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EDITORIAL

A Cool and Swinging Close to *PMMB*'s First Year of Quarterly Publication

Annabel J. Cohen

Jazz improvisation reflects the real-time integration of generative processes with musical knowledge representation. This impressive ability has surprisingly received little attention from the psychomusicological research community as a whole. Fortunately, in April 2013, Martin Norgaard and his colleagues at Georgia State University hosted a conference on the psychology of music improvisation called "The Improvising Brain." The present special issue of *Psychomusicology: Music, Mind & Brain* (*PMMB*) entitled "Jazz Improvisation: Cognitive Perspectives" is an outcome of that conference. The featured articles represent one of the first, if not the first, collections to focus on the music–cognitive–motor behaviors and processes associated with jazz improvisation. The authors use the style of jazz as a vehicle for broader discussions of improvisation in music, which of course is by no means limited to jazz. In other words, the special issue is more about music improvisation than about jazz per se.

I would like to thank Martin Norgaard, Susan Rogers, and Peter Vuust for serving as Guest Coeditors. Their issue for *PMMB* reaches a new milestone in the separate histories of jazz and music psychology. This milestone was unimaginable just a few decades ago and is reached today largely through the efforts and talents of the editorial team. Martin kindly accepted my invitation to consider a publication with his conference as a springboard. His experience in and enthusiasm for research on cognitive processes underlying jazz improvisation, his background as a jazz fiddler and jazz educator, his editorial experience and strong organizational skills served him well as the lead Coeditor. Guest Coeditor Susan Rogers was well placed as a faculty member at Berklee College of Music, historically a training ground for jazz musicians. A professional recording engineer and producer before coming to the field of music psychology, her psychoacoustic rigor and her experience with the nuances of performance offered valuable assets to the editorial team. Completing the trio was Peter Vuust of Aarhus University, in Denmark. As a professional jazz bassist and prolific neuroscientist, his insights and cooperation were invaluable. The resulting collection is full of lively original content. Though the articles were on jazz improvisation, it was not the case, however, that "anything goes." All submissions were internally reviewed, and, with the exception of the introduction by Martin Norgaard and a report on the conference, all were externally reviewed. In accordance with the publication policy of the American Psychological Association, for the two research articles submitted by the Guest Coeditors, neither the Guest Coeditors nor the Editor of the Journal, nor its Associate Editors served as action editors or reviewers. In the two exceptional cases, Amy Graziano and Christine Beckett kindly served as Guest Action Editors in charge of respective peer reviews. The journal also acknowledges the host of external reviewers who read and commented on submissions. First and foremost, however, the authors are thanked for sharing their work. Although each of their contributions stands on its own, together the collection provides a foundation that should well inspire research in this important area. *PMMB* will certainly welcome future manuscripts on this topic.

"Jazz Improvisation: Cognitive Perspectives" Volume 23, Issue 4, completes the first year of quarterly publication of *PMMB*. With this special issue, 2013 ends on an upbeat. The journal has much in store for its readership in 2014. While we look ahead, it is also important to look back to those on whom the achievements of the past year rely. The dedicated meticulous support of John Hill, who is the manuscript coordinator for the Journal, is greatly appreciated. The conscientious assistance of Carol Jones the Manager, APA Journal Production, and the generous guidance of Annie Hill, Managing Director, Educational Publishing Foundation APA, are also most gratefully acknowledged. My deepest appreciation is expressed to the unwavering

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intellectual and moral support of Jay Dowling, Lauren Stewart, and Renee Timmers, the *PMMB* Associate Editors. On their and my behalf, I acknowledge also the members of the *PMMB* Editorial Consulting Board who work hard to ensure publication of meritorious work. The Journal's mission is to provide an outlet for leading edge research in the field, but true success arrives when readers build on the new knowledge acquired. Your feedback and submissions to the journal portal are always welcome at (www.apa.org/pubs/journals/pmu), and we look forward to serving you and the discipline in the new year.

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Introduction to the Special Issue on Jazz Improvisation

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How do we define expert improvisers? What is the nature of their internal dialogue and external interaction during performance? How do we evaluate interaction between musicians during performance? Are certain domain-general abilities related to improvisation achievement? And, can a computer program model the improvisational process? These are some of the questions explored in this special issue of *Psychomusicology: Music, Mind & Brain* (*PMMB*) based on selected papers from the Improvising Brain Symposium held at Georgia State University in Atlanta, Georgia, April 7–9, 2013. The opening event consisted of a concert performed by jazz musicians and related interview in which the featured jazz violinist and the accompanying rhythm section players were asked about their thinking as they listened to short excerpts played back from the just completed performance. In this introduction, I briefly describe interview data from this event as a way to introduce selected articles that make up the core of this special issue. A separate conference report by Steven Anderson describes some of the other papers presented at the symposium.

The interview event was conceived as a way to explore interaction between jazz musicians during small group performance. Previous research has outlined the primary importance of this interaction (Berliner, 1994; Monson, 1996; Sawyer, 2006; Vuust & Roepstorff, 2008). Monson interviewed expert jazz musicians looking at a full transcription of a piano trio performance. They described how intimate knowledge of the style allowed them to signal to each other using various techniques including obscure musical references. However, the interview was conducted long after the actual performance took place.

The current event was based on a methodology I used in previous research with individual jazz performers (Norgaard, 2011). During each session, I first asked the improviser to perform a blues improvisation along with a recorded drum loop. I then converted their performance to approximate notation that I displayed while playing the original audio in synchrony. This served as the basis for a directed interview in which the performer described his thinking. This design specifically eliminated any external cues, as the performances were recorded in a solo setting. Though the results included important descriptions of the thinking of artist-level improvisers, obviously information about interaction with other players and audience could not be collected.

The Improvising Brain concert event offered an opportunity to investigate the thinking of artist-level jazz musicians in an ecologically valid concert environment. Though the participants were aware that the performance would serve as the basis for a subsequent interview, here they played in a group setting in front of an audience of about 300 people in a small concert hall. As in my previous study, an attempt was made to create approximate notation for the violin, piano, and bass parts. However, the technology did not cooperate and most of the interview was based on audio prompts only.

The methodology was as follows. The four musicians were asked to play an improvisation on a selected blues theme. They chose the blues composition, *Sonnymoon for Two*, by jazz saxophonist Sonny Rollins. The drummer was given a click track set to metronome 200 in a pair of headphones but was asked to take the headphones off as soon as the performance started. The tempo was therefore not necessarily constant. The performance was recorded on four separate tracks representing the four instruments violin, piano, bass, and drums into a computer using standard multitrack recording software ("Logic Pro," 2012). The first three were recorded using a direct line signal instead of individual microphones to eliminate cross talk. The drums were recorded with two overhead microphones.

After the performance, the musicians were seated in a row on one side of the stage and interviewers on the other about 10 feet away. The interviewers were Dr. Robert Zatorre (neuroscientist, musician, and keynote speaker), David Halpern (student representative), and myself. The output of the computer used for the recording was connected to the hall sound system. I played short sections of audio from the full performance and then asked questions such as "why did you play that?" and "describe the musical interaction in this segment." All performers were interviewed together owing to time constraints and to allow verbal interaction.

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Though some prompts were based on the music, general questions arose in a lively discussion in which both the interviewers and the performers asked and answered. The interview length was limited by the concert setting (about 30 min) and the audience presence (with frequent laughter) obviously influenced the responses. The entire interview session was recorded on video and audio. These data were used in a subsequent thematic qualitative analysis.

Several main themes emerged related to concepts mentioned in my previous study of solo improvisation (Norgaard, 2011). The violinist mentioned how some material emanated from a stored *bank of ideas*. Starting his solo, he described studying African American blues and how his initial simple melodic idea related to the classic AAB vocal blues form (Evans, 2002). In the first four measures of a 12-bar blues, a statement is made that is then repeated in the following four measures. Finally, a response to the statement appears in the last four measures. Later he described using a sequence of short melodic figures implying the circle-of-fifths over the traditional blues harmony. The violinist also described adding a harmony line to the theme as played by the piano but immediately being unhappy with the choice. This implies a *monitoring* process in which musicians evaluate what they just performed—also described earlier.

Unique to the current experiment were descriptions by the performers of their musical interactions. In the third improvised chorus of the first solo, the violinist started to imply a set of distinct harmonies initially used by Charlie Parker over the blues form in his tune *Blues for Alice.* The pianist caught this but explained: "from my point of view if I go exactly with him I might be forcing him to do all of it so I prefer to . . . play little things that kind of addresses it . . . then if he had done another chorus or two of it I would have gone 'oh yeah, I'm with you." The pianist was supportive but did not lock the soloist into the implied chord structure for a prolonged period.

In another example, the rhythm section appeared to be the instigator of a rhythmic effect that the soloist then had to address. The drummer explained the performance as being a musical conversation between three players, who knew each other well, and the guest soloist in which "we want to get the violinist into the things that we like to talk about but also check out what the violinist likes to do." In this example the drummer and bassist played a repeated three beat figure over the 12-bar form in 4/4 time. "If we, the rhythm section, keep looping it long enough it sounds like that is the actual time and that we switched to a slower tempo. It is something I know the bassist likes to do."

The give and take and the shared responsibility of group improvisation has been described both in jazz settings and improvisational theater (Berliner, 1994; Monson, 1996; Sawyer, 2006; Vuust & Roepstorff, 2008). In the current issue, Brian Wesolowski discusses the importance of interaction in jazz education and presents a rubric for evaluating interaction. Specifically, the rubric is capable of differentiating three performance levels on all criterions, three melodic, two harmonic, and three rhythmic. The author interprets the results in light of cognitive processes involved in interaction.

During the interview, a question of conscious control spurred a long discussion in which the musicians talked about the implications of inner dialogue. The pianist clearly found this dialogue a distraction from getting into "the zone." He explained "I play my very best when I don't think" and described a procedure for entering "the zone" in which he places his keys, watch, and wallet aside after walking on stage to perform. He went as far as saying "the reason I'm playing music is chasing the feeling of playing without picking [notes during improvisation]." The drummer cited *The Inner Game of Tennis* (Gallwey, 1974) as having helped him understand how to overcome interference from excessive inner dialogue (see also, Green & Gallwey, 1986).

In her article in this issue, Judith Lewis argues that dialogue is not limited to group improvisation but is indeed essential to solo improvisation. Based on interviews with three classical pianists learning to improvise in a solo setting, she relates their comments to cognitive studies of improvisation and concludes that solo improvisation is a dialogue between the musician and the "musical entity."

