metronome click beats that looped for 75 seconds before alternating to the other beat. The second session consisted of two different beats. These beats were representational of real world drum sounds; one was an example of syncopation and the other emphasized varying tempo to create space. The second session alternated between loops every 60 seconds.

Garageband 09 also features global tempo control of a project. This feature was used to normalize the loops for each session to 90 beats per minute. The tempo rate was chosen from an informal study and proved to be a comfortable rate for participants.

3.7 Behavior Analysis

As part of the experimental design, data analysis of the actual drumming sessions was planned. This provided information about what participants were actually doing, where as the self-reported pre-session and post-session questionnaires provided information about what participants perceived their experience to be.

3.7.1 Interaction Codes

In order to analyze the interactions present in each session, a criteria had to be established. Interactions were determined by *rhythm pattern*, Winnold(Winold, 1975) defined rhythm pattern as "a (repeating) series of identical yet distinct periodic short-duration stimuli perceived as points in time." Interactions were also determined by the simultaneity of the musicians playing. As a third criteria *tempo*, defined as the speed of the music, was used to identify interactions.

In order to determine what to code, *utterances* had to be identified. This term was borrowed from language composition analysis work, and refers to a complete, sometimes bounded fragment of language. In this case the language was music. Utterances were bounded by transitions, which were identified as changes to the tempo or rhythm of the current session, initiated by either the participant or partner, that caused the other party to change the tempo or rhythm they were currently playing.

In total 6 interaction codes were developed. A process similar to open coding was used to create the codes, in which a coder listened to each session and made notes about what they heard in terms of rhythm and tempo exchange. Those notes were then grouped according to common trends, and categorized. As shown by table-3.1 and table-3.2, there were 6 codes: *Mirroring*, *Stereo*, *Call and Response*, *Chorus*, *Counterpont*, and *Disconnected*. Given the possible combinations of rhythm pattern and tempo, there were 2 interactions that were possible to create but were extremely difficult to produce and were not heard in the session transcriptions. The rhythm, tempo, and synchronous play characteristics are shown in the tables below.

		Rhythm	
		Same	**Different**
Tempo	**Same**	"Mirror"	"Stereo"
	Different	"N/A"	"Call & Response"

Table 3.1: Non-Simultaneous Play Interaction Categories

		Rhythm	
		Same	**Different**
Tempo	**Same**	"Chorus"	"Counterpoint"
	Different	"N/A"	"'Disconnected"

Table 3.2: Simultaneous Play Interaction Categories

3.7.2 Inter-Rater Reliability

Inter-rater reliability was needed to add validation to the analysis of the drumming sessions. Two raters, one a professional musician of 15 years, the other an accomplished drummer of 10 years, were used to apply categorical codes to fragments of the drumming sessions. The statistical analysis tool, Cohen's Kappa was used to compare the two rater's results. Cohen's Kappa was used because it relies on absolute position when calculation correlation, unlike

Spearman and Pearson which relies on relative position of codings (Saal, Downey, & Lahey, 1980). It also takes into account the agreements that can occur by random chance.

Along with Cohen's Kappa, a percentage of agreement analysis for each code was also performed. This statistical measure is said to be less robust than Cohen's Kappa because it does not take random rater agreements into consideration. Some research (Strijbos, Martens, Prins, & Jochems, 2006) have noted that the k value in Cohen's Kappa takes observed category frequencies as given values. This can lead to underestimating agreement levels for a more commonly used category (Saal et al., 1980; Strijbos et al., 2006). Uebersax (Uebersax, 1987) posit that this is untrue, and to properly account for chance agreement would require a model demonstrating the correlation between chance and rater's decisions.

Both percentage of agreement measures and Cohen's kappa coefficient measures were provided to provide a robust analysis of the rater agreement. Because of the disagreements within the community about the validity of the k in Cohen's kappa, the percentage of agreement analysis helps provide a more robust visualization of the rater's agreements, as well as where disagreements occurred.

Chapter 4

Results

4.1 Introduction

The Digital Drumming study was comprised of three experiments. To review, experiment one was a two-by-two factorial study that investigated inexperienced versus experienced human participants playing digital instruments, paired with an experienced partner. The partner was either an experienced human also playing a digital drum instrument, or a computer playing back a pre-constructed drum track. The results showed that participants reported different experiences when paired with a computer then when paired with a human. When participants were paired with a computer, the reported ratings of enjoyment and the importance of partner were on average higher than when paired with a human partner. Participants reported a statistically significant higher rating for recommending the experience to a friend when paired with a human partner. Two additional experiments were performed to further investigate what impact technology played on the results.

Experiment two investigated inexperienced versus experienced human participants paired with experienced human partners. Participants and partners played analog hand drum instruments instead of the digital instruments used in experiment one. This study investigated how humans experienced the activity of collaboratively interacting while working with analog tools and a human partner. In reviewing the results from experiment one, an unintentional interaction was noticed. The original experimental design constructed two dyadic types that paired humans participants with a computer partner. Some peer reviews noted that all participants used a digital device to generate music, which could be viewed as a mode of interaction. In that sense, some dyads had two separate interactions with technology. Although this did not invalidate the original study, it did raise the question, *to what extent did the digital instrument influence the experience?*

Experiment three investigated inexperienced versus experienced human participants paired with a computer partner. Similar to experiment one, the computer partner used a pre-recorded drum track for playback. This drum track was a recording of a human playing a digital drum, not a computer generated digital drum. In reviewing the results from experiment one, a reoccurring comment from reviewers and participants was that the computer track was very rigid, and non-responsive to the participant. To help mitigate this, an expert track was selected from 3 human generated tracks, and used as playback instead. The purpose was not to implement a dynamic responsive system, but to add a human element to the playback (including off-timing sounds and repetitious patterns). The goal of these experiments was to help isolate at what point humans were interacting with technology, and how that influenced the experience of the creative task. Specifically, the subjective experience of music production and the behavioral interactions between activity participants and partners were investigated.

This chapter presents the results of the data analysis of each of the three experiments. Data presentation is divided into two types: *User-Reported Experiences* and *User Behavior Analysis*. The User-Reported Experiences section focuses on participants' responses to the pre-session and post-session questionnaires. Specifics of each questionnaire have been outlined in corresponding subsections at the beginning of the chapter.

The User Behavior Analysis section focuses on actions and interactions between participant and partner. Details of the development and use of the interaction codes are presented with regard to all three experiments. Inter-rater reliability validation was performed to provide a higher degree of validity to the occurrence of interaction frequency recognition. Specific details of the inter-rater reliability are discussed at the end of the chapter.

4.2 Experiment 1: (Inexperienced/Experienced) Human Participant : Experienced (Human/Computer) Partner

The first experiment was a two-by-two factorial study that investigated inexperienced versus experienced human participants playing digital instruments, paired with an experienced partner. The partner was either an experienced human also playing a digital drum instrument, or a computer playing back a pre-constructed drum track.

The post-session questionnaire results showed that participants reported statistically significant different experiences when paired with a computer then when paired with a human. Participants did not differ (in terms of statistically significant values) in their reported experiences of frustration, enjoyment, or their likelihood to recommend the experience to a friend. When participants were paired with a computer, the reported ratings of enjoyment and the importance of partner were statistically significant higher than when paired with a human partner. Participants also reported a statistically significant higher rating for recommending the experience to a friend when paired with a human partner. In terms of participant type, inexperienced participants paired with a computer reported ratings that were statistically significant higher than the reported ratings of experienced participants.

In terms of interaction behaviors, participants tended to play with the computer simultaneously more than taking turns. When looking at common trends between experience levels of participants, the occurrences of disconnected interactions was higher for inexperienced participants. This was true regardless of a computer partner or human partner. When comparing experienced participants paired with computers to experienced participants paired with humans, overall frequency of events was higher for each category. Experienced participants did more things when paired with human partners. Experienced participants also played asynchronously more often than inexperienced participants, with experienced participants paired with human partners using *"Mirroring"* (category 1) and *"Stereo"* (category 2) more than any other dyad type. Participants paired with a human partner exhibited more asynchronous playing, regardless of participant experience type.

4.2.1 User-Reported Experiences

The user-reported experiences and attitudes were collected through questionnaire data collected immediately before and after the recorded sessions. No discussion was held before the participants completed their questionnaires. This was to ensure validity to the answers given. Participants completed the pre-questionnaire and post-questionnaire in the same room as their partner. For sessions that involved a human participant playing with a computer partner, the participant completed the questionnaire on a different computer but in the same room. According to Nass (Nass & Moon, 2000), when users are reporting on an experience they had while interacting with a computer, questionnaire scores are higher when they are reporting on the same machine they are being asked about.

Participants Profile

This experiment was conducted with 30 participants recruited from the Virginia Tech Research in Gaming list server, an undergraduate CyberArts class, and through word of mouth via a local drum circle. There were 20 dyads constructed, with an n=5 for each of the four conditions. Twenty-one (21) males and 9 females participated in the experiment. The average age of participants was 24.3 years, with a standard deviation of 2.49 years. The participants were approximately divided equally between people with and without drumming experience, and those with knowledge of, or participation in drum circles. More than 80% of the participants described having some experience with a touchscreen device, which was important because the instrument user interface was a touchscreen. The majority of participants self-identified as liking to listen to music that was rooted in rhythmic and melodic qualities.

Prior Experience and Attitudes

The pre-questionnaire was given to participants as they entered the lab, immediately after turning in a signed IRB consent form. Participants were asked about their previous musical instrument training. The majority of the population had experience with musical instruments, 83.34% reported experience of one year or more playing an instrument. Separately, participants were asked about their drumming experience, where 53.34% of participants noted that they had actual drumming experience. Participants were asked if they were aware of what a drum circle was, and if so had they ever participated in one. Over 53% (53.34%) of the participants noted they were aware of what a drum circle was, and 43.34% of the participants had some experience in a drum circle.

Participants were asked to identify the type of music they like to listen to, as well as to name several examples of each genre. This was used to identify the diversity of the drumming groups. They were allowed to select multiple choices. Of the 30 participants, 66.67% identified themselves as fans of rock or some derivation of rock (alt-rock, post-rock, classic-rock, punk-rock) music. Over 36% (36.67%) identified themselves as fans of classical music. Forty percent (40.00%) identified themselves as fans of hip-hop music, and 26.67% identified themselves as fans of country music.

In order to assess technological familiarity, participants also were asked if they had any experience using touch screen devices, such as the Apple iPhone or iPod Touch. Over 86% (86.67%) reported having previous experience with touch screen devices.

Post-Session Questionnaire

At the end of the session, each participant was asked to complete a post-session questionnaire consisting of 15 questions. There were four questions that asked participants to rate the quality of their collaborative experience using a 1 to 5 subjective rating scale (a value of 1 indicated the least favorable rating, whereas a value of 5 indicated the most favorable rating). The collaborative experience qualities assessed by these four questions were: *enjoyment of activity, satisfaction or frustration with activity, importance of partner to activity,* and *recommendation of drumming experience to a friend.* The remaining 11 questions on the post-session questionnaire solicited open-ended comments about the collaborative drumming experience. Information from these questions was used to establish context for the experiment observations and the interpretation of the data trends. Content analysis was not performed on the remaining questions.

Data from each of the four subjective rating questions was organized into a two-by-two matrix for statistical analysis purposes. For each matrix, there were two independent variables: *partner type* and *participant experience.* Partner type consisted of human or computer. Participant experience consisted of inexperienced or experienced. Statistical values of mean, standard deviation, and ANOVA are provided for analysis.

The results from the subjective rating post-session questionnaire ratings were equivocal. As shown in the following subsections, by several measures, both inexperienced and experienced participants preferred to collaborate with the computer over collaboration with another person. However, they were more likely to recommend the experience to a friend if they had collaborated with a person. This lead to further investigation (through experiments 2 and 3) of what was really happening when participants played with technology. Were the participants reacting to the novel nature of the interaction device? Or were they reacting to the predictable nature of the computer partner's playback?

Self-Reported Enjoyment Rating of Activity

	Partner Type	
	Human	**Machine**
Inexperienced Participant	Mean: 3.40	Mean: 4.20
	SD: 0.89	SD: 0.44
	N: 5	N: 5
Experienced Participant	Mean: 3.80	Mean: 4.00
	SD: 0.44	SD: 0.00
	N: 5	N: 5

Table 4.1: Experiment 1: Self-reported Enjoyment Rating of Activity by Participant

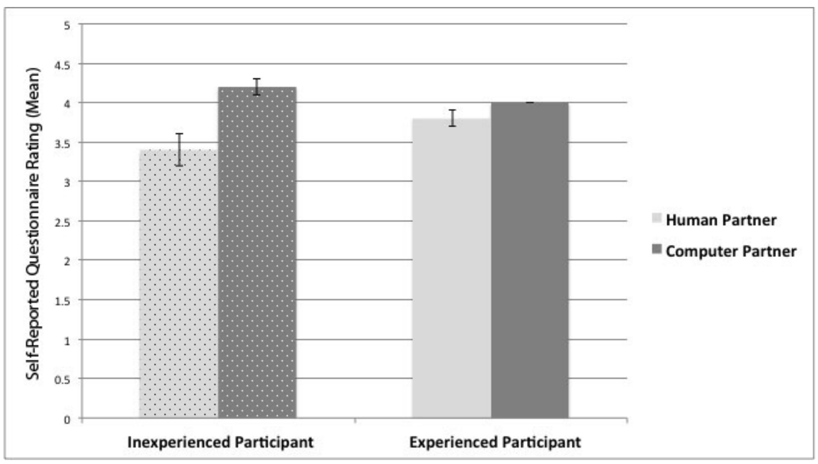

Figure 4.1: Experiment 1: Self-Reported Enjoyment Rating of Activity by Participant

As shown in figure-4.1, both inexperienced and experienced participants reported enjoying the experience more when paired with the computer than with a human partner. Table-4.1 shows there was an average rating of 4.1 (SD=0.31) when inexperienced and experienced participants were paired with a computer. When paired with a human partner, the average rating reported was 3.6 (SD=0.69) (Table-4.1), [$F(1,16) = 4.167$, $p = 0.058$]. Because this p-value is extremely close to the traditional $p=0.05$ significance rule, it suggests a need for further investigation.