Several musicians mentioned the importance of practicing motor skills to a level of automaticity. The violinist cited *Thinking, Fast and Slow* by eminent psychologist Daniel Kahneman (2011, cf. Kahneman & Miller, 1986; Kahneman & Tversky, 1973), to explain how certain skills were meticulously learned. The drummer concurred "it's too late to worry about how clean my double stroke rolls are [in performance]" that must be perfected during practice. In this issue, Andrew Goldman hypothesizes that learned motor patterns facilitate improvisation in familiar contexts where those patterns are available. In novel contexts, the improviser must rely on learned procedures to construct material. The author reports an ingenious experiment in which various quantitative results suggest that different processes guide improvisations in familiar and unfamiliar contexts. He argues that studies in improvisation should be guided by theoretical frameworks within cognitive science and suggests future directions for such research.

In an article describing a computer modeling project, Jonathan Spencer, Mariana Montiel, and I argue that stored patterns are central to the improvisational process. Our computer program is capable of producing novel output based on the transitional probabilities in a given corpus. Notably, no style-specific rules are incorporated into our model.

In a short report, Roger Beaty, Bridget Smeekens, Paul Silvia, Donald Hodges, and Michael Kane explore whether the skills necessary for expert musical improvisation are related to general measures of divergent thinking, working memory, and fluid intelligence. They found that ratings of jazz improvisations on an unfamiliar tune correlated highly with an independent measure of divergent thinking.

Much of the research on musical improvisation features experts, but what exactly constitutes expertise in this domain? Iwan Wopereis, Slavi Stoyanov, Paul Kirschner, and Jeroen Van Merriënboer explore this problem using a concept mapping procedure to analyze verbal comments about improvisational expertise. Key characteristics included self-regulation, basic (musical) skills, affect, risk-taking, creation, responsiveness, and ideal.

I would like to thank the authors, reviewers, and editors who made this special issue possible. In particular, my fellow guest editors, Susan Rogers and Peter Vuust, the action editor, Christine Beckett, who handled my own article, and the journal editor, Annabel Cohen. I am also grateful to the staff at the American Psychological Association for support. The organizing committee for the symposium, Dr. Patrick Freer, Dr. Katie Carlisle, Dr. Daniel Welborn, as well as the staff at the Georgia State University School of Music made the actual event possible. Finally, my most heartfelt thanks to all the presenters and attendees at the Improvising Brain Symposium; I hope the success of the event and the publication of this special issue of PMMB signals a growing interest in scientific enquiry related to musical improvisation.

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Towards a Cognitive–Scientific Research Program for Improvisation: Theory and an Experiment

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Despite often being conceived as a spontaneous and creative mode of performance, improvisation is predicated on prior knowledge. What characterizes this knowledge, and how is it represented or recalled differently as compared with other modes of music making? Asking about knowledge and trying to distinguish improvisation as a distinct performance process can locate research questions within the theoretical frameworks of cognitive science, but it is not clear how to make such questions experimentally accessible. Differences arising from music–analytical versus cognitive conceptions of improvisation are explored to provide a theoretical framework compatible with experimentation. Experimental research could concern itself with how the embodied interface between performer and instrument, when manipulated, invokes different cognitive processes of music making, helping to describe the cognitive characteristics of various modes of music performance. Here, an experiment is reported that synthesizes previous techniques used to analyze improvisations with experimental strategies from the neuroscientific literature aimed at differentiating performance processes within a given improviser. Jazz pianists improvised monophonically over backing tracks in a familiar and unfamiliar key as well as with their right and left hands. Among other findings, in some of the less familiar performance situations, participants relied more on diatonic pitches and produced more predictable improvisations as measured by entropy and conditional entropy. The nature of the different underlying processes and knowledge at play under these different conditions is explored, and future research directions to better describe them are identified, including incorporating motor theories of perception.

Keywords: improvisation, cognition, musical performance, music analysis

Despite often being considered a creative and spontaneous activity, musical improvisation is predicated on acquired knowledge (Ashley, 2009; Pressing, 1988). Improvisers may be creating something that is new or unplanned according to a particular set of structural–analytic criteria (e.g., the notes are new or the chords were not chosen beforehand), but they also have prior knowledge that enables their music making. How can what improvisers know be characterized? How might the nature or use of such knowledge differ when the same musician is improvising as compared with playing from memory, or when the same improviser plays in different performance contexts? Asking questions about a musician's knowledge can locate the topic of improvisation within the theoretical frameworks of cognitive science, but it is not clear how one might frame these questions so as to make them experimentally accessible. If improvisation is, by its definition, free, how could experimentation help to systematize its processes?

Previous research has approached these questions in few different ways. Many analytical methods have been used to examine transcribed and recorded improvisations to infer properties of their style and the underlying cognition of the processes that created them (e.g., Järvinen, 1995; Järvinen & Toiviainen, 2000; Pfleiderer & Frieler, 2010). These studies provide valuable insight into the processes of improvisation, but could go further by examining improvisations produced in the laboratory under a set of experimentally designed systematically varying conditions. Functional neuroimaging studies have had musicians produce improvisations in the laboratory to assess differences in performance process (memorized performance vs. improvisation) through measuring differences in brain activation (Bengtsson, Csíkszentmihályi, & Ullén, 2007; Berkowitz & Ansari, 2008, 2010; Limb & Braun, 2008), but could go further by not treating improvisation as a single kind of process. These two approaches could be usefully combined to form an experimental program in which improvisations are produced within the laboratory under experimentally varying conditions to reveal differences in process. With the goal to differentiate process from the neuroscience literature and the modes of inference that can identify differences in process through musical structures from the analytical literature, a more developed cognitive–scientific experimental program could access questions

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This article includes an experiment previously described and published in conference proceedings (Goldman, 2012). Additional analyses on the same data set are provided here as well as an expanded discussion and theoretical contextualization.

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about improvisational processes and help describe the nature of its underlying knowledge.

There are thus two goals in this article. The first is to arrive at a set of appropriate cognitive–scientific questions by reframing common conceptions of improvisation from the literature—which often focus on structural and analytical characteristics of improvisation—to a cognitive–scientific conception compatible with experimentation. In-laboratory improvisational experiments do not have an established approach and a somewhat broad theoretical context is thus necessary to construct a set of appropriate questions. Second, based on this reconsideration, an experiment is reported that has participants improvise in the laboratory under a set of varying experimental conditions and uses established analytical techniques to reveal differences in performance process and help describe the cognition of different improvisatory processes.

Reframing Conceptions of Improvisation

This first section presents an overview of how improvisation has been defined in previous theoretical literature. It focuses on a few key features common to many definitions of improvisation and considers whether they are compatible with a cognitive–scientific conception of improvisation. Such reconsideration is necessary to further develop an experimental approach.

The features in the definition of improvisation produced by Nettl et al. (2013) are present in many other definitions and so they serve well the purposes of this discussion:

> The creation of a musical work, or the final form of a musical work, as it is being performed. It may involve the work's immediate composition by its performers, or the elaboration or adjustment of an existing framework, or anything in between. To some extent every performance involves elements of improvisation, although its degree varies according to period and place, and to some extent every improvisation rests on a series of conventions or implicit rules.

There are four features of this definition that I wish to consider: First, the relationship between improvisation and the musical work; second, the notion that this work or composition is created immediately; third, the notion of frameworks, conventions, and rules; and fourth, the notion of "anything in between." My treatment of Nettl's definition is meant to address common themes in discussions of improvisation and is not meant to be a direct response to his particular definition. It is cited merely as a platform from which to launch a discussion of what the important issues of defining improvisation are as far as a cognitive approach is concerned.

Improvisation and the Musical Work

Alperson (1984) raises a useful distinction between two senses of the term "improvisation." One sense is improvisation as the act of improvising, and the other is improvisation as the thing-improvised. Nettl's definition would seem to be concerned with improvisation insofar as it creates an end product rather than focusing on the features of the process. One could interpret "the creation of a musical work" as "the process of creating a musical work," and in this sense, the definition could be read as concerning both process and product. But, why is a musical work mentioned at all? Whether Nettl meant to focus on process or product, a conception of improvisation as creating a musical work raises problems for a cognitive approach.

Nettl is probably using the term "work" as a placeholder to find a word to refer to the content of what is improvised. In this way of thinking, a composer creates a work as well through a different generational process. In fact, improvisations have often been compared with compositions, differing subtly in the process of their creation (e.g., Larson, 2005). To refer to a thing-improvised as a composition or work is to define what is produced in structural terms. The *thing* that is improvised must be defined somehow (with some structural criteria) if one wishes to refer to it as a distinct ontological entity. It is to say that an improvisation, like a composition, has structures that can be identified and described within the context of a theory such as a tonal theory (e.g., Järvinen, 1995), or a Schenkerian theory (e.g., Larson, 1998). This conception of an improvisation as a work might lead to questions about what structures there are and how they work together, as in an analysis of a composition. There is no problem with this in itself—the process of improvisation does produce *something*, and can thus be understood in terms of structures. In fact, analyzing structures can also help infer the performer's process as in the literature mentioned above and the experiment suggested below. One just needs to be careful in choosing an appropriate theoretical approach and concomitant technique of analysis. In other words, which structures does one examine, and why those? One of the goals of a definition of improvisation, presumably, is to distinguish it from other modes of performance. From a slightly different angle, another goal might be to speak to what is different about music that is produced by improvisation as compared with composition. Either way, the analytical technique chosen would need to support a theory aimed at understanding the improviser's performance process and not just to understand structural relationships in themselves. Because there is only a work when viewed after the act of creation, then during the performance, if one wants to distinguish improvisation from the act of a rehearsed performance or the act of composing, the question of process is central. What is different about the *way* the music is produced? One can develop ways to infer this from examining the work, but as far as a definition of improvisation is concerned, the focus should be on the "creation" and not the "work."

Immediacy

The second element in Nettl's definition to consider is immediacy. This could be construed in two senses. In the first sense, it could refer to music produced "in real time" (e.g., Ashley, 2009). Time is said to place pressures on an improviser with all of the listening, monitoring, synthesizing, and moving that has to be done online, and thus places constraints on how knowledge can be recalled and executed during performance. A composer can take as much time as necessary to work out a retrograde inversion of a tone row while an improviser must calculate more quickly in order to play it, and thus might tend to play different musical ideas that are able to be generated in real time. Sometimes a compose-able idea is not an improvise-able idea even if coming from the same musician.