Self-Reported Frustration Rating of Activity

	Partner Type	
	Human	**Machine**
Inexperienced Participant	Mean: 3.00	Mean: 2.60
	SD: 1.00	SD: 1.34
	N: 5	N: 5
Experienced Participant	Mean: 3.60	Mean: 2.20
	SD: 0.54	SD: 0.44
	N: 5	N: 5

Table 4.2: Experiment 1: Self-Reported Frustration Rating of Activity by Participant

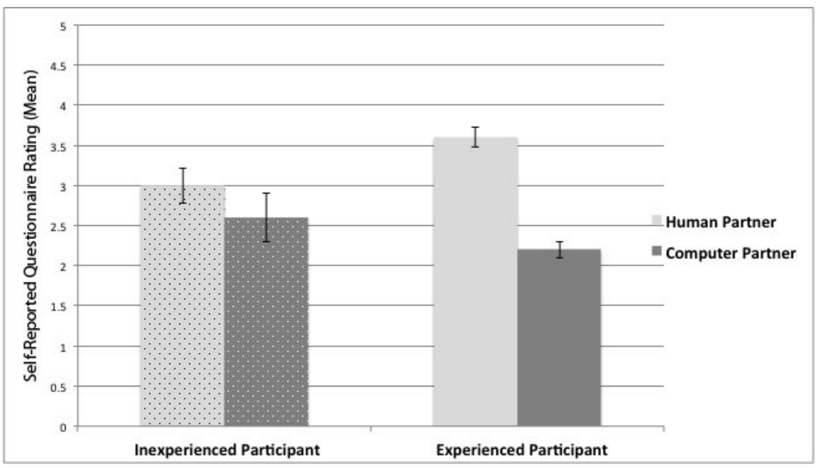

Figure 4.2: Experiment 1: Self-Reported Frustration Rating of Activity by Participant

As shown in figure-4.2, experienced participants reported a statistically significant higher frustration rating when paired with a computer partner than a human partner [$F(1,16) = 4.909$, $p = 0.041$]. Inexperienced participants reported a statistically significant higher frustration rating than experienced participants when both paired with a human partner. Table-4.2 shows the average rating of frustration reported by inexperienced and experienced participants paired with a computer was 3.3 (SD=0.82), while those paired with a human reported an average rating of 2.4 (SD=0.96). A reminder: lower scores represent a greater rating level of frustration.

Self-Reported Importance of Partner Rating of Activity

	Partner Type	
	Human	**Machine**
Inexperienced Participant	Mean: 4.00	Mean: 5.00
	SD: 0.70	SD: 0.00
	N: 5	N: 5
Experienced Participant	Mean: 2.80	Mean: 3.40
	SD: 1.30	SD: 0.54
	N: 5	N: 5

Table 4.3: Experiment 1: Self-Reported Importance of Partner Rating of Activity by Participant

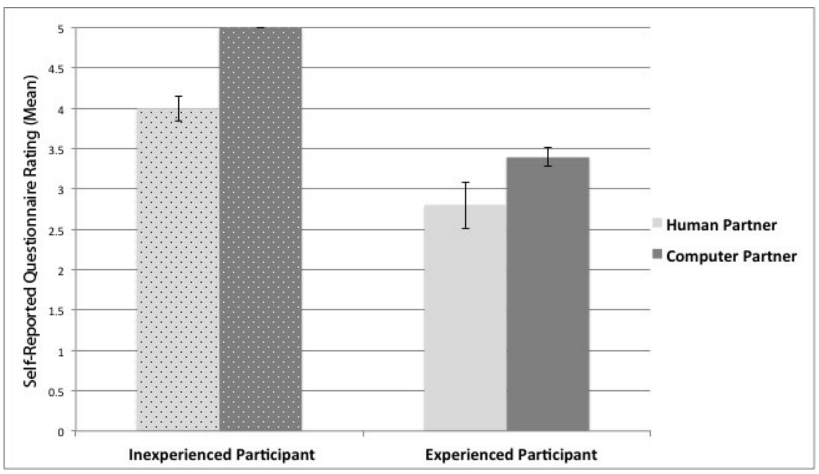

Figure 4.3: Experiment 1: Self-Reported Importance of Partner Rating of Activity by Participant

Table-4.3 shows that inexperienced participants rated the importance of the partner as 4.5 (SD=0.70), while experienced participants rated the partner as significantly less important, 3.1 (SD=0.99), [F(1,16) = 15.680, p = 0.001]. This was true whether the partner was a computer or a human.

Overall, both inexperienced and experienced participants rated the importance of a partner statistically significant higher when paired with a computer with an average reported rating of 4.2 (SD=0.91). As seen in figure-4.3 when paired with a human, inexperienced and experienced participants found the importance of a partner statistically significant less important with an average reported rating of 3.4 (SD=1.17) (Table-4.3) [F(1,16) = 5.120, p = 0.037].

Self-Reported Recommendation Rating of Activity

	Partner Type	
	Human	**Machine**
Inexperienced Participant	Mean: 4.60	Mean: 4.00
	SD: 0.54	SD: 0.70
	N: 5	N: 5
Experienced Participant	Mean: 4.80	Mean: 3.60
	SD: 0.44	SD: 1.14
	N: 5	N: 5

Table 4.4: Experiment 1: Self-Reported Recommendation Rating of Activity by Participant

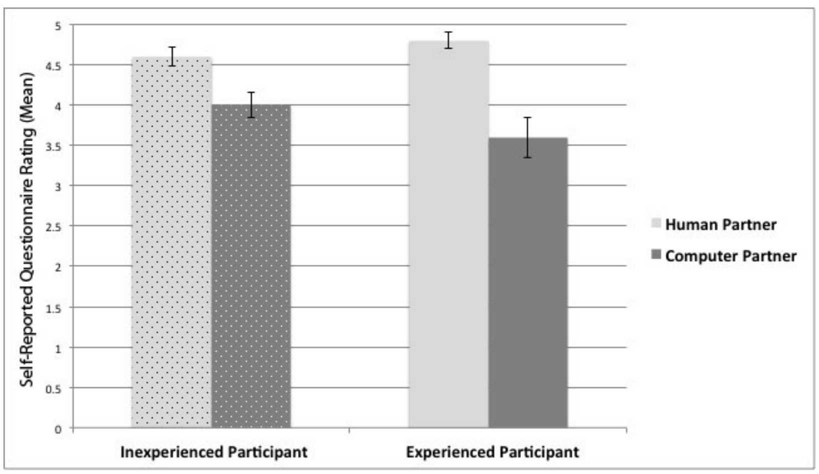

Figure 4.4: Experiment 1: Self-Reported Recommendation Rating of Activity by Participant

Figure-4.4 shows both inexperienced and experienced participants reported a statistically significant high likelihood of recommending the drumming experience to a friend when paired with a human. Table-4.4 shows inexperienced and experienced participants were likely to recommend the experience when their partner was a human, with an average of 4.7 (SD=0.48). Inexperienced and experienced participants paired with a computer were closer to neutral in regards to recommending the experience with an average of 3.8 (SD=0.91) (Table-4.4) [$F(1,16) = 7.043$, $p = 0.017$].

Brief Summary

Thus, results from the subjective rating post-session questionnaire ratings were equivocal. On the one hand, by the importance of partner, and enjoyment measures, both inexperienced and experienced participants preferred to collaborate with the computer over collaboration with another person. Conversely, experienced participants found the computer partner more frustrating than working with a human partner, and participants were more likely to recommend the experience to a friend if they had collaborated with a human partner.

4.2.2 Behavioral Analysis

This section details the behavioral interactions between participants and partners for experiment one. Each dyadic type has been addressed individually, detailing the frequency of interaction types observed and verified by 2 expert raters. Statistical summaries for each type have been provided, and an experiment summary across dyads has been provided at the end of the section.

Music Production Interactions

Each session of the experiment was recorded for behavioral analysis. Using the six behavioral interaction codes defined in this thesis (see Behavioral Analysis section later in this chapter), each session was divided by types of interaction. Transitions and changes in behavior were used to signal the end of one interaction and beginning of another. Because the nature of the task was focused on individual creativity and production, as opposed to meeting a lower-bound time requirement or count of certain sounds, focus during analysis was kept on what participants did, and not how long they did them.

Each dyadic type was analyzed separately. Interactions in each session were categorized and counted. Table-4.5 has been provided as a legend to the charts in this section, explaining the category rating and number scheme:

			Rhythm		Tempo	
	Category #	Name	Same	Different	Same	Different
Non-Simultaneous Play	1	Mirroring	x			x
	2	Stereo		x	x	
	3	Call & Response		x		x
Simultaneous Play	4	Chorus	x		x	
	5	Counterpoint		x	x	
	6	Disconnected		x		x

Table 4.5: Detailed Description of Behavior Interaction Categories

This section describes the distribution of interactions, and presents a characterization of each pairing. Data was presented in the form of bar graphs, representing the mean value of each interaction type.

Inexperienced Drummer-Computer Interaction Frequencies

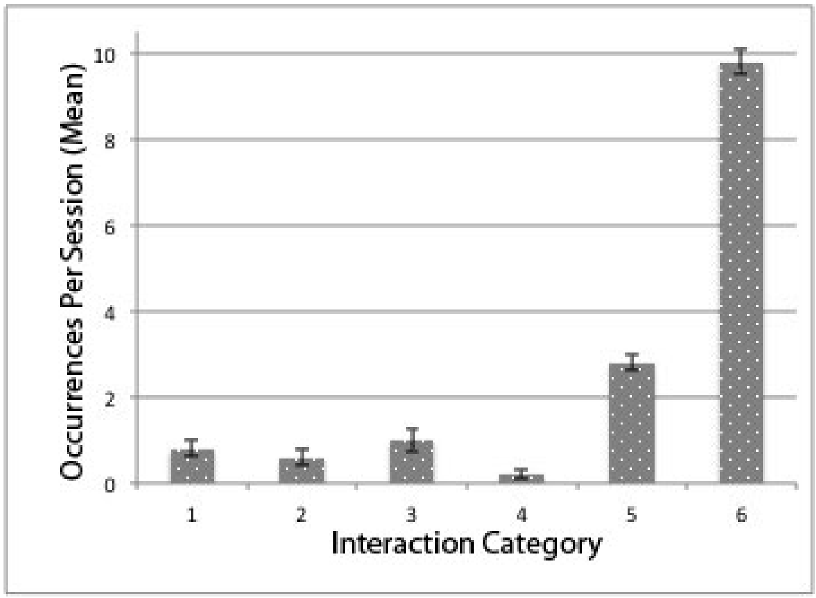

Figure 4.5: Experiment 1: Inexperienced Participant - Computer Partner Interaction Frequencies

The inexperienced participant: computer partner dyad can be characterized by primarily simultaneous play. At times there was a shared tempo, but most of the time there was not. When playing simultaneously, there were almost no instances of playing the same rhythm and tempo (labeled category 4, Chorus). Although there were sparse instances of non-simultaneous interactions, they were on average one time or less per session.

As seen in figure-4.5, the two primary interactions identified were counterpoint and disconnected. Each of these types were simultaneous interactions with different patterns. The difference was that counterpoint interactions featured a shared tempo, where disconnected did not. If the disconnected category is omitted, there is an overall low mean for all categories except counterpoint. Figure-4.5 shows low mean values for non-simultaneous interactions, with none reaching a value higher than 2 occurrence per session.

Experienced Drummer-Computer Interaction Frequencies

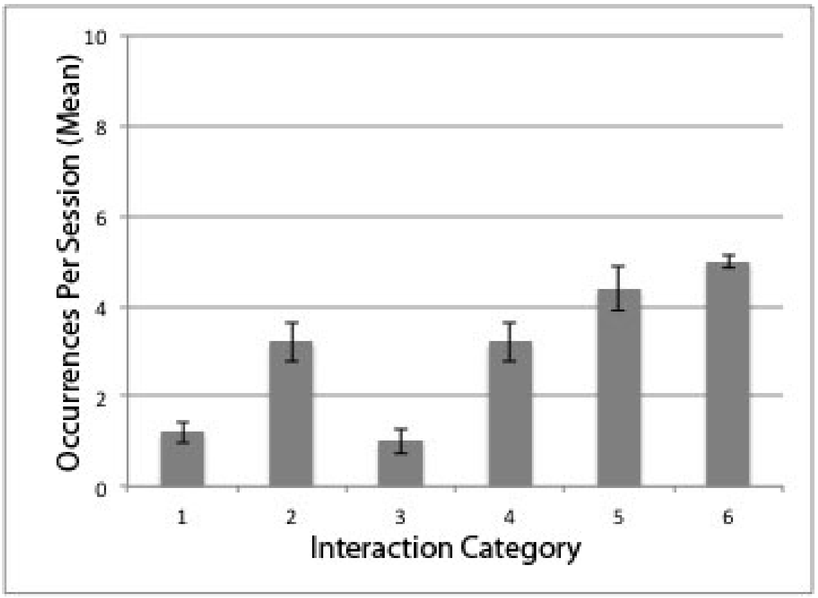

Figure 4.6: Experiment 1: Experienced Participant - Computer Partner Interaction Frequencies

The experienced participant: computer partner dyad can be characterized by primarily simultaneous play, but exhibiting a wider variety of interactions. At times there was a shared tempo, but most of the time there was not. When playing simultaneously, there were also several instances of playing the same rhythm and tempo. Although there were sparse instances of non-simultaneous interactions as a whole, there were instances of non-simultaneous play with a shared tempo but different rhythm (labeled category 2, Stereo). Overall, the experienced participant demonstrated a diverse interaction style, while primarily playing at the same time as the computer.

As seen in figure-4.6, the two primary interactions identified were counterpoint and disconnected. Each of these types were simultaneous interactions. Both counterpoint and disconnected were categorized by simultaneous play and different patterns. The difference was that counterpoint interactions featured a shared tempo, where disconnected did not. Figure-4.6 also shows a similar number of occurrences of stereo and chorus interactions. With the exception of stereo, low mean values were reported for non-simultaneous interactions, with values very close to 1 occurrence per session. Overall, the experienced participants played with diversity, as evident by the high mean values.

Inexperienced Drummer-Experienced Drummer Interaction Frequencies

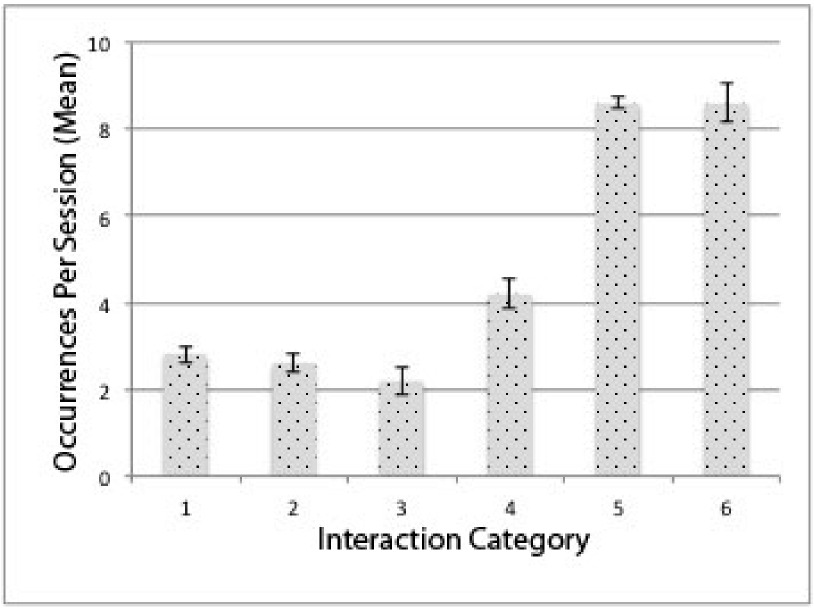

Figure 4.7: Experiment 1: Inexperienced Participant - Human Partner Interaction Frequencies

The inexperienced participant: human partner dyad can be characterized by simultaneous play. The participant and partner played simultaneously with a shared tempo approximately the same number of occurrences of disconnected play, where the tempo was not the same but the dyad still was playing at the same time. There was a moderately high average of occurrences of chorus play as well. Non-simultaneous interactions were more common than in other dyads, with around 2 or 3 occurrences per session.

As seen in figure-4.7, the two primary interactions identified were counterpoint and disconnected. Each of these types were simultaneous interactions. Both counterpoint and disconnected were categorized by simultaneous play and different patterns. The difference was that counterpoint interactions featured a shared tempo, where disconnected did not. Figure-4.7 also shows an occurrence of about four chorus interactions per session. There lower mean values for non-simultaneous interactions, with about 2 or 3 occurrence per session. The average means, and frequency of occurrences, was higher in this dyad than when inexperienced participants were paired with computers.

Experienced Drummer-Experienced Drummer Interaction Frequencies

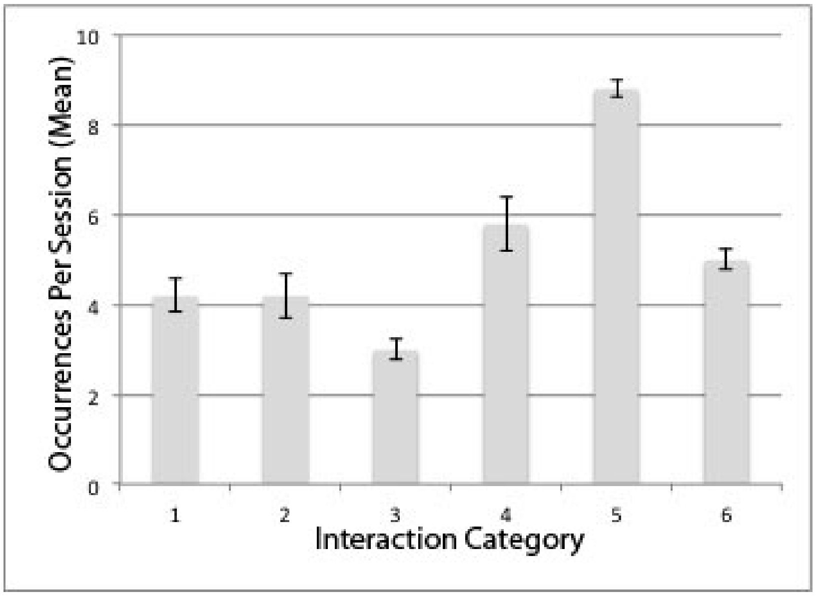

Figure 4.8: Experiment 1: Experienced Participant - Human Partner Interaction Frequencies

The experienced participant: human partner dyad can be characterized by simultaneous play. Participants and partners established a common tempo with the chorus and counterpoint interactions, and would either play the same rhythm pattern, or vary the rhythm patterns used. At times participants and partners would exhibit non-simultaneous play. In these instances, they would establish a common tempo, and vary between playing the same rhythm patterns or some variance.

As seen in figure-4.8, the primary interactions identified were counterpoint and chorus. Each of these types were simultaneous interactions. Both counterpoint and chorus were categorized by simultaneous play and a common tempo. The difference was that counterpoint interactions featured a different rhythm pattern, where chorus had the same rhythm pattern.

It is important to note that this was the only dyad type in experiment one where disconnected was not one of the primary interaction behaviors. Figure-4.8 also shows relative lower mean values for non-simultaneous in comparison to simultaneous interactions, with none reaching a value higher than 4 occurrence per session.

Brief Summary

There are several key points to take away from the interaction analysis above. When looking at common trends between experience levels of participants, the occurrences of disconnected interactions was higher for inexperienced participants. This was true regardless of a computer partner or human partner.

When comparing experienced participants paired with computers to experienced participants paired with humans, overall frequency of events was higher for each category. Experienced participants did more things when paired with human partners. Experienced participants also played asynchronously more often than inexperienced participants, with experienced participants paired with human partners using *"Mirroring"* (category 1) and *"Stereo"* (category 2) more than any other dyad type.

Experienced participants demonstrated more occurrences of establishing a common tempo, and then playing a different rhythm. In terms of non-simultaneous interactions, participants paired with a human partner demonstrated more occurrences, regardless of the participant's experience level. Overall, participants paired with a human partner exhibited more asynchronous playing, regardless of participant experience type.

4.3 Experiment 2: (Inexperienced/Experienced) Participant: Human Experienced Partner

Experiment two investigated inexperienced versus experienced human participants paired with experienced human partners. Participants and partners played analog hand drum instruments instead of the digital instruments used in experiment one. Experiment two study investigated how humans experienced the activity of collaboratively interacting while working with analog tools and a human partner. The same pre-session and post-session questionnaires were used by the participants and partners to rate their experiences.

Showing similar results to experiments one and three, the post-session questionnaire results showed that participants viewed the importance of their partner in the task different depending on their own prior experience level. Inexperienced participants reported ratings that were statistically significant higher than the reported ratings of experienced participants. Participants did not differ (in terms of statistically significant values) in their reported experiences of frustration, enjoyment, or their likelihood to recommend the experience to a friend.

In terms of interaction behaviors, participants tended to play with the computer simultaneously more than taking turns. Both inexperienced and experienced participants had between 2 and 3 occurrences of each non-simultaneous interaction per session. When looking at common trends across experience levels of participants, the occurrences of *"Counterpoint"* (category 5) interactions was the primary interaction technique. The occurrences of *disconnected* (category 6) interactions was higher for inexperienced participants. Experienced participants had disconnected interaction occurrences almost as frequently as *chorus* (category 4) interaction occurrences. Inexperienced participants had relatively low occurrences of chorus interactions, with on average less than 2 occurrences per session.

4.3.1 User-Reported Experiences

As with experiment one, the user-reported experiences and attitudes were collected through questionnaire data collected immediately before and after the recorded sessions. No discussion was held before the participants completed their questionnaires. This was to ensure validity to the answers given. Participants completed the pre-questionnaire and post-questionnaire in the same room as their partner. This section presents the results of the data analysis collected.

Participants Profile

This experiment was conducted with 20 participants recruited from the Virginia Tech Research in Gaming list server, an undergraduate CyberArts class, through the Virginia Tech SONA recruitment system, and through word of mouth via a local drum circle. There were

20 dyads constructed, with an n=10 for each of the two conditions. Twelve (12) males and 8 females participated in the experiment. The average age of participants was 19.9 years, with a standard deviation of 0.85 years. The participants were approximately divided equally between people with and without drumming experience, and those with knowledge of, or participation in drum circles. More than 91% of the participants described having some experience with a touchscreen device, which was important because the instrument user interface was a touchscreen. The majority of participants self-identified as liking to listen to music that was rooted in rhythmic and melodic qualities.

Prior Experience and Attitudes

The pre-questionnaire was given to participants as they entered the lab, immediately after turning in a signed IRB consent form. Participants were asked about their previous musical instrument training. The majority of the population had experience with musical instruments, 80.22% reported experience of one year or more playing an instrument. Separately, participants were asked about their drumming experience, where 67.74% of participants noted that they had actual drumming experience. Participants were asked if they were aware of what a drum circle was, and if so had they ever participated in one. Over 62% (62.02%) of the participants noted they were aware of what a drum circle was, and 34.62% of the participants had some experience in a drum circle.

Participants were asked to identify the type of music they like to listen to, as well as to name several examples of each genre. This was used to identify the diversity of the drumming groups. They were allowed to select multiple genres. Of the 20 participants, 51.73% identified themselves as fans of rock or some derivation of rock (alt-rock, post-rock, classic-rock, punk-rock) music. Over 21% (21.60%) identified themselves as fans of classical music. About 60% (60.35%) identified themselves as fans of hip-hop music, and 37.44% identified themselves as fans of country music.

In order to assess technological familiarity, participants also were asked if they had any experience using touch screen devices, such as the Apple iPhone or iPod Touch. Over 91% (91.22%) reported having previous experience with touch screen devices.

Post-Session questionnaire

As with experiment one, at the end of the session each participant was asked to complete a post-session questionnaire consisting of 15 questions. There were four questions that asked participants to rate the quality of their collaborative experience using a 1 to 5 subjective rating scale (a value of 1 indicated the least favorable rating, whereas a value of 5 indicated the most favorable rating). The collaborative experience qualities assessed by these four questions were: *enjoyment of activity, satisfaction or frustration with activity, importance of partner to activity,* and *recommendation of drumming experience to a friend*. The remaining

11 questions on the post-session questionnaire solicited open-ended comments about the collaborative drumming experience. Information from these questions was used to establish context for the experiment observations and the interpretation of the data trends. Content analysis was not performed on the remaining questions.

Data from each of the two subjective rating questions was organized for statistical analysis purposes. There was one independent variable: *participant experience*. Participant experience consisted of inexperienced or experienced. Mean, standard deviation, and T-Test results are provided for analysis. Participant experience consisted of inexperienced or experienced.

The results from the subjective rating post-session questionnaire ratings were equivocal. On the one hand, by three of the four measures, experience level had no significant effect on the subjective experience. However, in the case of how participants viewed the role of their partner in the activity, inexperienced participants rated the importance of their partner statistically significant higher than the ratings experienced participants gave. With the exception of the importance of partner rating, the other three scores were close to average, rating between three and four on a five-point scale. In the case of the frustration rating, the average fell more on the side of satisfaction than frustration.

Self-reported Enjoyment Level of Activity

	Human Partner Type
Inexperienced Participant	Mean: 3.60
	SD: 0.84
	N: 10
Experienced Participant	Mean: 3.40
	SD: 0.84
	N: 10

Table 4.6: Experiment 2: Self-reported Enjoyment Level of the Activity by Participant

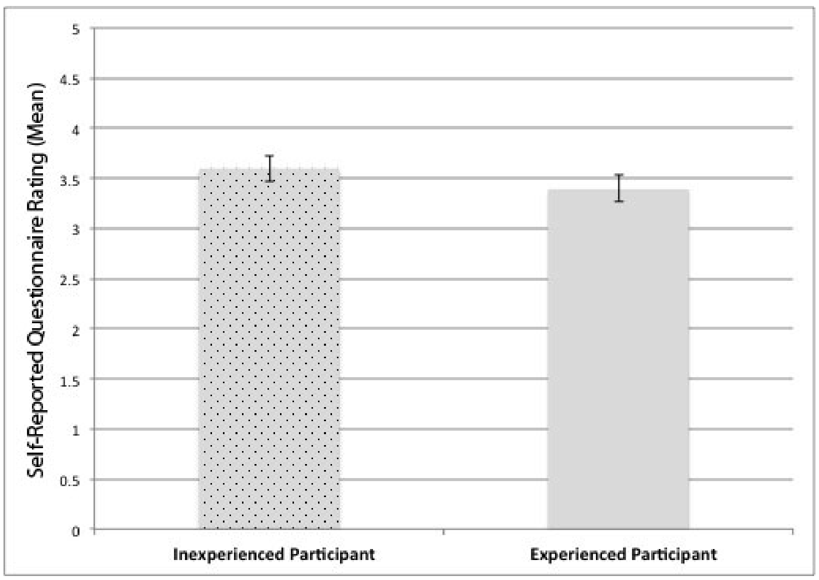

Figure 4.9: Experiment 2: Self-reported Enjoyment Level of the Activity by Participant

As shown in figure-4.9, both inexperienced and experienced participants reported enjoying the experience. Table-4.6 shows inexperienced participants had an average rating of 3.6 (SD=0.84). Experienced participants reported a mean of 3.4 (SD=0.84). The results of the T-Test were not significant at T(18) = 0.530, p = 0.602.