Notably, needing to distinguish improvisation from composition in terms of time only becomes an issue when conceiving of a musical product, a work. A musical product is conceived as having a kind of timeline; a composer can jump around on the timeline while creating a work whereas an improviser must progress linearly. Without considering a musical product, however, the consideration of time becomes less important—composing, improvising, and playing from memory, at least in cognitive terms, are all "in real time." What differ are the circumstances of the recall and representations of the musical ideas. What makes some musical knowledge improvise-able? What about the interface between the musician and the instrument enables the improvisatory performance of musical ideas? How is improvise-able musical knowledge represented and recalled and how does that compare to compositionally generated ideas, or the way ideas are recalled during a rehearsed performance? Again, this might be asked structurally: what sorts of structures are present, or more present, in improvisations as compared with compositions, or compared with rehearsed performance, and why it would be *those* structures. For instance, some empirical studies have searched for cues present in improvisatory music that may not be in rehearsed performances (e.g., Lehmann & Kopiez, 2010). Also, what about a particular performer–instrument interface would lead to the prevalence of certain musical structures? The experiment described below attempts to distinguish between different processes of recalling ideas by examining structural differences in improvisations produced under different experimental conditions. Discussions of "real-time" raise important questions about how knowledge is represented and recalled, but to distinguish between modes of musical production and different modes of musical improvisation, it is not *time*, exactly, that is the primary question.

In the second sense, immediate might mean that improvisation is not mediated. However, improvisation is indeed mediated. It is mediated by physical things like the body and instruments, cognitive things like the ways sounds and movements are represented and executed, and social things like group interactions and societal constructs of performance practices. Hogg (2011) describes various aspects of this embodied knowledge. All of these mediated sources of knowledge change what is possible and what is more likely to be played. Nettl is aware of these sources of knowledge considering his reference to constraints and frameworks (discussed below), but the point is that as far as a cognitive approach is concerned, the term "immediate" in terms of time could be refocused to questions of differences in the representation and recall of musical knowledge, and its use in the sense of mediation may discourage the examination of important sources of knowledge.

Frameworks and Rules

The constraints placed on music by frameworks or rules is well noted (e.g., Ashley, 2009), and is present in Nettl's definition. These frameworks are understood to be constraints on what an improviser is able to play or chooses to play. It might be something like a chord progression that limits the notes an improviser can play, or a more abstract rule like to trade four-bar sections of a solo with another improviser. It could also be cultural norms that are gradually acquired in training (see Pressing, 1998, p. 57).

The idea of musical constraints must be carefully considered if it is to be made compatible with a cognitive–scientific approach. First, it is useful to distinguish between music–theoretical constraints and cognitive constraints. Music–theoretical constraints include patterns that arise from the analysis of improvisations. It might be noted that improvisations in a particular style emphasize certain scale degrees more than others. It could show that a certain performance must conform to a particular harmonic progression or set of scales. Such constraints could group styles on the basis of these features and make predictions about which formal structures will occur in which performance contexts. Johnson-Laird (1991) takes these kinds of constraints to computationally model improvisation. He points out, however, in the tradition of Marr's (1982) computational account of vision, that a computational implementation may recreate *what* a human produces, but will not necessarily explain *how* it is produced. Further, it should be noted that music–theoretical constraints are also sometimes explicitly known by the improvisers. Berliner (1994), for example, examines how improvisers describe their own processes of playing on existing structures (frameworks) while improvising (p. 222). Improvisers know they are using chord progressions, for instance. On being asked, improvisers can adopt the role of an analyst and describe their own performance in such music–theoretical terms. Similar to Johnson-Laird's methodological limitation, being self-aware of such constraints is not necessarily knowledge of *how* the music is produced.

Generally speaking, the recurrence of music–theoretical patterns (like a particular key's set of pitch classes) only becomes a "constraint" by virtue of the existence of other similar patterns. For example, playing music in C major is "constraining" if one accepts the existence of the alternative possibility of E*b* major. The categories chosen by a particular music theory thus dictate which things can be called constraints. A different music theory could identify different constraints in the same improvisation after it was produced. In this way, music–theoretical constraints are a description of the product after a performance process has been executed and is not necessarily an explanation of that process.

By contrast, one can think of cognitive constraints as a kind of embodied situation arising from the way the mind and body interface with an instrument. In the course of learning to improvise, a musician acquires knowledge of how to create certain sounds with certain movements at an instrument. It could be thought to be constraining in the sense that a 10-fingered human can only play 10-fingered music, that the human brain can only process so quickly, or that a given instrument has a certain physical structure that affords many musical possibilities, but not every musical possibility. The relationship between the brain, body, and instrument creates a situation that requires an improviser to possess a kind of embodied knowledge. Pressing (1998) casts such knowledge in cognitive terms with his ideas of "referents" and the "knowledge base." The ability to play a given music–theoretical structure has cognitive correlates (such as motor programs and auditory images) dependent on the brain, body, and instrument. It may be misleading, however, to think of this kind of embodied knowledge as constraining. The boundaries between these cognitive referents do not necessarily align with music–theoretical boundaries. There may not be a completely distinct referent for C major and E*b* major. Because of this asymmetry, this kind of knowledge arising from the embodied situation between the performer and the instrument is perhaps better characterized as enabling, not constraining. The ability to play in C major does not rely on the ability to play the music–theoretical alternative of E*b* major. The body has to interface with an instrument to do either.

Nothing is constrained by knowing or not knowing how to do the other.

Music–theoretical constraints are a particular description of what is produced; by contrast, embodied knowledge is an attempt to explain how music is enabled and produced by minds, bodies, and instruments. Again, understanding this *how* question may still need to rely in part on considering music–theoretical contexts through making inferences about the presence of certain patterns and structures. With an appropriate theory of which structures are notable and why, however, an understanding of this enabling embodied knowledge may be inferable. This is a goal of the experiment described below.

Everything in Between—Continuum

The final point in Nettl's definition is the notion of "anything in between." The amount of things that are constrained could be said to be varied, leading to ideas of a spectrum of how improvisatory something is. For example, perhaps the melody is fixed but the harmony is not. Some theorists suggest that no performance has everything completely determined and thus all performance is somewhat improvisatory. For example, Gould and Keaton (2000) suggest that because thoughts and intentions do not exactly match the movements we actually execute, performance of music, as performance of speech, inevitably must have some discrepancy from what is intended. To Gould and Keaton, improvisation is necessary to account for this gap. Merker (2006) suggests that improvisation in performance could be structural, expressive, or both. The classical pianist producing a rehearsed performance still improvises the expressive elements (such as the precise amount and placement of dynamic variation, articulation, etc.) whereas the harmonic and melodic structure may be fixed. On the other hand, a jazz pianist may improvise the harmonic and melodic content itself as well as the expressive elements. He notes that methods of improvisation around the world " . . . span the gamut from mild embellishment to de novo creation, though the extent to which genuine on-the-spot novelty is created even in genres that prize it is a question as important as it is difficult to answer" (p. 27). Similarly, Clarke (1988) distinguishes between structural and expressive improvisation.

Similar to the notion of constraints described above, this anything-in-between reasoning depends on a particular music–theoretical framework. One must be able to delineate and count such constraints before arriving at a conception of a continuum. Because the enabling cognitive mechanisms are not necessarily symmetrical with music theoretical constraints (see Clarke, 1989), there should be at least initial skepticism of a cognitive continuum. Separating expression from structure is a music–theoretical distinction, and it might have symmetrically dissociable cognitive analogues. Then again, it might not. Music theoretical categories can define improvisation according to a continuum, but it stands as an open question whether there are cognitive mechanisms that enable improvisatory abilities that are in any sense continuous.

Toward an Experiment

The first section of this article reconsidered some common elements of the definition of improvisation to raise questions compatible with cognitive–scientific experimentation. In summary, the cognitive approach should use the analysis of music–theoretical structures as a means to reveal process and not as a definition of improvisation in itself. To answer the *how* question, the cognitive approach should focus on how knowledge is differently accessible in different performance situations to describe the different ways musical knowledge is represented, and the different processes that underlie its recall and execution. These differences will help form a cognitive taxonomy of performance that can distinguish between not only rehearsed performance and improvisation, but also between different types of improvising. The second section of this article will identify a more specific experimental strategy that answers to the questions raised here.

Despite sensitivity in the literature to the plurality of different approaches to improvisation around the world (e.g., Nettl & Russell, 1998), the multiple improvisational processes within a single musician are less questioned. How the processes might differ within improvisers depending on a varying music–theoretical performance context (e.g., playing in different keys, or using different musical material) or between groups of musicians who have been trained by different pedagogical methods, such as Sudnow's (1978) "Ways of the Hand" method versus Haerle (1978) who advocates learning licks and chords in all 12 keys, are cognitive–scientific questions that could be compatible with experimentation.

Structural analysis still plays a role in this experimental approach. Any cognitive–scientific experiment trying to dissociate process and strategies in the laboratory based on what music participants produce would at some point need to cast certain musical features as data (e.g., pitch class distributions), and by doing so must use structural analysis. Previous empirical literature on the cognition of improvisation could be usefully synthesized to develop this approach. In particular, as mentioned above, two main strands of this research provide the basis for the experiment proposed below. First, many studies seek to understand something about the cognition of musical improvisation through analyzing improvisations that have been produced outside of the laboratory with various metrics to infer something about how the improvisations were produced. Järvinen (1995) and Järvinen and Toiviainen (2000) analyzed transcriptions of Charlie Parker solos to look for properties of their pitch class distributions and the relation between the use of pitch class and metrical placement. Engel and Keller (2011) noted that improvisations tended to have a greater variation of key-strike velocities (as measured with entropy) and correlated such variation with activation in the amygdala of listeners. The greater unpredictability of the intensity of the key strike was a notable formalized feature of improvisatory playing. Pfleiderer and Frieler (2010) examine improvisations with a number of analytical metrics including Markov chain analysis to seek out patterns and indicate differences in style between performers.

The other strand of research involves trying to compare performance processes within a single performer. Neuroscientists have looked for neural correlates of rehearsed and improvised performance to describe differences in the processes (Bengtsson et al., 2007; Berkowitz & Ansari, 2008, 2010; Limb & Braun, 2008). These studies are useful in their goal to dissociate between performers' processes, but, notably, they do not try to dissociate different improvisational strategies within a given performer. For instance, Berkowitz and Ansari define improvisation as "the spontaneous generation, selection, and execution of novel auditory—motor sequences" (p. 535). Improvisation may not be homogenously spontaneous or novel. With a more subtle understanding of how improvisation might differ between performance contexts in terms of process, and how that would change the music that is produced, the interpretation of such neuroscientific evidence could be enhanced. Improvisation is not a single kind of behavior. This approach can be usefully expanded with a consideration of differences in improvisatory process, and what kinds of bodily, instrumental, and cognitive factors would lead to such differences.

A final point of reference is that of Hargreaves (2012) theoretical piece, which identifies several "sources of ideas" from which improvisers can draw, including strategy-generated ideas (e.g., deciding to use perfect fourths), audiation-generated ideas (e.g., getting ideas from what an improviser "hears" with mental imagery), and motor-generated ideas (unconscious procedural knowledge). This type of reasoning helps ground the experimental method proposed below. The performance situation may change which sources the improviser can access.