Self-reported Frustration Level of Activity

	Human Partner Type
Inexperienced Participant	Mean: 3.40
	SD: 0.97
	N: 10
Experienced Participant	Mean: 3.20
	SD: 0.79
	N: 10

Table 4.7: Experiment 2: Self-reported Frustration Level of the Activity by Participant

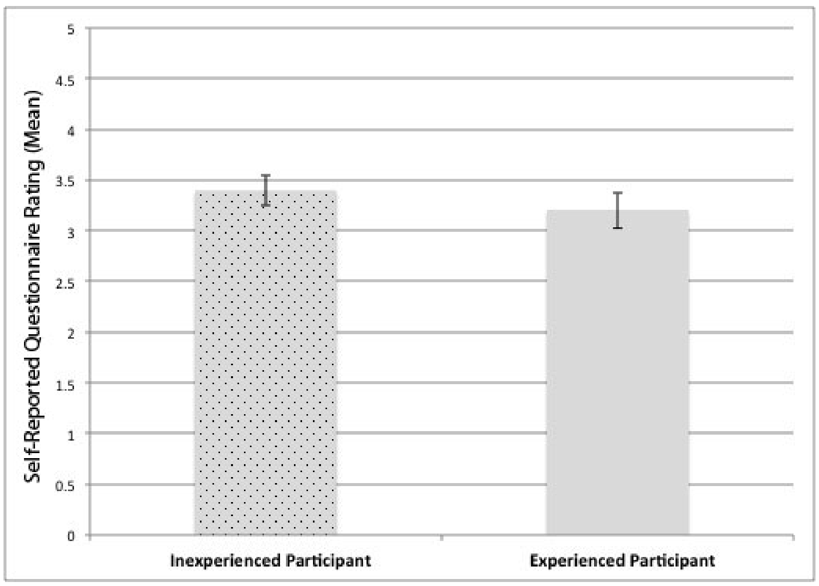

Figure 4.10: Experiment 2: Self-reported Frustration Level of the Activity by Participant

As shown in figure-4.10, both inexperienced and experienced participants reported neutral levels of frustration. Table-4.7 shows that inexperienced participants had an average rating of 3.4 (SD=0.97). Experienced participants reported a mean of 3.2 (SD=0.79). The results of the T-Test were not statistically significant at T(18) = 0.507, p = 0.618.

Self-reported Importance of Partner in Activity

	Human Partner Type
Inexperienced Participant	Mean: 4.00
	SD: 0.67
	N: 10
Experienced Participant	Mean: 3.20
	SD: 0.92
	N: 10

Table 4.8: Experiment 2: Self-reported Importance of Partner Level of the Activity by Participant

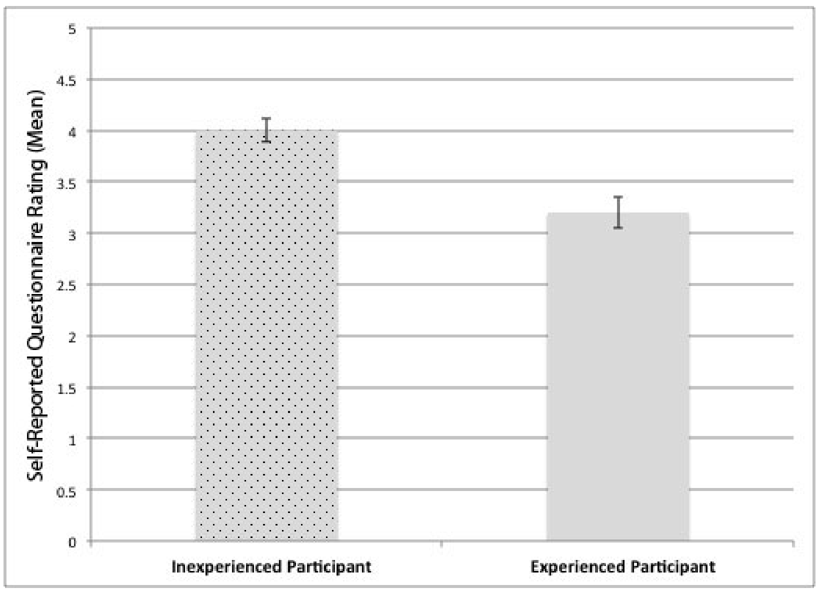

Figure 4.11: Experiment 2: Self-reported Importance of Partner Level of the Activity by Participant

Inexperienced participants significantly rated their partner as playing an important role in the experience. As shown in figure-4.11, both inexperienced and experienced participants reported high ratings to the importance of the partner in the experience. Table-4.8 shows that inexperienced participants had an average rating of 4.0 (SD=0.67). Experienced participants reported a mean of 3.2 (SD=0.92). The results of the T-Test showed a significant difference at $T(18) = 2.228$, $p = 0.039$.

Self-reported Recommendation of Activity

	Human Partner Type
Inexperienced Participant	Mean: 3.90
	SD: 0.57
	N: 10
Experienced Participant	Mean: 3.70
	SD: 0.82
	N: 10

Table 4.9: Experiment 2: Self-reported Recommendation Level of the Activity by Participant

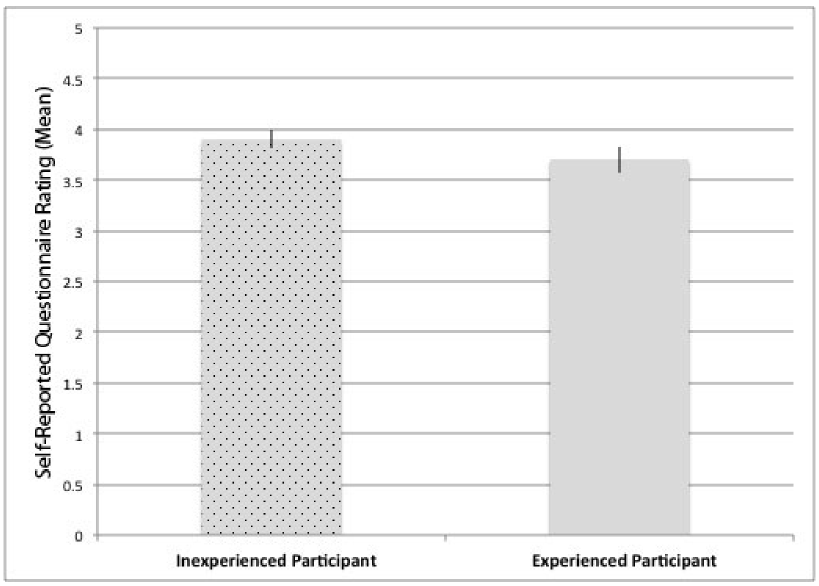

Figure 4.12: Experiment 2: Self-reported Recommendation Level of the Activity by Participant

As shown in figure-4.12, both inexperienced and experienced participants reported moderate ratings of recommending the experience to their friends. Table-4.9 shows that inexperienced participants had an average rating of 3.9 (SD=0.57). Experienced participants reported a mean of 3.7 (SD=0.82). The results of the T-Test were not significant at T(18) = 0.632, p = 0.535.

Brief Summary

Thus, results from the subjective rating post-session questionnaire ratings were equivocal. On the one hand, by three of the four measures, experience level had no significant effect on the subjective experience. However, in the case of how participants viewed the role of their partner in the activity, inexperienced participants rated the importance of their partner statistically significant higher than the ratings experienced participants gave. With the exception of the importance of partner rating, the other three scores were close to average, rating between three and four on a five-point scale. In the case of the frustration rating, the average fell more on the side of satisfaction than frustration.

4.3.2 Behavioral Analysis

This section details the behavioral interactions between participants and partners for experiment 2. As with analysis of experiment 1, each dyadic type has been addressed individually, detailing the frequency of interaction types observed and verified by 2 expert raters. Statistical summaries for each type have been provided, and an experiment summary across dyads has been provided at the end of the section.

Music Production Interactions

As with experiment one, each session of the experiment was recorded for behavioral analysis. Using the six behavioral interaction codes defined earlier (see Experimental Design section), each session was divided by types of interaction. Transitions and changes in behavior were used to signal the end of one interaction and beginning of another. Because the nature of the task was focused on individual creativity and production, as opposed to meeting a lower-bound time requirement or count of certain sounds, focus during analysis was kept on what participants did, and not how long they did them.

Each dyadic type was analyzed separately. Interactions in each session were categorized and counted. Please refer to table-4.10 (a detailed explanation was provided by table-4.5 in behavioral analysis of experiment 1) for explanation of the category rating and number scheme.

	Category #	Name
Asynchronous Play	1	Mirroring
	2	Stereo
	3	Call & Response
Simultaneous Play	4	Chorus
	5	Counterpoint
	6	Disconnected

Table 4.10: Condensed Description of Behavior Interaction Categories

This section describes the distribution of interactions, and presents a characterization of each pairing. Data was presented in the form of bar graphs, representing the mean value of each interaction type.

Inexperienced Drummer-Experienced Drummer Interaction Frequencies

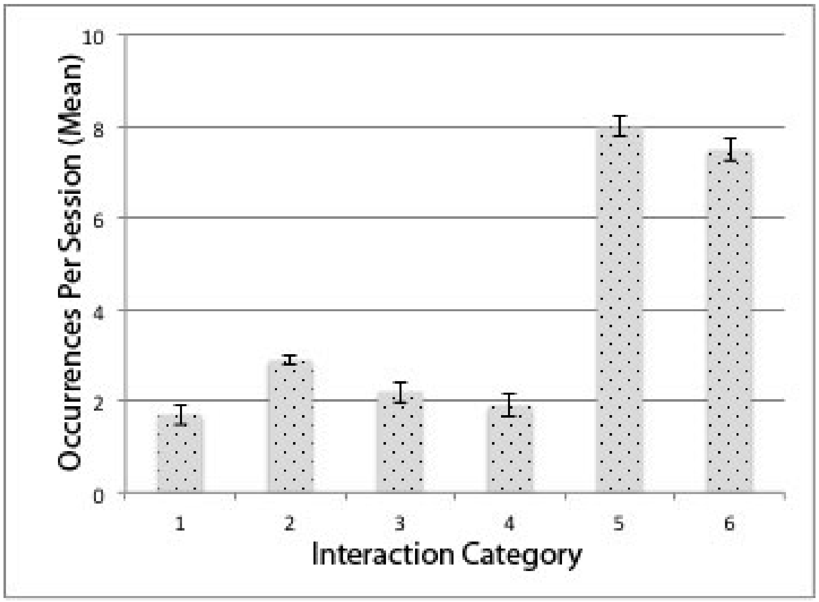

Figure 4.13: Experiment 2: Inexperienced Participant - Human Partner Interaction Frequencies

The inexperienced participant: human partner dyad can be characterized as simultaneous play. At times there was a shared tempo, but most of the time there was not. When playing simultaneously, there were very usually less than 2 occurrences per session of playing the same rhythm and tempo. There were sparse instances of non-simultaneous interactions, usually on average of 1 or 2 occurrences per session.

As seen in figure-4.13, the two primary interactions identified were counterpoint and disconnected. Each of these types were simultaneous interactions. Both counterpoint and disconnected were categorized by simultaneous play and different patterns. Figure-4.13 also shows relatively low mean values for non-simultaneous interactions, with none reaching a value higher than about 3 occurrence per session.

Experienced Drummer-Experienced Drummer Interaction Frequencies

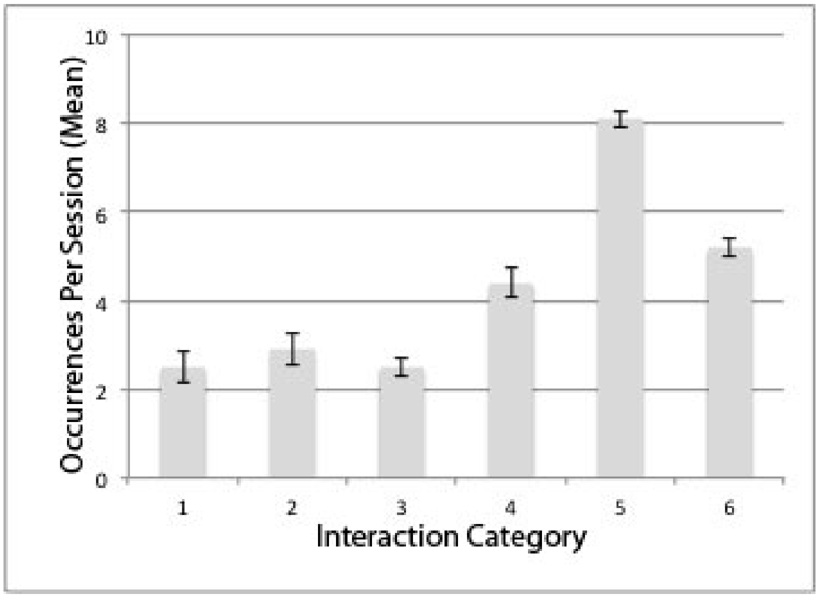

Figure 4.14: Experiment 2: Experienced Participant - Human Partner Partner Interaction Frequencies

The experienced participant: human partner dyad can be characterized as simultaneous play. There were several instances of playing the same rhythm and tempo simultaneously (between 4 and 5 occurrences per session). Primarily the sessions consisted of counterpoint interactions. Although there were sparse instances of non-simultaneous interactions, they were on average about 2 occurrences per session.