How, then, could music–theoretical performance contexts be varied to reveal differences in an improviser's use of or access to embodied knowledge? How can manipulating these contexts be shown to manipulate cognitive processes? What can be learned about the nature of the embodied knowledge through such an experiment? How can different improvisational strategies be characterized cognitively? The experiment reported below, initially discussed in Goldman (2012), begins to address these questions experimentally. It keeps the goal of the neuroscientific literature of distinguishing between an individual's different performance processes, expands it by considering different modes of improvisation, and combines it with analytical techniques used in previous improvisation literature. It offers a new synthesis of these by devising experimental conditions under which the same improviser's performances can be compared, and the effect of different performance context variables can thus be measured. It also offers a way to make inferences about differences in cognitive processes based on these measurements.

The task required jazz pianists to perform monophonic improvisations with one hand in a familiar music–theoretical context (playing over *Rhythm Changes*, the chord progression from Gershwin's song *I Got Rhythm*), but varied the situation between the performer and the instrument by varying the key signature between a common key (B*b* major) and a less familiar key (B major), and by varying which hand played which musical function (bass line or melody). B*b* is generally more familiar than B for jazz pianists in part because jazz standards are written and played in keys that accommodate horn and wind players playing on instruments that transpose to flat keys, and pianists play at concert pitch. Keys with many sharps, like B, are thus uncommon for pianists in jazz standards. To play the same musical idea in these different conditions would require a different set of movements. From a music–analytical point of view, all of these performance conditions are improvisational and could be said to follow the same (or a similar) framework. Cognitively speaking, however, the conditions were meant to force the improvisers to rely on different improvisational strategies and cognitive processes by changing the familiarity of their mind–body–instrument interface. Comparing the resultant improvisations could help characterize the cognition of these strategies.

The less familiar performance conditions were meant to take away access to familiar and overlearned motor patterns ("muscle memory") and require the performers to rely on an alternative strategy. Pressing (1998) describes a knowledge base for improvisers. Here, it may not be that different parts of a single knowledge base are accessed depending on the situation—it may be that several knowledge *bases*, distinguished on the basis of separate kinds of representations and processes of execution, are at play. Trying to understand whether there is such a difference and what its nature would be is a goal of this experiment.

Hypothetically, if improvisers are not able to use overlearned and practiced movements as would be available in the familiar keys, they would need to rely on a more explicit strategy to create improvisations appropriate for the musical style. Without this kind of procedural knowledge, improvisations should become less varied and more predictable. They would have a smaller repertoire of ideas in terms of their ability to use the range of tonal possibilities available to them in the key and in terms of more specific licks and patterns acquired over years of practice. In a less familiar situation, participants would be less familiar with how to move their hands at the instrument to get the sounds they would want. In the absence of this connection, they would still have to play something that worked over the harmonic progression. Without knowing how to create the more complex chromatic sounds, participants would likely rely on the use of more diatonic scale and chord tones to play something that, while less harmonically complex, would still work over the chord changes. The metrics used to test these hypotheses are described in detail below.

Experiment: Inferring and Describing Different Improvisational Processes Through Structural Analysis

Method

Participants. Ten jazz pianists (all male, nine right-handed) with an average age of 24.3 years ($SD = 4.9$) participated in the study. Eight were students or recent graduates of a jazz piano program at the Birmingham Conservatoire, one was a music student at the University of Cambridge, and one was a music student from a university in the United States. The participants had similar periods of formal musical study ($M = 17.3$ years, $SD = 4.22$) and similar periods of specifically improvisational training ($M = 8.0$ years, $SD = 4.88$). All participants volunteered to participate after receiving an invitation from the author.

Materials. Aebersold's (2000) backing track for *Rhythm Changes* from the Play-A-Long series was chosen to accompany the pianists. The track is a recording of a drummer playing a swing pattern, a walking bass line, and a pianist comping. The length of one chorus was extracted (~1 min long). The track was transposed from its original key of B*b* major to B major using Logic Pro's Time and Pitch Machine. A version in each case was also created without a bass line (the original tracks are recorded in stereo such that panning to one side eliminates the bass line). The backing tracks thus needed to be slightly altered to accommodate the experimental design and could potentially introduce additional variance. A strictly controlled MIDI backing track could have been used for the purpose of this experiment, but the Aebersold backing tracks are a more ecologically valid option. They were produced as practice aids for musicians. Such alterations to these recordings were deemed acceptable for the purposes of this experiment. Participants improvised on an 88-key weighted keyboard and listened through headphones. MIDI recordings were made through Logic Pro, which also was used to play the backing tracks. The keyboard was set to a generic piano sound.

Design. Eight conditions were chosen (three factors with two levels each). The factors were key (B or B*b*), hand (left or right), and function (melody or bass line). Each condition was repeated five times, totaling 40 MIDI file improvisations collected for each participant.

Procedure. Before the improvisational task, the participants filled in questionnaires about their demographic information including age, gender, handedness, and musical training. Participants were then instructed to improvise over the *Rhythm Changes* backing track on the MIDI keyboard. They were told which hand to use, which key to play in, and whether to play a melody or bass line via the recorded voice of the experimenter, depending on the condition. Trials were arranged in a pseudorandom order such that identical conditions did not occur consecutively. After 20 trials, participants took a short break before completing the remaining 20 trials. Participants were further instructed to play bass lines as a walking bass line and not a bass solo, and to consider the melodies as solo horn lines. Finally, for melodies, they were advised that they could use the whole keyboard with either hand and should adapt their sitting posture accordingly. Following the improvisational task, a postexperiment interview was conducted to discuss the task, practice methods, and any other comments participants had.

Analysis

Data. A total of 400 MIDI files were collected. The data was processed using MATLAB and Eerola and Toiviainen's (2004) MIDI Toolbox. A total of five trials were excluded from analysis for various reasons such as the participants playing with the wrong hand for the condition or using both hands. Because one of the metrics described below incorporates conditional probabilities, additional trials were discarded for those analyses. Occasionally, for all of the trials, the participants would produce two note events very close in time (<10 ms). Sometimes these were grace notes, sometimes they appeared to be errors (such as playing two notes at once on accident), and sometimes they were deliberate uses of harmony. For conditional probability measures, it is necessary for the data to be monophonic, as the analysis is sequential in nature. However, because it is sometimes difficult to tell whether two notes in proximity are deliberate or not, discarding all instances of this could eliminate meaningful data. The events never occur simultaneously in time, so as far as the analysis is concerned, they are able to be treated as separate sequential events. Trials with a few of such instances were tolerated for this analysis, but some trials had a large number of them. Trials with more than five of such instances were discarded. Eleven of such trials were found. Therefore, a total of 16 trials were discarded in total for the conditional probability analysis. For the ANOVAs described below, the values for missing trials were replaced with the average value across all data within that condition. Also, for the purpose of analyses, notes were treated according to their pitch class and not their absolute MIDI note number.

Metrics. In designing a study such as this, some kind of formal analysis is needed to infer and describe differences in cognitive strategy from recorded MIDI data. For this study, two relatively gross measures were used initially, and followed up with a more specific metric. First, to test the hypothesis that less familiar conditions would lead to more predictable improvisations, the entropy of the pitch class distributions for the improvisations was measured. The entropy metric has a long precedent in the literature and has been interrogated for its musical relevance (Knopoff & Hutchinson, 1983; Margulis & Beatty, 2008; Meyer, 1957; Snyder, 1990; Youngblood, 1958). The equation for calculating entropy is

$$H = -\sum_{i}^{n} p_i * \log_2(p_i)$$

where H is the entropy in bits of a sample, n is the number of elements in the set (in this case, 12 different pitch classes), and $p(i)$ is the likelihood of a particular pitch class from the set occurring within the sample (the number of times a particular pitch occurs divided by the total number of notes for that sample). The highest possible entropy occurs when all pitch classes are used equally ($\approx$3.58 bits). More predictable improvisations should have a lower entropy value, as they rely on some pitch classes more than others.

To refine the assessment of predictability in the improvisations, a conditional entropy metric was also used. An improvisation that, for instance, used many chromatic scales, would return a high entropy value because all possible pitch classes would be used more evenly, but would nevertheless be a predictable improvisation. For this study, a one-back measure was used, which considers each note within the context of the note immediately preceding it. For instance, in this case, an improvisation with many chromatic scales would return a low value because a given note would strongly predict the note that follows it. To calculate this value, Margulis and Beatty (2008) provide the equation

$$H_{x(y)} = \sum_{i,j} -p_{(i,j)} * \log_2 p_{i(j)}$$

where H is the conditional entropy in bits of a sample, $p_{(i,j)}$ represents the likelihood that a pair of successive events (x,y) will have the values i and j, respectively, and where $p_{i(j)}$ represents the likelihood that event y will have value j given that x has value i. A higher conditional entropy would mean it is generally harder to predict which pitch class will occur after an observed occurrence of a particular pitch class. It thus represents a more refined measure of unpredictability.

Also, the proportion of diatonic pitch classes was measured by dividing the total number of diatonic notes in a given improvisation by the total number of notes in that improvisation. In less familiar conditions, if improvisers are relying more on chord tones and diatonic scale tones as predicted, this metric should offer a relatively gross assessment of this effect. Each MIDI file thus had an associated entropy value, conditional entropy value, and diatonic proportion value.

Further, the improvisations all contained different numbers of notes (ranging from 64–384, M = 167.6, SD = 46.4). This presents a potential problem for assessing the entropy and conditional entropy values. After the entropy values were calculated, it was observed that the number of notes correlated significantly with the entropy value, $r(398) = .234$, $p < .001$. There were also significant correlations between the number of notes and the entropy value within the melody conditions, $r(198) = .157$, $p < .05$, and in the bass line conditions, $r(198) = .254$, $p < .001$. The number of notes also correlated with the conditional entropy values overall, $r(398) = .503$, $p < .001$, within the melody conditions, $r(198) = .396$, $p < .001$, and within the bass line conditions, $r(198) = .314$, $p < .001$. The number of notes thus introduced a potential confound. Knopoff and Hutchinson (1983) advise large sample sizes to ensure the entropy value is confidently estimated for a sample of music in question. As the number of notes increases, the entropy estimate becomes more accurate. In this experiment, there is assumed to be a true entropy value for each condition similar to the way previous research has assumed a true entropy value for styles of music (e.g., Youngblood, 1958). The longer improvisations may represent more accurate estimates of entropy and conditional entropy values. For this reason, a statistic is also reported that combines the individual MIDI files by factor so that a single entropy value for each factor was calculated rather than an average as would be calculated in an ANOVA. This dramatically increases the number of notes for a given calculation and thus more accurately estimates the true value. That being said, the number of notes in a given improvisation may not be a source of variance that should necessarily be eliminated for the purpose of this experiment. A given improvisation, regardless of how long, still has an entropy value that measures its predictability. Fewer notes may not necessarily mean more predictability according to entropy metrics.

Results

For each of the metrics, a three-way repeated measures ANOVA was conducted with the independent variables hand (two levels; right and left), key (two levels; B*b* and B), and function (two levels; bass line and melody). As described above, for the entropy and conditional entropy metrics, the improvisations were also pooled by factor to provide single values from a larger sample.

Entropy. There were no main effects of hand or function, but a highly statistically significant effect of key, $F(1, 9) = 40.194$, $p < .001$. The improvisations in the familiar key, B*b*, had higher entropy values than those in B (see Table 1). There were no significant interactions. Table 2 provides a set of entropy values calculated by combining the individual improvisations by factor. The entropy values calculated from this combination show that right-hand improvisations had a higher entropy value than left-hand improvisations, B*b* improvisations had a higher entropy value than B improvisations, and melody improvisations had a higher entropy value than bass line improvisations.

Table 1
Entropy Values by Key (in Bits)

Key	Mean	*SE*	95% Confidence interval	
			Lower bound	Upper bound
B	3.230	0.042	3.135	3.325
B*b*	3.318	0.039	3.229	3.408

Note. The mean value for improvisations in each key and standard error values are indicated.

Conditional entropy. There were significant main effects of hand, $F(1, 9) = 19.97$, $p < .005$, and function, $F(1, 9) = 16.39$, $p < .005$ (see Table 3). The right-hand improvisations had higher conditional entropy values than the left-hand improvisations, and melody improvisations had higher conditional entropy values than bass line improvisations. There was no main effect for key and there were no significant interactions. Table 2 provides a set of conditional entropy values calculated by combining the individual improvisations by factor. The entropy values calculated from this combination show that right-hand improvisations had a higher conditional entropy value than left-hand improvisations, B*b* improvisations had a higher conditional entropy value than B improvisations, and melody improvisations had a higher conditional entropy value than bass line improvisations.

Diatonic proportion. There were no main effects of hand or function, but a highly statistically significant effect of key, $F(1, 9) = 124.47$, $p < .001$ (see Table 4). In the unfamiliar key, B, the improvisations had higher proportions of diatonic pitches than the B*b* improvisations.

There were two significant interactions. The interaction between key and function was highly significant, $F(1, 9) = 32.10$, $p < .001$ (see Table 5 and Figure 1). The key of the improvisations had a greater effect on melodies than on bass lines.

A three-way interaction between hand, key, and function was also significant, $F(1, 9) = 5.21$, $p = .048$ (See Table 6 and Figure 2). For bass lines, the left hand showed more of a difference between the keys than the right hand. For melodies, the left hand showed less of a difference between keys than the right hand.

Interview transcripts. Audio recordings of the participants' interviews were made and transcribed. Several potential issues with the method were raised by the participants and are addressed below. The interviews also served as further evidence that the experimental conditions indeed influenced participants to rely on different forms of knowledge. These findings are described below.

Discussion

Main effects for hand. No statistically significant differences in the entropy or diatonic proportion were found. This could be because the analysis was too blunt to detect a difference between the hands with regard to pitch class choices. The hand conditions may have produced equal values, but for different reasons. The left-hand improvisations could have simply been using different musical patterns than the right hand, resulting in the same diatonic proportion or entropy. For example, while the right hand may have been using a variety of musically appropriate nondiatonic pitch classes, the left hand may have been relying on chromatic scales, or guessing which notes to play.

The conditional entropy metric, however, did show a significant main effect, with right-hand improvisations returning a higher value than left-hand improvisations, which may help account for this missing effect for context-free entropy. This result suggests that the right-hand improvisations had a greater variety in their transitions between pitch classes. The more familiar and facile interface that improvisers could use when playing with their right hands demonstrated a wider variety of pitch-class transitions. They would seem to have access to a wider range of tonal possibilities.

Given that the number of pairs of notes used to calculate this value correlated significantly with it, it could be suggested that

Table 2
Entropy and Conditional Entropy Values by Factor

Metric	Left hand	Right hand	B	B*b*	Bass line	Melody
Entropy	3.438	3.460	3.415	3.473	3.424	3.459
Length of combined sample	30,498	33,618	30,777	33,339	25,932	38,184
Conditional entropy	3.220	3.268	3.217	3.256	3.114	3.210
Length of combined sample	30,304	33,428	30,583	33,149	25,738	37,994

Note. These values were obtained by combining the trials within the levels of a given factor and taking a single measurement of the entropy and conditional entropy values from that larger sample of notes. The higher number of notes in the sample reflects a more accurate estimate of the entropy values. All of the trials were transposed to the same key before making these calculations, so the entropy values use the distribution of scale degrees, not pitch classes. Entropy values are given in bits, and the length of the samples is given in the number of notes.

these improvisations only had a higher conditional entropy value because the right hand is more facile than the left and is thus able to play more notes. However, the ability to play more notes in itself would not necessarily correlate with a higher conditional entropy if they were the same combinations again and again. Not only were there more notes, but more variety in what was played, which could still be interpreted as having a wider range of tonal possibilities when playing with the right hand. A similar criticism is that the challenges in fingering between the hands are different. Parncutt, Sloboda, Clarke, & Raekallio (1997), for example, provide a model to determine ergonomic fingering possibilities. The challenges posed to the left hand would be different than the right to play the same passage, and the challenges would differ by key. This could cause a difference between the conditions. But again, this difference could still be interpreted in light of the experiment's premise. The way to execute a similar musical idea becomes different, and the same performer resorts to other sources of knowledge to perform. Either way, the tonal content changes, and the cognitive strategy changes. Improvisers could have taken their time and played less, but more varied musical phrases that were perfectly ergonomic.

Main effects for key. There were significant main effects between key conditions. The improvisations in the familiar key, B*b*, had significantly higher entropy and a significantly lower diatonic proportion than the unfamiliar key, B. Both of these findings support the hypotheses. The entropy metric shows that the overall variability of pitches used was greater in the familiar key, and thus the improvisations were less predictable with regard to pitch classes. This suggests that in familiar motor contexts, the pianists are able to rely on a greater and more varied repertoire of figurations and harmonic relationships. In the unfamiliar key, the pianists used more diatonic pitch classes. In this unfamiliar motor context, pianists would not have access to the procedural knowledge of complex chromatic lines they might use in the familiar key. They are replaced by a greater reliance on diatonic pitch classes, suggesting that pianists are relying on their explicit harmonic understanding of scale degrees and chord tones.

As for the conditional entropy metric, the absence of a main effect for key and the absence of a significant interaction between hand and function are notable. According to the hypotheses, there should have been a difference between keys as well as an interaction between hand and function because the hands are differently familiar with the musical functions. However such effects were not found. It could be that in the unfamiliar conditions (e.g., playing in B, or using a hand to play an unfamiliar function), the participants produced similarly varied material that was otherwise musically inappropriate. Wrong notes or guesses, in other words, could possibly account for the absence of this effect. A further analysis involving how subjectively stylistically consistent the improvisations were could potentially sort out this question.

Key interaction effects. There was a significant interaction between key and function for the diatonic proportion metric. The bass lines, overall, were less affected than the melodies, both of which had fewer diatonic pitches in the familiar key. This may be because bass lines are typically more limited in their note choices anyway, and are more likely, functionally speaking, to use chord tones and thus diatonic pitch classes.

There was a three-way significant interaction for the diatonic proportion metric. This observed finding is in line with the hypotheses. The right hand shows a difference between the familiar and unfamiliar keys for melody while as the left hand is unfamiliar with either key when playing a melody, it shows less of a difference. For bass lines, the reverse is true. The right hand is unfamiliar with either key, so it shows less of a difference while the left hand is familiar with one of the keys and not the other, so it shows a greater difference.

Function effects. Melodies had a higher conditional entropy measure than bass lines. Bass lines are typically more constricted

Table 3
Conditional Entropy Values

Factor	Level	Mean	*SE*	95% Confidence interval	
				Lower bound	Upper bound
Hand	Left hand	2.359	0.036	2.278	2.439
	Right hand	2.442	0.032	2.370	2.515
Function	Bass line	2.287	0.058	2.157	2.418
	Melody	2.514	0.019	2.472	2.557

Note. The mean value for improvisations produced with each hand and in each musical function as well as standard error values are indicated.

Table 4
Diatonic Proportion by Key

Key	Mean	*SE*	95% Confidence interval	
			Lower bound	Upper bound
B	0.803	0.016	0.767	0.840
B*b*	0.750	0.016	0.714	0.786

Note. The mean value for improvisations in each key and standard error values are indicated.

Table 5
Diatonic Proportion Interaction Between Key and Function

Key	Function	Mean	*SE*	95% Confidence interval Lower bound	95% Confidence interval Upper bound
B	Bass line	0.796	0.019	0.754	0.838
	Melody	0.811	0.018	0.771	0.850
B*b*	Bass line	0.756	0.018	0.715	0.796
	Melody	0.744	0.019	0.700	0.787

Note. Mean values and standard error values are indicated.

Table 6
Diatonic Proportion Interaction Between Hand, Key, and Function

Hand	Key	Function	Mean	*SE*	95% Confidence interval Lower bound	95% Confidence interval Upper bound
Left hand	B	Bass line	0.802	0.018	0.763	0.842
		Melody	0.809	0.018	0.769	0.849
	B*b*	Bass line	0.752	0.018	0.710	0.793
		Melody	0.751	0.017	0.712	0.790
Right hand	B	Bass line	0.79	0.021	0.743	0.836
		Melody	0.812	0.018	0.772	0.852
	B*b*	Bass line	0.760	0.019	0.717	0.803
		Melody	0.736	0.023	0.685	0.787

Note. Mean values and standard error values are indicated.

in their use of pitch classes, as they more often use chord tones. The context-free entropy metric, however, did not show a difference between bass lines and melodies. The bass lines still used the pitch classes as evenly distributed as in melodies, but there may have been simply less opportunities to show variety in their transitions both because there were fewer notes in bass lines, and because they need to stick to certain note transitions to outline the appropriate harmony.

Trials pooled by factor. Table 2 provides a set of entropy values and conditional entropy values calculated by combining the individual improvisations by factor. These were calculated using a far larger amount of notes. Pooling these is analogous to searching for an entropy value of a style by combining multiple separate pieces of music. This is another way to compare values between conditions that can begin to account for the difference in the number of notes between the improvisations. The predicted differences emerge here for both metrics (right hand is greater than left hand, Bb is greater than B, and melody is greater than bass line). The more familiar motor contexts result in a more even use of pitch classes and a more varied use of transitions from one pitch class to the next. In addition, melodies are more varied than bass lines, which makes sense in light of the musical function of each.