As seen in figure-4.14, the primary interaction identified were counterpoint. In fact, each simultaneous interaction independently had more occurrences than any non-simultaneous interactions. Figure-4.14 also shows moderate mean values for non-simultaneous interactions, with an average value between 2 and 3 occurrence per session.

Brief Summary

There are several key points to take away from the interaction analysis above. When looking at common trends across experience levels of participants, the occurrences of *"Counterpoint"* (category 5) interactions was the primary interaction technique. The occurrences of *disconnected* (category 6) interactions was higher for inexperienced participants. Experienced participants had disconnected interaction occurrences almost as frequently as *chorus* (category 4) interaction occurrences. Inexperienced participants had relatively low occurrences of chorus interactions, with on average less than 2 occurrences per session.

In both dyad types, simultaneous play interactions occurred more than non-simultaneous interactions. Both inexperienced and experienced participants had between 2 and 3 occurrences of each non-simultaneous interaction per session.

4.4 Experiment 3: (Inexperienced/Experienced) Participant: Computer Experienced Partner With Human Rhythm

Experiment three investigated inexperienced versus experienced human participants paired with a computer partner. Experiment experiment isolated the partner type (only computer partner used), and varied the participants' prior experience level. Similar to experiment one, the computer partner used a pre-recorded drum track for playback. For experiment three, the drum track was a recording of a human playing a digital drum, not a computer generated digital drum. In reviewing the results from experiment one, a reoccurring comment from reviewers and participants was that the computer track was very rigid, and non-responsive to the participant. To help mitigate this, an expert track was selected from 3 human generated tracks, and used as playback instead. The purpose was not to implement a dynamic responsive system, but to add a human element to the playback (including off-timing sounds and repetitious patterns).

As with experiments one and two, the post-session questionnaire results showed that participants viewed the importance of their partner in the task different depending on their own prior experience level. Inexperienced participants reported ratings that were statistically significantly higher than the reported ratings of experienced participants. Participants did not differ (in terms of statistically significant values) in their reported experiences of frustration, enjoyment, or their likelihood to recommend the experience to a friend.

In terms of interaction behaviors, participants tended to play with the computer simultaneously more than taking turns. Overall, the frequency of interactions was low, with 4 of the 6 interaction types having on average 3 or less occurrences per session. When looking at common trends across experience levels of participants, the occurrences of *counterpoint* and *disconnected* interactions (categories 5 and 6) were the primary interaction techniques. Inexperienced participants had a higher frequency of disconnected interactions. Experienced participants had slightly higher frequencies of non-simultaneous play, as well as being able to play the same thing as their partner at the same time (category 1). This could be associated to their higher skill level from prior experience.

4.4.1 User-Reported Experiences

As with experiments one and two, the user-reported experiences and attitudes were collected through questionnaire data collected immediately before and after the recorded sessions. No discussion was held before the participants completed their questionnaires. This was to ensure validity to the answers given. Participants completed the pre-questionnaire and post-questionnaire in the same room as their partner. This section presents the results of the data analysis collected.

Participants Profile

This experiment was conducted with 20 participants recruited from the Virginia Tech Research in Gaming list server, an undergraduate CyberArts class, through the Virginia Tech SONA recruitment system, and through word of mouth via a local drum circle. There were 20 dyads constructed, with an n=10 for each of the two conditions. Thirteen (13) males and 7 females participated in the experiment. The average age of participants was 20.95 years, with a standard deviation of 3.62 years. The participants were approximately divided equally between people with and without drumming experience, and those with knowledge of, or participation in drum circles. More than 84% of the participants described having some experience with a touchscreen device, which was important because the instrument user interface was a touchscreen. The majority of participants self-identified as liking to listen to music that was rooted in rhythmic and melodic qualities.

Prior Experience and Attitudes

The pre-questionnaire was given to participants as they entered the lab, immediately after turning in a signed IRB consent form. Participants were asked about their previous musical instrument training. The majority of the population had experience with musical instruments, 61.23% reported experience of one year or more playing an instrument. Separately, participants were asked about their drumming experience, where 64.43% of participants noted that they had actual drumming experience. Participants were asked if they were aware of what a drum circle was, and if so had they ever participated in one. Seventy-one percent (71.00%) of the participants noted they were aware of what a drum circle was, and 29.92% of the participants had some experience in a drum circle.

Participants were asked to identify the type of music they like to listen to, as well as several examples of each genre. This was used to gauge the diversity of the drumming groups. They were allowed to select multiple genres. Of the 20 participants, 70.22% identified themselves as fans of rock or some derivation of rock (alt-rock, post-rock, classic-rock, punk-rock) music. Over 30% (30.41%) identified themselves as fans of classical music. About 55% (54.88%) identified themselves as fans of hip-hop music, and 18.71% identified themselves as fans of country music.

In order to assess technological familiarity, participants also were asked if they had any experience using touch screen devices, such as the Apple iPhone or iPod Touch. Over 84% (84.51%) reported having previous experience with touch screen devices.

Post-Session questionnaire

At the end of the session, each participant was asked to complete a post-session questionnaire consisting of 15 questions. There were four questions that asked participants to rate the quality of their collaborative experience using a 1 to 5 subjective rating scale (a value of 1 indicated the least favorable rating, whereas a value of 5 indicated the most favorable rating). The collaborative experience qualities assessed by these four questions were: *enjoyment of activity, satisfaction or frustration with activity, importance of partner to activity,* and *recommendation of drumming experience to a friend*. The remaining 11 questions on the post-session questionnaire solicited open-ended comments about the collaborative drumming experience. Information from these questions was used to establish context for the experiment observations and the interpretation of the data trends. Content analysis was not performed on the remaining questions.

Data from each of the four subjective rating questions was organized into a two-by-two matrix for statistical analysis purposes. For each matrix, there were two independent variables: *partner type* and *participant experience*. Partner type consisted of human or computer. Participant experience consisted of inexperienced or experienced. Statistical values of mean, standard deviation, and ANOVA are provided for analysis.

The overall results from the subjective rating post-session questionnaire ratings were equivocal. As in experiment two, by three of the four measures, experience level had no significant effect on the subjective experiences. However, in the case of how participants viewed the role of their counterpart in the activity, inexperienced participants rated the importance of their partner statistically significantly higher than the ratings experienced participants gave. With the exception of the importance of partner rating, the other three scores were close to neutral, rating between high two-point ratings and four-point ratings on a five-point scale.

Self-reported Enjoyment Level of Activity

	Human Partner Type
Inexperienced Participant	Mean: 3.60
	SD: 1.07
	N: 10
Experienced Participant	Mean: 3.0
	SD: 0.99
	N: 10

Table 4.11: Experiment 3: Self-reported Enjoyment Level of the Activity by Participant

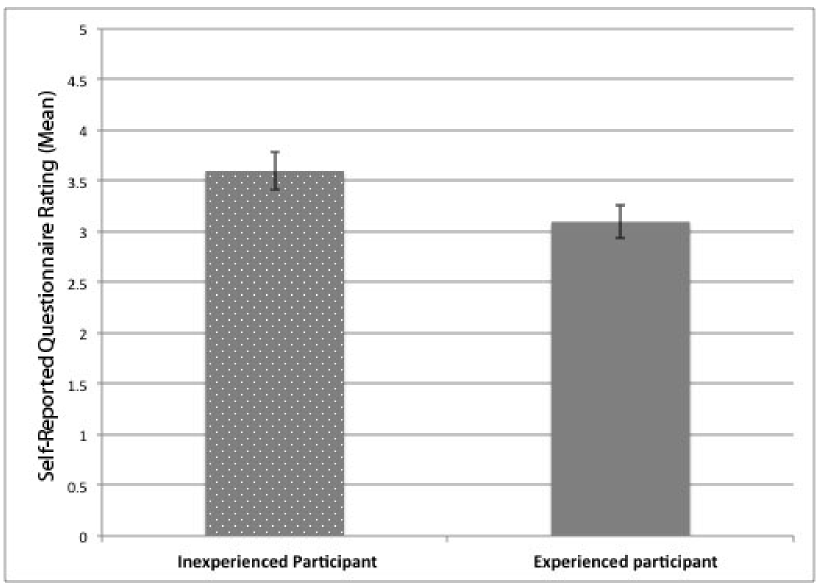

Figure 4.15: Experiment 3: Self-reported Enjoyment Level of the Activity by Participant

As shown in figure-4.15, both inexperienced and experienced participants reported neutral ratings of enjoyment of the experience. Table-4.11 shows inexperienced participants had an average rating of 3.6 (SD=1.07). Experienced participants reported a mean of 3.1 (SD=0.99). Results of the T-Test were not significant at T(18) = 1.080, p = 0.295.

Self-reported Frustration Level of Activity

	Human Partner Type
Inexperienced Participant	Mean: 3.10
	SD: 0.99
	N: 10
Experienced Participant	Mean: 2.80
	SD: 0.79
	N: 10

Table 4.12: Experiment 3: Self-reported Frustration Level of the Activity by Participant

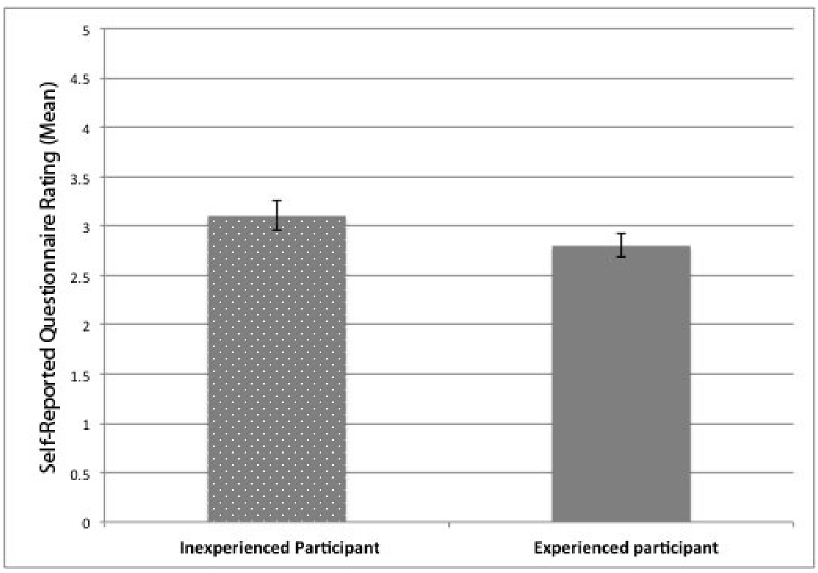

Figure 4.16: Experiment 3: Self-reported Frustration Level of the Activity by Participant

As shown in figure-4.16, both inexperienced and experienced participants reported neutral ratings of enjoyment of the experience. Table-4.12 shows inexperienced participants had an average rating of 3.1 (SD=0.99). Experienced participants reported a mean of 2.8 (SD=0.79). Results of the T-Test were not significant at T(18) = 0.747, p = 0.464.

Self-reported Importance of Partner in Activity

	Human Partner Type
Inexperienced Participant	Mean: 4.00
	SD: 0.82
	N: 10
Experienced Participant	Mean: 3.10
	SD: 0.74
	N: 10

Table 4.13: Experiment 3: Self-reported Importance of Partner Level of the Activity by Participant

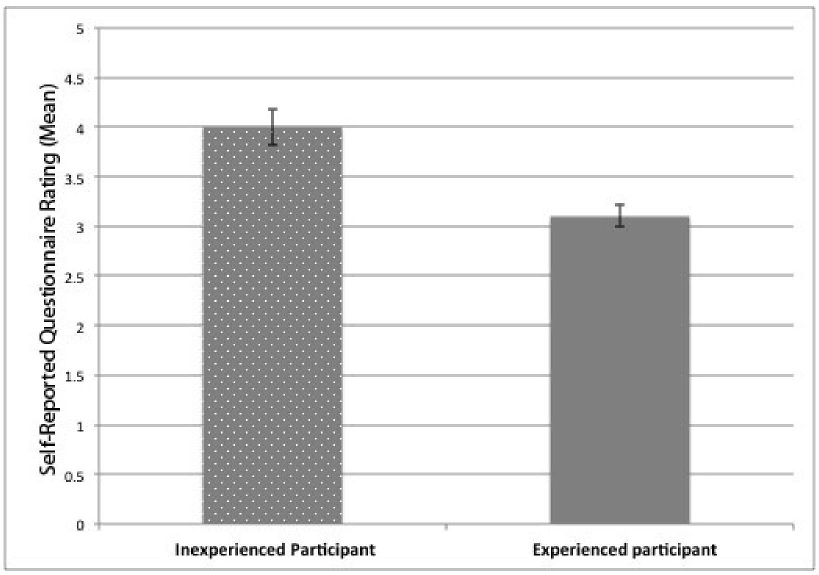

Figure 4.17: Experiment 3: Self-reported Importance of Partner Level of the Activity by Participant

Inexperienced participants significantly rated their partner as playing an important role in the experience. As shown in figure-4.17, Inexperienced participants reported a high rating of the importance of their partner . Experienced participants reported a neutral rating of the importance of their partner. Table-4.13shows that inexperienced participants had an average rating of 4.0 (SD=0.82). Experienced participants reported a mean of 3.1 (SD=0.74). The results of the T-Test showed a significant difference at $T(18) = 2.586$, $p = 0.019$.

Self-reported Recommendation of Activity

	Human Partner Type
Inexperienced Participant	Mean: 3.70
	SD: 1.06
	N: 10
Experienced Participant	Mean: 3.60
	SD: 0.84
	N: 10

Table 4.14: Experiment 3: Self-reported Recommendation Level of the Activity by Participant

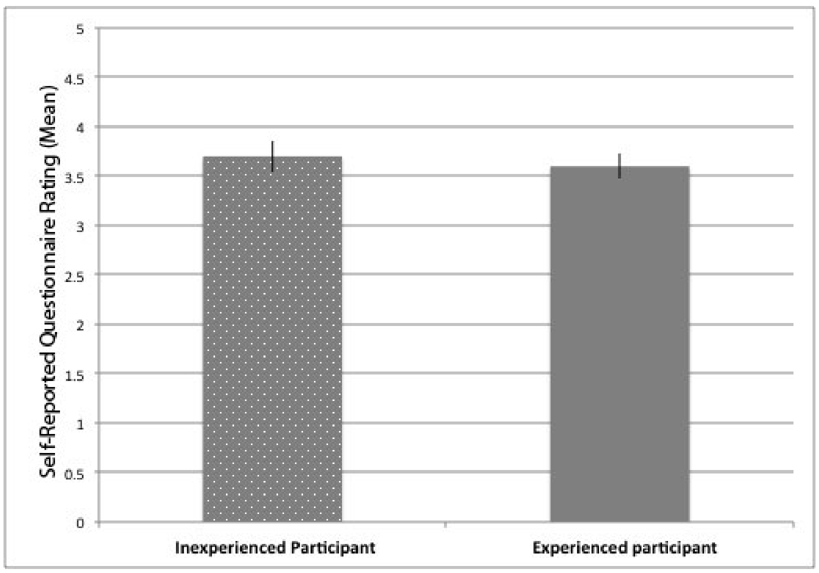

Figure 4.18: Experiment 3: Self-reported Recommendation Level of the Activity by Participant

As shown in figure-4.18, both inexperienced and experienced participants reported moderate ratings of recommending the experience to their friends. Table-4.14 shows inexperienced participants had an average rating of 3.7 (SD=1.06). Experienced participants reported a mean of 3.6 (SD=0.84). Results of the T-Test did not show a significant difference at $T(18) = 0.234$, $p = 0.818$.

Brief Summary

Thus, results from the subjective rating post-session questionnaire ratings were equivocal. As in experiment two, by three of the four measures, experience level had no significant effect on the subjective experiences. However, in the case of how participants viewed the role of their counterpart in the activity, inexperienced participants rated the importance of their partner statistically significant higher than the ratings experienced participants gave. With the exception of the importance of partner rating, the other three scores were close to neutral, rating between high two-point ratings and four-point ratings on a five-point scale.

4.4.2 Behavioral Analysis

This section details the behavioral interactions between participants and partners for experiment 3. As with analysis of experiments one and two, each dyadic type has been addressed individually, detailing the frequency of interaction types observed and verified by 2 expert raters. Statistical summaries for each type have been provided, and an experiment summary across dyads has been provided at the end of the section.

Music Production Interactions

As with experiments one and two, each session of the experiment was recorded for behavioral analysis. Using the six behavioral interaction codes defined earlier (see Experimental Design section), each session was divided by types of interaction. Transitions and changes in behavior were used to signal the end of one interaction and beginning of another. Because the nature of the task was focused on individual creativity and production, as opposed to meeting a lower-bound time requirement or count of certain sounds, focus during analysis was kept on what participants did, and not how long they did them.

Each dyadic type was analyzed separately. Interactions in each session were categorized and counted. Please refer to table-4.15 (a detailed explanation was provided by table-4.5 in behavioral analysis of experiment 1) for explanation of the category rating and number scheme.

	Category #	Name
Asynchronous Play	1	Mirroring
	2	Stereo
	3	Call & Response
Simultaneous Play	4	Chorus
	5	Counterpoint
	6	Disconnected

Table 4.15: Condensed Description of Behavior Interaction Categories

This section describes the distribution of interactions, and presents a characterization of each pairing. Data was presented in the form of bar graphs, representing the mean value of each interaction type.

Inexperienced Drummer-Computer Interaction Frequencies

The inexperienced participant: computer partner dyad can be characterized primarily by simultaneous play. Most of the time there was a shared tempo between the participant and computer. When playing simultaneously, there were few instances of playing the same

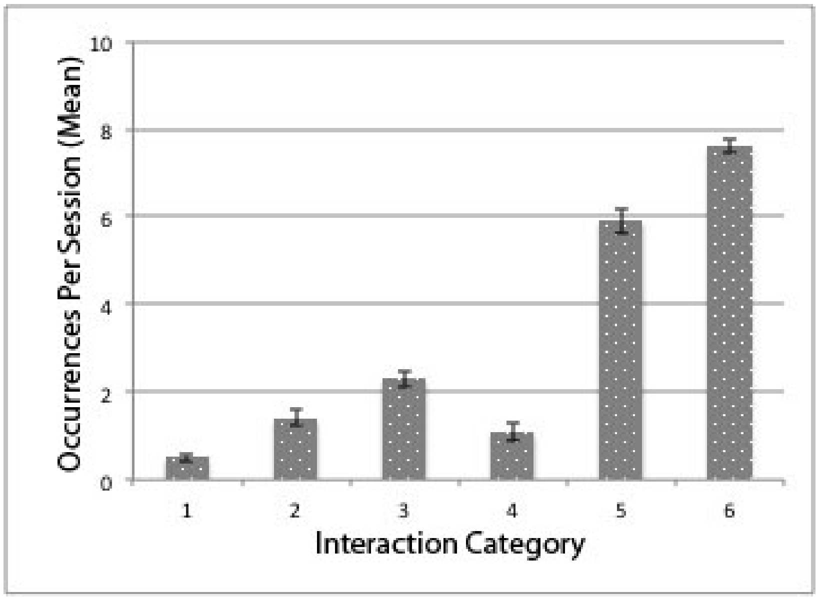

Figure 4.19: Experiment 3: Inexperienced Participant - Computer Partner Interaction Frequencies

rhythm and tempo, at most 2 occurrences per session. There were also several instances of non-simultaneous interactions, they were on average less than 2 occurrences per session.

As seen in figure-4.19, the primary interaction identified was disconnected (category 6). The second most observed interaction was the counterpoint (category 5) interaction. Both of these interactions were instances where the participant and partner were playing at the same time. The non-simultaneous interactions were on par in terms of occurrence with the the simultaneous interaction, stereo. Stereo, call and response, and chorus each had an occurrence of at most 2 times per session. Mirroring interactions were low with no more than 1 occurrence per session.

Experienced Drummer-Computer Interaction Frequencies

The experienced participant: computer partner dyad can be characterized as diverse, and slightly dominated by simultaneous play. Overall, the frequency of interactions was low, but spread across more types. Most of the time there was a shared tempo between the participant and computer. When playing simultaneously, there were few instances of playing the same rhythm and tempo, between 2 and 4 occurrences per session. There were also several instances of non-simultaneous interactions, they were on average 2 or 4 occurrences per session.

As seen in figure-4.20, interactions were slightly skewed to the right of the graph. The

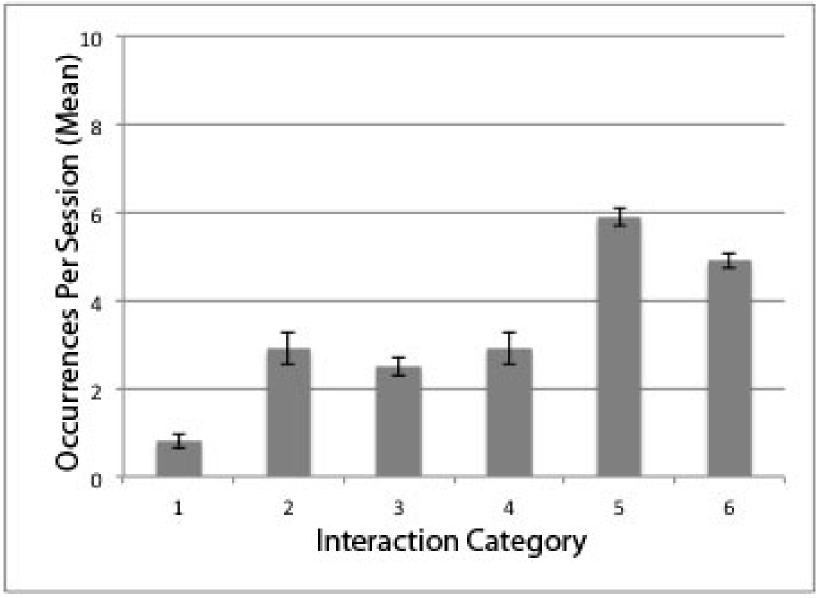

Figure 4.20: Experiment 3: Experienced Participant - Computer Partner Interaction Frequencies

primary interaction identified were counterpoint. The second most observed interaction was disconnected interaction. Both of these interactions were instances where the participant and partner were playing at the same time. The non-simultaneous interactions were on par in terms of occurrence with the the simultaneous interaction, stereo. Stereo, call and response, and chorus each had an occurrence between 2 and 4 times per session. Mirroring interactions were low with no more than 1 occurrence per session.

Brief Summary

There are several key points to take away from the interaction analysis above. Overall, the frequency of interactions was low, with 4 of the 6 interaction types having on average 3 or less occurrences per session. When looking at common trends across experience levels of participants, the occurrences of *counterpoint* and *disconnected* interactions (categories 5 and 6) were the primary interaction techniques. Inexperienced participants had a higher frequency of disconnected interactions.

In both dyad types, simultaneous play interactions occurred more than non-simultaneous interactions. Experienced participants had slightly higher frequencies of non-simultaneous play, as well as being able to play the same thing as their partner at the same time (category 1). This could be associated to their higher skill level from prior experience.

4.5 Perceived Leadership Differences

This section details how leadership was perceived across the experiments, according to additional comments from the subjective post session questionnaires. Although questions about leadership were not specified by the questionnaire, several participants discussed it while describing their experiences. Each grouping of drummers demonstrated unique ways of creating rhythm patterns. The nature of leadership impacted how and when drummers created their individual drumming patterns. The experience level of the participants and their partners was not revealed to any of the drummers during the data collection sessions. Leadership was never defined by the participants, and no formal definition was given. Each dyad type seemed to have their own unique collection of factors that defined “leadership.”

Following subsections outline observed reports of leadership from the self-reported post-session questionnaires. Each experiment is discussed independently. A summary is provided at the beginning of each subsection.

4.5.1 Experiment 1 Leadership Summary

The computer partner was viewed as the leader whenever it was present in a dyad. This was viewed as a positive for inexperienced drummers, offering guidance and reference points. Experienced drummers disliked the computer as a partner, citing the computer as non-responsive and unforgiving. Contrasting with the human partner, inexperienced participants cited a feeling of unpredictability from their partner. The inexperienced musician was searching for guidance from the more experienced partner, but said it was difficult to communicate a steady state of intention. Experienced participants commented leadership being fluid, focused around “turn-taking” and complementing their partner’s pieces. Experienced participants paired with experienced partners said there was no single static leader throughout the session, rather each person assuming the leader role for short periods of time.

In the inexperienced drummer-computer dyads, the inexperienced drummers viewed the computer as the leader of the dyad. Self-reported questionnaire responses suggested that the computer offered a consistency in rhythm and tempo that gave the inexperienced drummers a sense of guidance. One inexperienced drummer said, “The computer kept me on beat. I based my actions off the computer.”

The computer also offered examples of timbre that inexperienced drummers used to decide on which drum sound to trigger. Inexperienced drummers discussed setting their tempo by finding the tempo of the computers drum pattern. During the drumming sessions, two inexperienced drummers commented on trying to mimic the computers drumming pattern with their own.

In the experienced drummer-computer dyads, drummers used the computer in a similar way. Instead of mimicking the computers tempo and drumming pattern, experienced drummers used it as a starting point. Experienced drummers elaborated on the computers drumming pattern, and would try to, as one experienced drummer stated, “fill in what was missing.” Four drummers reported using a call-and-response method, where the computer would play a drum pattern and the drummer would play back a slightly modified counterpoint rhythm.

Unlike the inexperienced drummers paired with the computer, experienced drummers did not like the computer having the leadership role. One experienced drummer commented, “This was one sided collaboration. My drumming had no effect on the computer.” Instead of trying to match exact timing, experienced drummers would focus on synchronizing one beat. In musical terms, if the computer was playing a rhythm in four-four timing, the experienced drummer would align one of their beats with the ‘one’ beat. Another experienced drummer commented, “Its important to find something that goes with the computers rhythm, it will naturally sound good.”

For the inexperienced drummer-experienced drummer dyad, the partner played a different role. At the beginning of the sessions the inexperienced drummer would start by creating a simple rhythm. The experienced drummer would then try to supplement the rhythm by adding in more complexity. Each pairing used an informal call and response method in this way. After a steady rhythm had been established, one of the drummers would improvise a new rhythm on top of the current one. The inexperienced drummer stated during the analysis phase that she felt flustered during the session, “sometimes my partner would switch rhythms without saying anything.” Several inexperienced participants reported that their partner was the leader of the group, while the experienced partner reported their partner was the leader. One experienced partner reported, “I let —- set the rhythm and just played over top.” While an inexperienced participant reported, “—- was great! She set a fun beat for me to follow.”

In the experienced drummer-experienced drummer dyad, three of the experienced drummers reported randomly tapping buttons for extended period of time. Others reported playing with an intent to “make my partner sound good.” Three drummers also noted a lack of a single leader during the sessions. Every participant talked about the importance of “turn taking.” Two drummers reported focusing on playing a steady beat for their partner to improvise from, and only taking a turn at improvisation once their partner had established a steady rhythm.