Interview transcripts. In the debriefing interviews conducted with the participants in this study, some described what seemed different about their strategies when the interface with the keyboard became less familiar. One participant reflects on his performance in the experiment:

> In the right hand you're doing things because you can hear the notes and you play them. Whereas in the left hand, it's almost like you're trying to follow the rules of how to jazz improvise. Like, these are the chord tones, and this is how I'm going to work around them. Whereas when you're improvising with the right hand, you're just thinking, well this is how this, you hear notes, and you play them.

Another participant also describes a difference:

> But, because it's in B, there's a lot of thought involved, just trying to, remembering what the chords are and that kind of thing. When you're in B*b*, more of it gets to the subconscious. The process of, you know, oh yeah, c minor 7, F 7, that kind of thing. In B, you have to transpose a bit more. It's more of a conscious process. It's more difficult, I would say.

These comments reaffirm the validity of the experiment and point to further research possibilities to more precisely describe the differences in process underlying the different performance conditions. Such differences in what one "hears" while playing and what is "subconscious" may be a further route to describe differences in modes of improvisation that use different cognitive processes. These ideas are explored below. In the interviews, the participants also raised concerns about the experimental design, which are also discussed below.

Problems with the experimental design. Some participants complained that because the backing track was the same every time, they were not able to interact with it. This is not the most ecologically valid circumstance, but it was judged to be appropriate for the theoretical premise of this experiment.

Another problem with ecological validity is that it may not be fair to assess motor familiarity with a key when improvisers are only using one hand at a time. The knowledge pianists acquire to play certain musical phrases or ideas may well be distributed across both hands. That being said, it is not a wholly unfamiliar task to improvise one hand at a time, or one note at a time. It was necessary for the analysis of this study to ask the improvisers to play monophonically, but it may not need to be included in future studies depending on the metrics used to analyze the music.

In the postexperimental interviews, participants reported getting fatigued toward the end of the experiment. This may have differ-

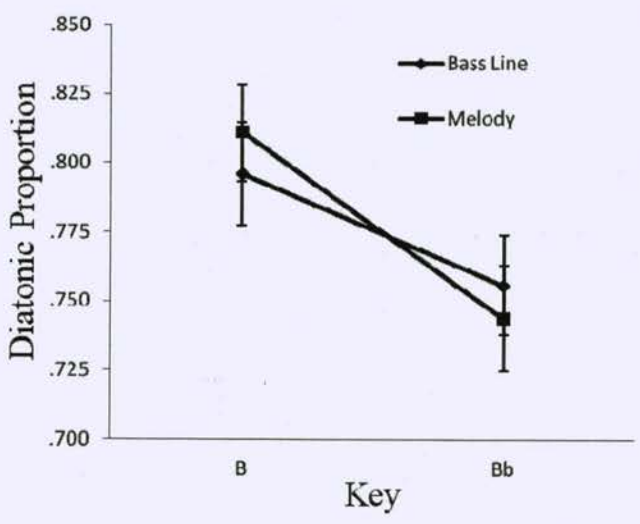

Figure 1. Graph of diatonic proportion interaction between key and function. Diatonic proportion is showed as a function of key and function. Error bars display one standard error in either direction.

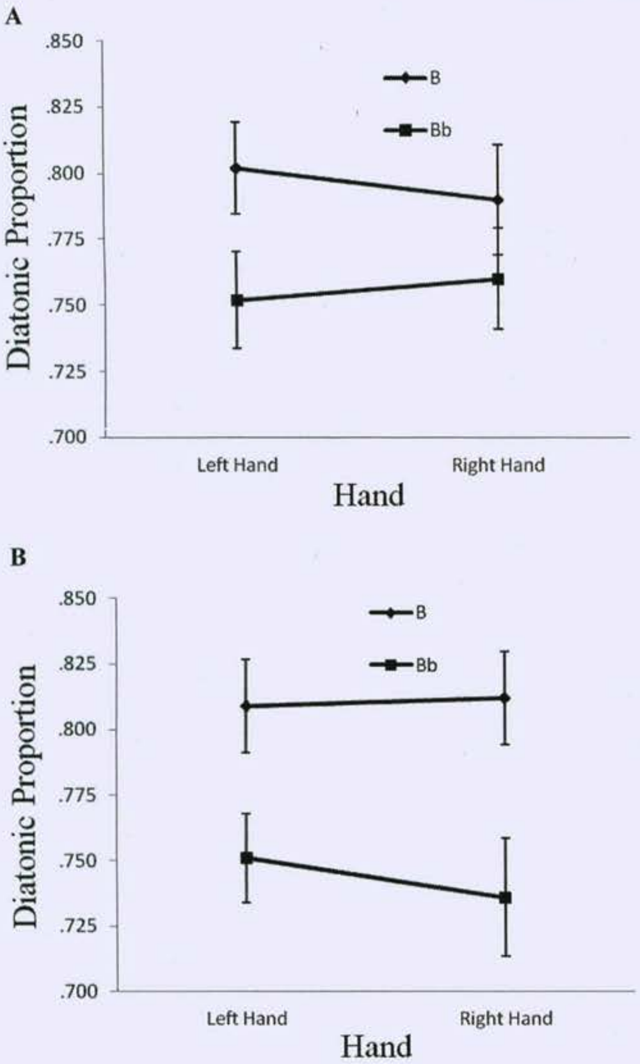

Figure 2. Graphs of diatonic proportion interaction between hand, key, and function. Diatonic proportion is shown as a function of hand, key, and function. (A) Function = bass line, (B) function = melody. Error bars display one standard error in either direction.

entially affected their improvising over the course of the experiment. It is difficult to anticipate, however, how such fatigue would affect metrics based on pitch class distributions.

Perhaps more of a problem is the possibility that participants learned things from themselves. Improvising melodies with the left hand is not something the participants normally practice, according to their interviews. Between trials, they may have tried to mimic what one hand played with the other hand. This may have introduced confounding variance in the data, but it is also in itself an interesting possibility. If this were indeed the case, it would be another way to consider how access to musical knowledge differs in different performance circumstances. Finding instances of this transfer would be a valuable possibility for a future study.

One could imagine that an improvisation, regardless of how the metrics used here assess it, could possibly use different improvisational processes. Procedural knowledge can perfectly well produce low entropy improvisations and the explicit strategies could produce highly variable improvisations. Given the specific nature of the task for this study (to improvise over Rhythm Changes), and because the style was familiar to the participants, it is still likely that the use of different strategies explain the differences in the metrics. Future research, as suggested below, may be designed differently to more confidently characterize and identify instances of such differences in process.

Finally, generally speaking, the statistics in this study did not consistently support the hypotheses that unfamiliar motor contexts would result in less variance between the use of different pitch classes and less predictability. However, many of the hypothesized effects are present, and the study can still be seen to demonstrate what happens when the situation between the performer and the instrument is made more unfamiliar. With the same music–theoretical knowledge but a different situation between a performer and an instrument, the playability of ideas changes. This describes a difference in improvisational and cognitive process. The best way for future experiments to follow from this one should involve methods to more precisely characterize what about the difference in the interface makes ideas more or less playable (not just in terms of the ergonomics of fingering, but also in the cognitive representations of musical knowledge) to further characterize the nature of the knowledge used in the multiple different processes of improvisation.

Further Research

This study has begun to characterize different improvisatory strategies and some of their structural correlates, but precisely characterizing how the cognition differs is still an open question. What makes different ideas playable depending on the performance situation? As some of the participants noted, the connection between hearing and moving may be crucial. Sometimes the connection would seem to be more fluent than others leading to differences in structural characteristics and subjective reports of performance strategies. This difference could be further understood within the context of motor theories of perception. Such theories, including ideomotor theory (for a review, see Shin, Proctor, & Capaldi, 2010), simulation theory (for a review, see Hesslow, 2012), and the theory of event coding (Hommel, Müsseler, Aschersleben, & Prinz, 2001), generally suggest that actions and their perceptual correlates share a common representational domain. These theories combine research from sensory mental imagery (see Finke, 1989) and motor mental imagery (see Jeannerod & Decety, 1995) to demonstrate how they may be related. Musical knowledge may be represented in this way for improvisers under familiar conditions. Hearing something in your head can easily be translated into playing something with your hands. In unfamiliar performance conditions, however, a different cognitive process may be at play. It could be that what is heard with auditory imagery cannot be linked to any motor output because the motor context is different (e.g., an abnormal key layout). It could also be that what is played is not simulated and heard with auditory image at all, and the musician only knows what it sounds like after playing it. The jazz pianist and pedagogue Lennie Tristano reportedly criticized students when he thought they were not "hearing" (mentally) what they were playing (Shim, 2007).

Motor theories of perception provide a potential way to explain why sensory feedback (tactile and auditory) may be more or less important under certain performance conditions. Altered auditory feedback (both delayed feedback and altered pitch) has been explored with musicians playing and singing (Pfordresher, 2006), but not as it pertains to understanding improvisation. It may be that altered auditory feedback may affect improvisation differently under different conditions as well as differently affect improvisation as compared with rehearsed performance or sight reading, helping to further construct theoretical differences between cognitive modes of performance. For instance, it may be less disruptive to have altered pitch feedback if the musicians do not have an idea of what sounds their finger movements will make before making them, as was perhaps the case when the jazz pianists here played in B major or with their left hands. These theories may also help describe differences in other musical skills. Kopiez and Lee (2008) have identified mental imagery ability as an important predictor of sight-reading ability, for instance. The same cognitive capacities might also correlate with improvisation experience.

There are several ways forward to advance the research program proposed above. Trying to differentiate between cognitive representations and processes of different modes of performance can help develop a cognitive–scientific taxonomy of performance that diverges from a definition stemming from music theory and structural analysis. Music analysis can instead be used in tandem with cognitive theories to build an understanding of such modes of performance.

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What Makes a Good Musical Improviser? An Expert View on Improvisational Expertise

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This study presents an expert view on musical improvisational expertise. A group concept mapping procedure was used to identify key characteristics of such expertise among a group of 26 renowned musical experts. Multivariate analyses, including 2-dimensional multidimensional scaling (MDS) of unstructured sort data, hierarchical cluster analysis of the MDS coordinates, and the computation of average ratings of 169 statements resulted in a 7-cluster concept map. The cluster self-regulation was located at the heart of the cluster map and was, therefore, regarded a core constituent of improvisational expertise. The other clusters were basic (musical) skills, affect, risk-taking, creation, responsivity, and ideal. Implications for instruction, limitations of the study, and future research are commented on.