4.5.2 Experiment 2 Leadership Summary

Six participants commented on leadership in their additional comments section of the self-reported questionnaire. Inexperienced participants viewed the experienced partner as the primary leader, reporting that each had a designated role to play. Several of their experienced partners reported following the inexperienced participant, or “playing around them.” When Experienced participants were paired with an experienced partner, they were more likely to describe a fluid movement of leadership between the partner and participant throughout the sessions.

Similar to experiment one, the inexperienced drummer-experienced drummer dyads interacted primarily through turn-taking and building upon rhythms. One inexperienced participant said, "my partner would change rhythms, but I would keep the beat." After a basic rhythm had been established, one of the dyad members would improvise a new rhythm on top of the current one. This process could build until the rhythm became too complex, or one of the partners lost interest. Three experienced partners said they let their partner get comfortable. One experienced partner said he played an easy rhythm so they could play together.

In the experienced drummer-experienced drummer dyads, four drummers reported focusing on playing a steady beat to enable their partner's improvisation. Drummers practiced taking turns at improvisation once their partner had established a steady rhythm. Three participants reported paying deliberate attention to the processes of their partner, such as, "waiting for my partner to get funky" and "giving him space to move."

4.5.3 Experiment 3 Leadership Summary

Five participants made comments about leadership in their additional comments section of the self-reported questionnaire. Regardless of participant experience type, participants reported the computer was viewed as the leader whenever it was present in a dyad. This was reported as a positive and negative characteristic. Inexperienced drummers reported using the computer for guidance and reference points. Two experienced drummers said they disliked the computer as a partner, citing the computer as non-responsive and unforgiving, feeling constrained at times.

The inexperienced drummers appeared to view the computer as the leader or boss of the dyad. They reported that the computer offered a consistency in rhythm and tempo that gave them a sense of guidance; however, this was a mixed blessing. One inexperienced drummer commented, "The computer told me what to play, but I wasn't good enough to keep up." The guidance gave the participants a gauge against which to rate their skills, but such ratings are not always desirable. The computer at times appeared to make the human feel inadequate.

In the experienced drummer-computer dyads, drummers used the computer in a similar way. The computer was still the leader, but instead of mimicking the computer, experienced drummers used the computer's rhythm and tempo as a starting point. Experienced drummers elaborated on the computers drumming pattern, and would try to build new parts off of it. Although experienced drummers reported recognizing the computer as being the leader, they did not like it. One experienced drummer commented, "It's like playing to a CD." Instead of trying to match exact timing, experienced drummers would focus on synchronizing their play to one element of the rhythm. In traditional rhythm production, this is considered a sophisticated technique.

4.6 Behavioral Analysis

The section above describes the results of the perceived experience of the participants immediately following their sessions. As a way to get a deeper understanding of the activity and the differences that could be caused across dyads, the in-moment interactions of participant and partner were measured. Looking at common trends of interaction frequencies, the behavioral analysis corroborates the importance of partner to inexperienced participants. Specifically, proportional analysis revealed dissimilar results when between experiments one and three.

This section presents the analysis of the frequency of the interactions exhibited during the sessions. The first section examines the proportional differences between the experiments in the spread and frequency of interaction types. These interaction types / coding categories were verified by two expert raters, afterwards 2 separate statistical measures were performed to establish inter-rater reliability. The expert raters were expert musicians with a concentration on rhythmic activities, as well as formally trained computer scientists.

4.6.1 Interaction Spread

In order to analyze the frequency of interaction behaviors present in each of the three experiments, generalizable categories were established. The six interaction behaviors were grouped into 2 categories: *synchronized* and *disconnected*. Interaction behaviors 1-5 were categorized as synchronized, because each of the behaviors required some level of synchronization between the participant and partner to generate that behavior. For example, for interaction type 3 (Call & Response), if rhythm and tempo were different between the participant and partner, there was a level of synchronization present that kept each from playing at the same time as each other.

The other category, *disconnected* was identified by a lack of coordination between the partner and participant. If the participant and partner were not able to collaborate successfully, disconnected was the default interaction behavior. This category was characterized by the participant and partner playing different rhythms and tempos over one another's drum track.

Figure-4.21 shows the sum of behavior events for each of the two categories in a stacked column graph. The bottom stack represents the sum synchronized group, and the top stack represents the sum of the disconnected group. Columns were arranged by participant and partner type. Note that experiments 2 and 3 had a population of n=10 for each dyad type, while experiment 1 had a population of n=5 for each dyad type.

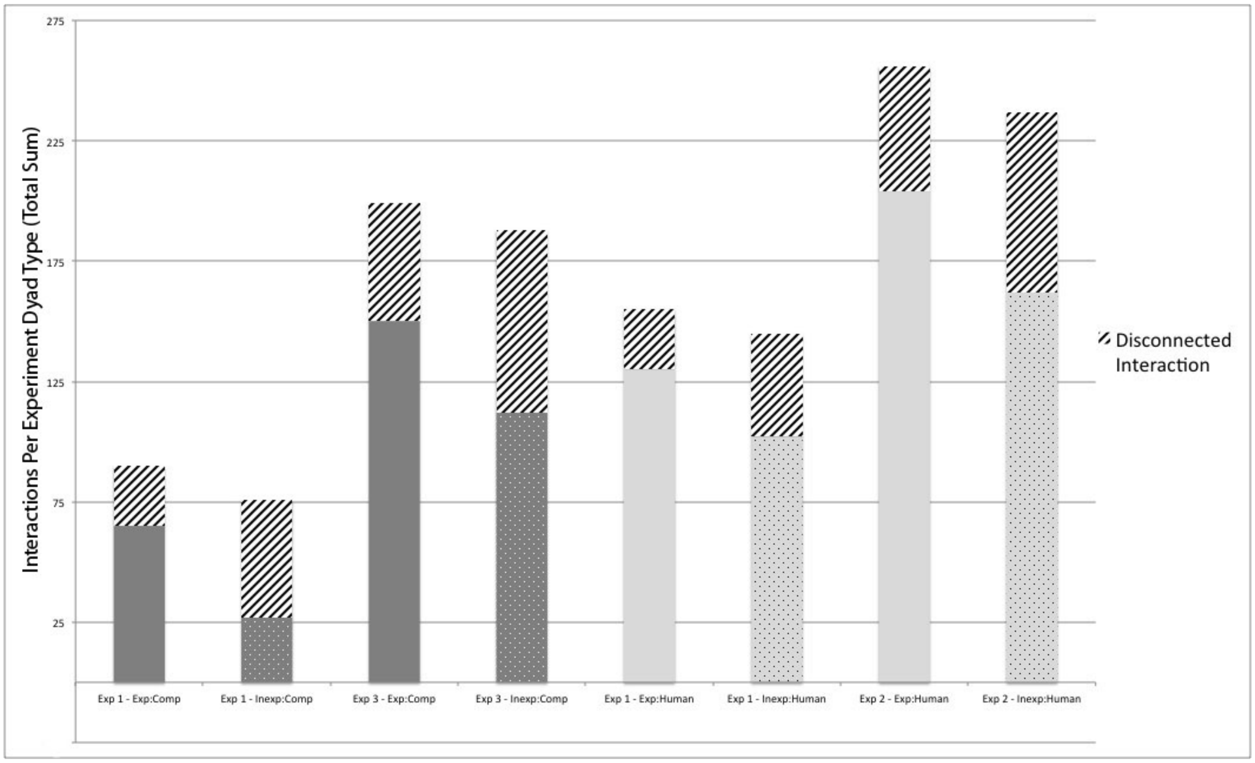

Figure 4.21: Overview of Behavioral Interaction Spread Across Experiments

In experiments 1 and 3, the *inexperienced participant:computer partner* dyads were outliers from the other dyads. According to figure-4.21, the *inexperienced participant:computer partner* dyads had the largest highest proportion of disconnected behaviors to their total behaviors. These dyads spent less time successfully collaborating than the other dyads. Between these dyads, experiment 1 had a noticeably higher proportion of disconnected play, suggesting a difference between the experiences.

Dyads of expert participants paired with an expert partner (human or computer) showed lower proportions of disconnected behaviors to total behaviors, spending more time successfully collaborating with each other. Looking at the individual experiments, experienced participants consistently did more things (had more observed interaction) than the similar inexperienced participant dyad.

Experiment	Dyad Type	Total	Synchronized	Disconnected	Proportion
Experiment 1	Exp:Comp	90	65	25	0.72
	Inexp:Comp	76	27	49	0.36
Experiment 3	Exp:Comp	199	150	49	0.75
	Inexp:Comp	188	112	76	0.59
Experiment 1	Exp:Human	155	130	25	0.84
	Inexp:Human	145	102	43	0.70
Experiment 2	Exp:Human	256	204	56	0.80
	Inexp:Human	242	167	75	0.69

Table 4.16: Description of Behavior Interaction Proportions by Experiment Type

Table-4.16 shows the numerical view of the data values of each dyad type, presented by experiment and participant:partner dyad type. Results were grouped by dyad type, grouping experienced participant:computer partners together, as well as experienced participant:human partners together. In order to investigate common trends across experiments, the proportion of synchronized behaviors to total behaviors was calculated. This measure is not directly affected by the n-size of the experiment, because it is based off of the average mean values.

The majority of proportions fell within the range of 69% to 84%. There were two outliers, both inexperienced participant:computer partner dyads for experiments 1 and 3, that were noticeably lower. This was consistent with the visual analysis in figure-4.21. An interesting observation was that the inexperienced participant:computer dyad in experiment 1 had a proportion of 36%, and the inexperienced participant:computer dyad in experiment 3 had a proportion of 59%. The difference (delta = 23%) between the two proportions was greater than other dyad comparisons (same dyad matching, different experiments) which were each within 4% of each other. Judging by the coherence of the outcomes of the proportions for the inexperienced participant:computer dyad in experiments 1 and 3, the partner is more important to the experience as compared to the expert drummer.

Experiments 1 and 2 paired inexperienced and experienced participants with an expert human partner. Both experiments had similar trends of proportions with respect to synchronized behavior occurrences. The experienced participants were within 4% of eachother, and the inexperienced participants were within 1% of each other. With respect to the media equation (Reeves & Nass, 1996), these results provide evidence that humans respond socially to cues from computers in a similar way as they do from humans. Again, the majority of proportions fell within the range of 69% to 84%. Based on these results, the instrumentation differences between experiments 1 (digital drum simulator on iPhone) and 2 (analog hand drums), did not affect the behavior of the dyads.

Brief Summary

Judging by the coherence of the proportions for the inexperienced participant:computer dyads in experiments 1 and 3, the partner is more important to the inexperienced participant as compared to the experienced participant. The delta for the experienced participants was 3%, while the delta for the inexperienced participants was 23%. This corroborates findings in the self-reported questionnaire data, where the importance of partner was statistically different between participant experience types. This also highlights the impact of prior experience on the experience of an activity, both self-reported experience and observable interactions.

In general, partner type did not have a noticeable impact on the interactions during the experiments. The proportion spread was between 69% and 84%. When examining similarly constructed dyads across experiments, proportions were trending similarly to each other (within 4%). Based on these results, the different instruments used by the participant (digital drum simulator on iPhone or analog hand drums), did not affect the behavior of how the dyads collaborated.

4.6.2 Inter-Rater Reliability

In order to provide validation to the reported behavioral analysis interaction codes, as well as the occurrence of the interaction types in the sessions, an expert consultant was used to cross check the reports. As described in the previous chapter, two independent raters were used to analyze and code the interaction segments. Both raters were experts in music production and computer science, each majoring in computer science as an undergraduate degree, and each involved in music semi-professionally in percussion and rhythm activities. In total, 24 experimental sessions were coded, identifying 177 individual segments.

Cohen's Kappa Correlation Coefficient

Cohen's Kappa correlation coefficient, or Cohen's Kappa, was used to measure the statistical dependency between two the results of the two code sets. As outlined in the previous section, Cohen's Kappa is a measurement of concordance between 2 raters. Significance of correlation is tied to the resulting Kappa. In general, a kappa < 0.2 denotes poor concordance, 0.21-0.40 is fair, 0.41-0.60 is moderate, 0.61-0.80 is strong, and 0.81 or greater denotes extremely high agreement. A 95% confidence interval for Kappa is the value of Kappa +/- 1.96 * standard error. The count matrix, Cohen's Kappa, and standard error are presented below.

Interaction ID	**1**	**2**	**3**	**4**	**5**	**6**	**Total**
1	6	1	0	0	0	0	7
2	0	15	1	0	0	0	16
3	0	4	14	1	0	0	19
4	0	0	1	27	0	2	30
5	0	0	0	3	53	4	60
6	0	0	0	0	6	39	45
Total	6	20	16	31	59	45	177
Kappa= 0.9079				SE= 0.0493			
95% Critical Interval=0.8113 to 1.0046							

Table 4.17: Cohen's Kappa for Inter-Rater Reliability

As represented by table-4.17, the Cohen's Kappa value of the two coder's ratings was 0.9079. This value represents a high overall concordance, and indicates extremely high agreement between the two raters.

Percentage Agreement

As discussed in the Experimental Setup chapter of this thesis, there are some statisticians that believe Cohen's Kappa takes observed category frequencies for given values (Strijbos et al., 2006), leading to misunderstanding agreement levels (Saal et al., 1980; Strijbos et al., 2006). To provide a more robust statistical analysis, percentage agreement of each category was also performed.