Keywords: improvisation, expertise, concept mapping, music, jazz, instruction

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Creativity in the musical domain amounts to the generation of music, which includes both composition-based and performance-based modes of expression (Deliège & Wiggins, 2006; Hargreaves, MacDonald, & Miell, 2012). Belonging to the latter category, musical improvisation signifies the real-time instance of music making when musical parameters like pitch, timbre, order, and density of notes are not specified in advance. As such, it contrasts with forms of musical performance closely related to imitation in which generation and expression are largely prescribed (Clarke, 2005; Palmer, 1997; Sloboda, 1996, 2000). Improvisation is universal, ingrained in various old and new musical cultures. It even cuts across cultures, being a driving force for musical evolution (MacDonald, Wilson, & Miell, 2012). Besides this cultural function, improvisation serves as an important expedient for individual musical development. For musicians belonging to musical cultures where improvisation is the backbone of music making, this is self-evident. But also musicians extraneous to such traditions who mainly perform pieces of written music benefit from a certain expertise in improvisation, as research shows that the act of improvising music adds to deep understanding of musical rules and structures, personal expressivity, and creativity in music and beyond (Koutsoupidou & Hargreaves, 2009; Lewis & Lovatt, 2013; McPherson, 1993). The significance of improvisation for both individual (musical) development and (cross-)cultural musical evolution explains the growing demand for an attentional focus on improvisational skill learning in music education and successive professional practice (cf. McPherson, Davidson, & Faulkner, 2012; Sawyer, 2007; Smilde, 2012).

An increased interest in improvisational expertise raises the question what it exactly entails. This question is particularly relevant as improvisational expertise is subject to change due to the evolutional nature of improvisational practice. Changing expertise warrants a recurrent analysis, which is most informative for musical instructors and (lifelong) learners to design and redesign both instructional and learning activities (Fidlon, 2011). The present study contains such an analysis and provides a contemporary view on improvisational expertise that can be characterized as expert, holistic, and domain-specific (cf. Hoffman & Lintern, 2006). Before elaborating on the research goal of the study and existing literature related to improvisational expertise, these three characteristics will be briefly explained.

This study invited experts with an extensive track record to reveal improvisational expertise. Asking renowned experts to scrutinize their expertise is not as self-evident as it seems. Chi (2006), for instance, contends that experts often have problems articulating their expert knowledge, as it is predominantly tacit. However, Hoffman and Lintern (2006, p. 216) refute this "hangover issue from the heyday of Behaviorism" and illustrate that various techniques contribute positively to the elicitation of expert knowledge, including the tacit components. The present study used Trochim's (1989) *group concept mapping* (GCM) to educe expert knowledge on improvisational expertise, a method also referred to as *expert concept mapping* (Stoyanov & Kirschner, 2004). GCM is a mixed

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method that applies (a) structured (group) activities for data collection and (b) multivariate statistical methods for data analysis to produce a graphical representation of a domain of ideas that signifies a "collective" knowledge base of a group of experts.

"Holistic" refers to three issues. First, it means that improvisational expertise is looked at from different angles, resulting in complementary views on the topic that ultimately fuse into one comprehensive view on expertise. For the present study this was established by means of consulting a variety of actors in the field of musical improvisation, namely musicians, teachers, critics, and researchers (cf. Csikszentmihalyi & Rich, 1997). Second, holistic indicates that the scope of the analysis is wide-ranged and extends the prevailing cognitive focus in improvisation research. As such it aims at revealing conative, affective, and motor attributes of improvisational proficiency as well (cf. Ackerman & Beier, 2006). Third, holistic means that the system of interest for the analysis covers the improvising musician acting in a professional context (e.g., a community of practice; Barrett, 1998; Wenger, 1998), rather than the individual performer who creates music in isolation. Professional improvisational tasks are normally situated in a rich and dynamic context, and therefore it is important to include this context in the system of analysis.

Besides "expert" and "holistic" the view on improvisational expertise in this study can be characterized as "domain-specific." The domain of jazz music was selected as research context because improvisation is the hallmark of jazz (Berliner, 1994). Because there is a perpetual controversy regarding the definition of jazz (Ake, Garrett, & Goldmark, 2012; Gridley, Maxham, & Hoff, 1989), a broad conception was chosen to select participants for the study. As a result, the group of participants included experts with knowledge on improvisation in jazz music that covers the spectrum from traditional "idiomatic" subgenres to more eclectic and "freer" ones.

Improvisation is complex human behavior, which is aptly expressed by Pressing (1998, p. 51) who states that "the improviser must effect real-time sensory and perceptual coding, optimal attention allocation, event interpretation, decision-making, prediction (of the actions of others), memory storage and recall, error correction, and movement control, and further must integrate these processes into an optimally seamless set of musical statements that reflect both a personal perspective on musical organization and a capacity to affect listeners." This description illustrates that improvisation consists in a complex of mental and motor processes that altogether heavily challenge the human system. Further, it articulates that a certain degree of proficiency is necessary to meet this challenge, which is emphasized by the two performance criteria mentioned by Pressing, namely a *personal perspective* and a *capacity to affect listeners*. A personal perspective or *personal voice* corresponds to high levels of improvisational expertise (Bailey, 1992; Kratus, 1991; McMillan, 1999; Sudnow, 1978) and strongly relates to *originality*, one of two defining features of *creativity* (Runco & Jaeger, 2012). For that matter, the other feature is *effectiveness*, which might be connected to a capacity to affect listeners. Finally, Pressing's description of improvisation touches the conscious–unconscious dichotomy that characterizes thinking in the course of improvisational action (cf. Baumeister, Schmeichel, DeWall, & Vohs, 2007; Dietrich, 2004; Limb & Braun, 2008; Liu et al., 2012; Sawyer, 1992). In a footnote that corresponds to the element "attention" in the description above, Pressing connects this concept with selective activation and deactivation of particular brain structures. Interestingly, recent studies that used functional MRI (fMRI) to reveal the neural correlates of expert improvisation, found evidence of altered states of consciousness. Limb and Braun (2008) for instance observed a decrease in neural activity in areas of the prefrontal cortex in expert improvising jazz musicians. This finding indicates that expert improvisers "experience" transcendent states of consciousness, a result that can be related to concepts like *flow* or *peak experience* (cf. Csikszentmihalyi & Rich, 1997; Maslow, 1968). A study of Berkowitz and Ansari (2010) detected deactivations in another brain area (i.e., the right temporoparietal function), which might indicate a focused attentional state when experts improvise. It should be remarked that results of these fMRI studies should be interpreted with care (see Dietrich and Kanso [2010] and Sawyer [2011] for discussions on methodologies of cognitive neuroscience).

Although improvisation is an activity everyone can engage in at some level (Kratus, 1991; MacDonald et al., 2012), it is the expert improviser who can create something that is both comprehensible and interesting for a larger audience. Contrary to novices or laypersons, expert improvisers manage to maintain themselves within the scene of constraint that defines the improvisational act. They have been adapted maximally to the constraints related to task performance (cf. Ericsson & Lehmann, 1996; Gruber, Jansen, Marienhagen, & Altenmueller, 2010; Lehmann & Gruber, 2006), which means in the case of improvisation they have the resources to circumvent (and affect) internally (i.e., psychologically and physiologically) and externally (i.e., socioculturally) imposed constraints (Berkowitz, 2010; Johnson-Laird, 1988; Kenny & Gellrich, 2002). The *internal constraints* relate to different systems of the human body that collectively form the "hard- and software" of the human system (cf. Charness, Tuffiash, & Jastrzembski, 2004). Although most of the bodily systems are active when improvising, it is especially the musculoskeletal system (i.e., muscles for playing an instrument), the respiratory system (i.e., lungs for singing and playing a wind instrument), and the nervous system (i.e., senses and memory for action, control, storage, and reflection) a musician uses to produce good-quality improvisations. Research shows that these three "hardware" systems change as musical expertise develops, indicating neural and physiological plasticity (Gruber et al., 2010; Lehmann & Gruber, 2006). An important internal constraining "piece of hardware" of the human system is working memory (WM; Baddeley, 1992, 2012; Charness et al., 2004). WM is necessary for maintaining and manipulating information while performing a task. Because of its limiting processing capacity (cf. Miller, 1956), WM is the bottleneck in real-time music making. Johnson-Laird (2002), for instance, emphasizes this limitation in his computational theory of improvisation, which specifies no WM for intermediate results when melodies are being generated. The theory says that the creation of melodies relies on rules and information that are stored in long-term memory. As a result, WM capacity can be used for keeping track in the overall musical sequence and registering what other musicians are playing. This monitoring function of WM relates to the aforementioned altered states of consciousness that features improvisation and includes activities like musical planning and evaluation (Hargreaves, Cork, & Setton, 1991; Kenny & Gellrich, 2002; Norgaard, 2011) and reflection in (musical) action (Schön, 1983). Interestingly, Baumeister et al. (2007) pose that only stereotyped melodies are the result of nonconscious processes (i.e., no WM is necessary for intermediate results), and that conscious processing is needed to generate melodies that can be labeled "creative." This claim gives rise to the notion that high WM capacity is necessary for creative action (De Dreu, Nijstad, Baas, Wolsink, & Roskes, 2012).

Another important internal but referred to as "software-type-of" constraint is the knowledge base, which includes "musical material and excerpts, repertoire, subskills, perceptual strategies, problem-solving routines, hierarchical memory structures and schemas, generalized motor programs, and more" (Pressing, 1998, p. 53). According to Kenny and Gellrich (2002, p. 118), the knowledge base signifies the "internalization of source materials that are idiomatic to individual improvising cultures." The knowledge base includes the referent, which is "an underlying formal scheme or guiding image specific to a given piece, used by the improviser to facilitate the generation and editing of improvised behavior" (Pressing, 1984, p. 346). Parts of the knowledge base relate to *external constraints* as well. Musical material, excerpts, and repertoire strongly relate to musical style, which includes rules that limit the improvisational act. Other external constraints may refer to status given to improvisation and the extent to which improvisation is part of the musical culture.