Mirroring Percentage Agreement

		Rater 1	
		Yes	**No**
Rater 2	**Yes**	6	1
	No	0	170
Percentage of Agreement: 85.7%			

Table 4.18: Percentage Agreement of Mirroring Category

As indicated by table-4.18, the percentage of agreement was about 86%. There was only 1 instance of raters disagreeing about a segment being rated as “mirroring”. This rating was the least identified across the sessions.

Stereo Percentage Agreement

		Rater 1	
		Yes	**No**
Rater 2	**Yes**	15	1
	No	5	156
Percentage of Agreement: 71.40%			

Table 4.19: Percentage Agreement of Stereo Category

As indicated by table-4.19, the percentage of agreement was about 71%. There were only 6 instances of raters disagreeing about a segment being rated as “stereo”. This was the most identified rating for non-synchronous behaviors.

Call and Response Percentage Agreement

		Rater 1	
		Yes	**No**
Rater 2	**Yes**	14	5
	No	2	156
Percentage of Agreement: 66.7%			

Table 4.20: Percentage Agreement of Call and Response Category

As indicated by table-4.20, the percentage of agreement was about 67%. There were 7 instances of raters disagreeing about a segment being rated as “call and response”. Rater 1 identified more instances of this behavior than rater 2.

Chorus Percentage Agreement

		Rater 1	
		Yes	**No**
Rater 2	**Yes**	27	3
	No	4	143
Percentage of Agreement: 79.4%			

Table 4.21: Percentage Agreement of Chorus Category

As indicated by table-4.21, the percentage of agreement was about 80%. There were 7 instances of raters disagreeing about a segment being rated as “chorus”. Each rater identified about 6 unique segments as chorus that the other rater did not agree with.

Counterpoint Percentage Agreement

		Rater 1	
		Yes	**No**
Rater 2	**Yes**	53	7
	No	6	111
Percentage of Agreement: 80.3%			

Table 4.22: Percentage Agreement of Counterpoint Category

As indicated by table-4.22, the percentage of agreement was about 80%. There were about 13 instances where raters disagreed about a segment being rated as “counterpoint”. Each rater identified about 7 unique segments as counterpoint that the other rater disagreed with. Of the 6 possible ratings, counterpoint was the most frequently used.

Disconnected Percentage Agreement

		Rater 1	
		Yes	**No**
Rater 2	**Yes**	39	6
	No	6	121
Percentage of Agreement: 76.5%			

Table 4.23: Percentage Agreement of Disconnected Category

As indicated by table-4.23, the percentage of agreement was about 77%. There were about 12 instances where raters disagreed about a segment being rated as "disconnected". Each rater identified about 6 unique segments as disconnected that the other rater disagreed with. This rating was used approximately as frequently as the counterpart rating.

Brief Summary

From the agreement percentages above presented above, the 2 raters demonstrated similar ratings. The interactions of "call and response" and "stereo" had the lowest agreement percentages. Each of these were categories was different non-simultaneous tempos and different patterns, but the stereo interaction had a similar rhythm pattern while call and response did not. Counterpart and disconnected were the most identified. This showed that participants had a tendency to play at the same time, but playing different things. Chorus has the the highest percentage agreement, although it was the least identified. Counterpart had the second highest percentage agreement, and as the most identified interaction type, only 13 of the 66 identified instances were disputable.

As discussed in the previous chapter, some of the controversy with Cohen's Kappa stems from it's assumptions about unintentional, or random agreements. With an extremely strong correlation value, corroborated by high scoring individual code percentage agreements, there is evidence of a high overall concordance.

Chapter 5

Conclusion

5.1 Discussion

The Digital Drumming study examined subjective processes associated with collaborative work involving a creative music-production task. Specifically, the focus of this work was: *How do inexperienced versus experienced drummers solve problems of what to produce when they have a human partner, versus a computer partner?* The subjective processes associated with the task of rhythmic music production by inexperienced and experienced participants working collaboratively either with a human or computer partner to produce complex polyrhythm sounds are investigated. Specifically, the subjective experience of music production and the behavioral interactions between activity participants are assessed.

Prior research focused on the role of dyadic collaborative music production, citing it's importance for individual musician's technical skill improvement, as well as performance improvement(Crick et al., 2006; Schmidt, 1994). The converse is that amateur musicians can suffer from anxiety, stemming from feelings of personal inadequacy to other actors in the activity, or performance anxiety of being singled out as a weaker musician. These feelings of anxiety can be reduced by the introduction of anonymity. By disguising the musician's physical world identity, musicians reported feeling less anxious and enjoying the experience more. It's clear that the role of the partner is essential to this, anonymity hides the musician from judgments of one self. Therefore, this study also examined the importance and perceived role of the partner from the participant's perspective by varying the partner type between human agent and computer agent.

Several questions were raised about the impact of technology on a collaborative, experience driven activity. *What is the impact on the subjective experience of a person when collaborating with a computer partner? In what ways are behaviors similar or different when people complete the same type of task, but with either a human or computer partner? How does the performance change for the musician when their partner is a piece of technology?? What im-*

pact do these differences have on the subjective behavioral interactions of a pair collaborating within a task? From the previous subsections and the results provided in the corresponding chapter, the Digital Drumming study shows that the partner type has more impact on inexperience musicians than experienced musicians. Across the three experiments, inexperienced participants rated the importance of partner statistically significantly higher than experienced participants of the same partner type. When examining the behavioral data, the proportional distribution of interactions showed a significant difference in the characteristics of play for inexperienced participants across partner types.

The Digital Drumming study asked the question, *How do inexperienced versus experienced drummers solve problems of what to produce when they have a human partner, versus a computer partner?* From this work, two main phenomena were identified. The first was that for inexperienced musicians, the partner that they interact with impacted their experience at an experiential and behavioral level. Differences in subjective reports and behavioral analysis corroborate this point. The second was that construction of perceived leadership was affected by participant experience level and by partner type. When a computer was present as a partner in a dyad, it was perceived to be the leader. This was true regardless of the participant's experience level. But when an expert human was present as partner in a dyad, the role of the leader was perceived as fluid and dynamic. Inexperienced and experienced participants had different preconceived ideas of how their partner should behave in the activity. The following sections describe in detail the implications for each of these phenomena.

5.1.1 Importance of Partner

The type of partner that participants were paired with was a consistent effect in the post-session questionnaire questions. Across all three experiments, there was significant statistical difference between participant types with respect to the importance of partner. Behavioral analysis showed that there was also a proportional difference in the collaborative interactions that inexperienced participants had when the partner type varied between computer and human, as well as between the type of drum track that the computer used for playback.

These findings corroborate the notion that there are differences to working collaboratively with human or computer partners. The findings related to differences in the inexperienced participant align with the previous work of Chiasson and Gutwin(Chiasson & Gutwin, 2005) and Shechtman and Horowitz (Shechtman & Horowitz, 2003), which called into question a claim of The Media Equation, citing that people respond socially to computers, and more specifically, people respond similarly to social cues regardless of whether they come from a computer or human agent.

When focusing on dyads with an experienced participant, the results were not the same. The self-reported questionnaire data showed no difference with respect to partner type. Behavioral analysis showed that experienced drummers had minimal proportional difference in the collaborative interactions when the partner type varied between computer and human. These results support the claim made by the Media Equation, that people respond similarly to cues from humans and computers.

In pedagogical settings, these results have introduced a seam. For inexperienced participants, the difference in partner type calls attention to itself enough that people notice a difference. Seams can be used to cause users to stop and think. It could be about a difficult decision, to revise a body of work, or to construct the next action in a series. The task of drumming is a experience-driven, constructed of microcoordinated actions. In constructing the inexperienced participant-computer dyad, participants had to focus on what their partner was playing, as well as what their abilities were. Chiasson and Gutwin(Chiasson & Gutwin, 2005), discuss different streams of attention that each participant must be aware of during an activity. One stream is the self-aware judgment of abilities, and the perceived opinions of others with respect to their skills as a composer and a partner. The other stream is the self-aware judgment of self, and the opinion of one's own skill set with respect to the overall quality of the final composition.

These findings provide insight into the experience of coordinated collaboration in a creative activity. The collaboration of a human working with a computer offers stability and safe a experience for inexperienced drummers. This type of collaborative pairing can be limiting and unsatisfying for experienced drummers. Although the Amateur Musicians Paradox is minimized through computer pairing for inexperienced musicians, the computer becomes detrimental to the experience of the experienced drummer. All participants agreed that when the computer was present in the dyad, it held the leader role.

5.1.2 Leadership

Although participants were not specifically asked about leadership, several participants discussed it while describing their experiences in the self-reported post-session questionnaires. The perceived nature of leadership impacted how and when drummers created their individual drumming patterns. Across the three experiments, participants reported the computer as being the leader of the dyad whenever present. This was true regardless of the participant's experience level. Inexperienced participants reported this as a good thing, reportedly using the computer to stay on beat, learn new rhythms, and improvise with. This constructed an experience for the inexperienced musician where they could play without fear of being watched or judged by another party (Gurevich, 2006). For the experienced musician, the computer appeared unresponsive and created a one-sided collaboration. Experienced participants paired with the computer reported using it as a metronome, but not trying to collaborate with it. One experienced participant commented how easy it was to sound good just by matching rhythms when playing with the computer.

When participants were paired with human partners, leadership was reported as being more two-sided. In dyads of inexperienced participants and experienced partners, several participants and partners each reported the other person as being the leader. Inexperienced participants reported following the rhythm patterns established by the experienced partner, relying them on a similar way as inexperienced participants when paired with a computer. Experienced partners reported letting the inexperienced participant establish their own rhythm, then improvising around it. These different perceptions of leadership suggest a different meaning of leadership for each participant type. The expectation that the inexperienced participant had for their partner was to act as a guide, providing support and keeping a steady tempo. The expectation that the experienced partner had for their partner was to be self-reliant, and be able to follow a pattern if they were not able to create their own rhythms.

Experienced participants reported a dynamic sense of leadership when paired with an experienced human partner. Several drummers reported a lack of single leader during the sessions. Two drummers reported focusing on playing a steady beat for their partner to improvise from, and only taking a turn at improvisation once their partner had established a steady rhythm. This form of turn-taking was common among this dyad. Based off of the self-reported questionnaire comments, experienced drummers were versatile and able to work successfully collaborate with inexperienced and experienced musicians, while assuming different roles for each.

Earlier in the related work chapter, the question about how novices adjust to experts when the nature of the expertise is about coordination was raised. Prior work shows the presence of a leader with adequate expertise could be linked to successful task completion outcomes, regardless of any further relationships between the leader and individual(Isaacs & Clark, 1987; Fullan, 1998). The experiment results from Digital Drumming show that inexperienced participants look for guidance from others, and that partner type can affect the experience and behaviors. In the compiled task of music production, the subjective behavior of the inexperienced participants showed proportional variance in the interaction behaviors across experiments. For experienced participants, they expected their partner to be somewhat competent in technique and ability to improvise, and reported wanting more interaction and response from the computer.

5.2 Future Work

While much has been learned about the construction of leadership and the role of a partner in a coordinated activity through the Digital Drumming study, there is still more work to be done.

The digital drumming study focused on two types of participants, inexperienced and experienced. There also exists a transitional state, an intermediary between the two. Future work should focus on the transition from inexperienced to experienced player, and how the role of partner changes. This would require a temporal study, focusing on perceived role of the partner, and the construction of perceived leadership. An expanded literature review should focus on learning technologies, and the impact of technology over long-term exposure.

Another area of future work is to investigate the impact of a responsive or dynamic drumming system as a partner instead of a drum track. Instead of the computer partner playing a static predefined audio loop, the computer could follow a heuristic model to generate sounds responsively. With this, a sophisticated level of artificial intelligence would be necessary to mimic the decision making of a human. As evident in the digital drumming sessions, the role of the leader can be dynamic or static depending on the skill sets of the partners. Does a more responsive drumming system change the construction of leadership for the human participant?

As described in the previous section, leadership and the perceived importance of partner are influenced by the prior experience of the participant. The Media Equation does not replicate for the inexperienced participants, but it did for the experienced participants. Further investigation into this is necessary. *How do the anticipated experiences differ between prior experienced participants? What happens at a subjective and behavioral level in the transition time?* The scope of the experiments could be made temporal, to investigate subjective experiential and behavioral changes over time.

The concept of 'leadership', much like 'together' seems to be socially and contextually dependent on the participant and partner. Future studies could investigate the role of a 'leader', and the act of 'leading' through various lenses. What are the expectations that an inexperienced participant have for their partner? Do they expect to follow? At no point during the three experiments was the participant or partner's individual skill level discussed among the dyads, yet the participants and partners were able to assess each other and assume roles very quickly. Experienced participants recognized the role of a leader as a metaphoric token, that could be passed dynamically. Are there contrasting assumptions about the role of the partner in mixed experience level dyads?

In this study, drumming dyads were located in the same physical proximity or space. For future work, a study of distributed dyads would provide additional insight into the processes and experience of collaborative coordination. Furthermore, the audio produced in the present experiment required speakers in a common space. This audio configuration allowed third parties to overhear the musical composition and collaborative activities. Isolation of sound production could be limited by headphones or soundproof rooms to negate a potential source for anxiety among inexperienced drummers by decoupling the music performance aspect from the music creation aspect.

Another logical step for future work would be to incorporate group dynamics while performing in drum circles. For example, it would be interesting to study how 5-10 participants experience collaboration while performing with computer partners simultaneously. A series of experiments involving single performance, dyad, triad, etc group sizes could be measured, and interaction techniques and experiences could be cross-referenced against each other. This work is similar to previous work by Lee (Lee et al., 2010) where triads of users collaboratively completed a numerical Sudoku puzzle. An interesting side to this would be the lack of anonymity, something that as discussed in previous sections(Gurevich, 2006), has been shown to help mitigate the anxiety amateur musicians experience when performing with other musicians, or when performing in front of an audience.

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