As is mentioned above, improvisational expertise means that the musician has the resources to circumvent and affect constraints related to improvisational task performance. These resources not only include knowledge, skills, and characteristics (e.g., specialist memory) necessary to improvise consistently on a high level (cf. Eisenberg & Thomson, 2003; Ericsson, 2006), but also those required to facilitate the development, maintenance, and adaptation of improvisational expertise (Sawyer, 2007; cf. Zimmerman, 2006). The latter aspect touches the concept of deliberate practice, which according to Ericsson (2006; Ericsson, Krampe, & Tesch-Römer, 1993; Lehmann & Ericsson, 1997) is the key to expert performance. Charness et al. (2004) follow Ericsson and posit deliberate practice as mediating variable at heart of a taxonomy of skill factors between factors like motivation and personality on the one side and the cognitive system and subsequent expert performance on the other. They underline that the former constructs are relatively underexposed in present expertise research, a statement that also counts for improvisational expertise research (Pressing, 1998). Besides, most information in the literature on practice-predisposing factors related to improvisational expertise development, maintenance, and adaption is rather speculative or is based on studies in more general contexts (e.g., popular music or just "music"). Kenny and Gellrich (2002) for instance note that flow or peak experience is an important "motivator" to persevere with performing (professional) improvisational tasks, but do not substantiate this claim with research conducted in an improvisational context. Studies on musical ability (Hallam, 2010; Hallam & Prince, 2003), musical identity (Hargreaves, Miell, & MacDonald, 2002; MacDonald & Wilson, 2005), ideal musicianship (Creech, Papageorgi, & Welch, 2010), but also creativity (e.g., Feist, 1998; Kaufman & Beghetto, 2009; Sternberg, 1985) provide valuable information on constructs besides the cognitive ones. According to Ruthsatz, Detterman, Griscom, and Cirullo (2008), it takes more than just practice to become a musical expert and probably this also counts for maintaining expertise and standing ground in a community of practice in the field of jazz (MacDonald & Wilson, 2005). A model of ideal musicianship by Creech et al. (2010) seems to validate the above as it discerns performance skills, versatility, commitment to excellence, personality, and absolute expertise (i.e., talent) as constructs that ultimately make an ideal musician. Unfortunately, the underpinning of this model is meager as it is based on in-depth interviews with 27 musicians of which four are professional jazz musicians.

In sum, studies that focus on broad conceptions of improvisational expertise are scarce and existing studies are based on relative small samples. Results of studies that elucidate more general concepts like creative expertise and musical expertise are informative but need to be validated in similar studies in the domain of improvisational (jazz) music. It is of interest to see whether core characteristics of creativity such as innovation/imagination, intrinsic motivation, independence, risk taking, breadth of interest, intelligence, high activity/energy level, and a sense of humor (cf. Sternberg, 1985) also hold for expert improvisers. The same applies for core characteristics of musical expertise such as competence in reading musical notation, quick at learning new music, superior musical memory, refined problem-solving skills, self-monitoring skill, know-how to address errors, and being good at sustaining skills (cf. Creech et al., 2010; Papageorgi et al., 2010). The present study tries to validate such findings within the context of contemporary musical improvisation in the domain of jazz music. Its goal is to reveal improvisational expertise and to identify knowledge, skills, and other characteristics that define a present-day expert improviser in the domain of jazz and improvised music. The research questions of the study are as follows (research activity between brackets):

- "Which characteristics constitute an expert musical improviser?" (Generation)
- "Which clusters/complexes of characteristics constitute an expert musical improviser?" (Clustering)
- "Which characteristics are regarded important" (Rating)
- "Which clusters/complexes of characteristics are regarded important?" (Rating)

Methodology

Participants

A total of 26 renowned musical experts residing in the Netherlands took part in the study. The experts had many years of professional experience in performing, teaching, and/or reviewing jazz and contemporary improvised music ($M_{\text{performing}} = 28.1$, $SD = 7.8$; $M_{\text{teaching}} = 23.9$, $SD = 8.4$; $M_{\text{reviewing}} = 19.7$, $SD = 11.2$). In addition to professional improvisational experience, the musicians reported on average 35.6 years ($SD = 6.5$) of general improvisational experience (i.e., inclusion of experience before performing professionally). Besides experience, the experts had excellent track records with regard to professional output (i.e., number and quality of recordings, performances, graduated students, writings, and/or broadcasts). Mean age of the experts was 51.5 years ($SD = 10.6$). All but one of the participants were men. The group of participants covered three expert subgroups, namely experts whose daily routines (a) target musical performance ("musicians"), (b) concentrate on teaching ("tertiary-level music teachers"), and (c) consist of scrutinizing and reflecting on musical performance ("critics/researchers"). Participants could belong to different subgroups. The musicians/teachers (n = 16) played bass (n = 1), drums (n = 2), guitar (n = 2), piano (n = 8), trombone (n = 2), or reed (n = 1) as main instrument. The critics/researchers (n = 10) reviewed for daily newspapers (n = 7), magazines (n = 8), and/or national public radio and TV (n = 1) (combinations of media are possible).

The experts participated in a GCM study that included two data collection stages: (a) statement generation and (b) statement sorting and rating (see the "Procedure" section for a detailed description of this). The majority of experts took part in both stages. Sixteen experts (all men; representing all subgroups) entered the first data collection activity of the concept mapping study, a brainstorm session aimed at statement generation. Two groups of experts (Group 1: n = 8; Group 2: n = 4), generated statements during the sessions. Four experts who could not attend the sessions, generated statements at home, using an adapted but similar data generation procedure.

Twenty-four experts completed the second data collection activity, namely the sorting and rating of statements. This group of experts included 14 out of 16 experts participating in the first data collection activity and 10 newly recruited experts.

Procedure

Trochim's (1989) GCM method was used to reveal improvisational expertise. This method consists of a *preparation phase*, where focus, participants, and scheduling are specified; a *data collection phase*, where results of respective generating, sorting, and rating tasks are recorded; and a *data analysis phase*, where results are analyzed and interpreted. The data collection phase was adapted for reasons of output optimization (see Stoyanov & Kirschner, 2004; Wopereis, Kirschner, Paas, Stoyanov, & Hendriks, 2005). Adaptations will be emphasized here; for an elaborate discussion on the method see Kane and Trochim (2007).

Preparation phase. The first preparatory step for concept mapping was the development of the focus for generating and rating information. It included (a) the formulation of a focus prompt to start the brainstorm sessions and (b) the specification of a measure of interest to rate the results of the brainstorming. The focus prompt, worded in a complete-the-sentence format, was derived from the research goal of the study and ran as follows: "A good improviser is someone who . . ." The measure of interest for the rating aimed at the assessment of the importance of generated information. Participants valued each generated statement on a 5-point Likert scale from 1 to 5, representing *relatively unimportant, somewhat important, important, very important*, and *extremely important*, respectively. The second step in the preparation phase was the selection of participants. In this process, experts helped finding other experts. The third step contained the construction of materials and the scheduling and orchestration of the data collection activities. Materials made in this phase included the invitations and instructions for the data collection activities. Materials for sorting and rating (e.g., cards with statements and forms for clustering) were created halfway through the data collection phase, after the final set of statements was determined.

Data collection. Participants successively generated, sorted, and rated characteristics ("statements") of improvisational expertise. For the statement generation task, group meetings were organized; sorting and rating tasks were carried out individually at the participant's home (or other preferred place). Data collected from the three tasks were entered in Concept System Core (Version 4; Concept Systems, Inc.) and SPSS by the first author.

The statement generation task included two 10-min individual brainstorms, each followed by a round-robin presentation of results in front of the other participants for which there was no time limit. The first round-robin presentation was added to the brainstorm procedure to elicit ideation through the second brainstorm. The final presentation nurtured the closing group discussion of the meeting. To start the brainstorm session, participants were presented the focus prompt "A good improviser is someone who . . ." Complements of the focus prompt were written down on 20.5 by 9.5 cm cards and pinned to large notice boards during the round-robin presentations.

Experts who could not attend the group meetings generated statements at home. They sent the results by e-mail to the researcher. After the generation phase, all generated statements were compared in a pairwise manner to identify identical statements. Doubles and equivalent statements were removed from the set. Statements with a difference in nuance were not combined into one single statement. For instance, a statement with an adjective (clause) can have a different overall meaning compared with a similar statement with no or a different adjective (clause).

For the sorting and rating tasks, participants received an envelop by surface mail, holding a concise instruction booklet, a set of statements printed on paper cards, paperclips to bundle the cards, and a self-addressed envelope. Each statement was printed on a 10.5 by 6.4 cm card. On each card an area in the right bottom corner was allocated for rating the card statement. Further, each card included a randomly assigned identification number (#). An authentic "tabletop-based" card sort procedure was preferred to an electronic "screen-based" one because the final set of statements was too large to display on a computer screen. Further, it was expected that a conventional approach would have a less deterrent effect on task performance than a computer-based procedure.

A stepwise instruction guided the individual sorting and rating activities. This instruction included minimal rules for sorting and rating and fully relied on the structured GCM methodology for group conceptualization. For sorting, the participants were instructed to group the ideas into meaningful, content-related categories "in a way that makes sense to you." Besides the aim of the study ("We want to know what characterizes an expert improviser") no other information related to content was provided to the participants. Procedural rules for sorting included "Do not sort all statements into one category," "Do not sort every statement as its own category," "When a statement cannot be sorted together with other items, group the statement by itself," "Do not sort an item into more than one category," and "Do not create a residual category." Instructions for rating included "Rate the importance of each statement on a scale from 1 to 5, where 1 = relatively unimportant, 2 = somehow important, 3 = important, 4 = very important, and 5 = extremely important," and "Make use of the range of possible answers."

Data analysis. The analysis included three main steps. First, all sorted data of participants were aggregated into one (overall) similarity matrix (i.e., an "n-by-n" matrix where "n" is the number of generated statements). This matrix is the result of adding the cell values across the similarity matrices of the participants. Cell values in a participant's similarity matrix can either be 1 or 0, which means that a pair of statements has either been sorted together (1) or not (0). Cell values in the total similarity matrix can range from 0 ("None of the participants sorted Statement A with Statement B") to "the total number of participant's matrices" ("All participants sorted Statement A together with Statement B"). The latter cell value indicates "proximity" of statements.

Second, a multidimensional scaling (MDS) of the total similarity matrix was conducted to locate statements as separate points on a two-dimensional point map. To determine the quality of the point map, a stress value was calculated. This diagnostic statistic measures the goodness of fit of the distances between points on the map (converted into a distance matrix) and cell values in the overall similarity matrix. Stress values can range from 0 to 1, where lower values indicate a better fit (Kane & Trochim, 2007; Kruskal & Wish, 1978). Although a clear cutoff for stress has not been agreed on in the literature, general guidelines suggest that stress values between .05 and .35 are acceptable for GCM (Petrucci & Quinlan, 2007). Meta-analytic studies on the quality of Trochim's GCM method by Rosas and Kane (2012) and Trochim (1993) support this range. They reported average stress values of .29 over 33 studies (SD = .04; range: .16–.35) and .28 over 69 studies (SD = .04; range: .17–.34), respectively. In addition, Rosas and Kane (2012, p. 241) state that multidimensional maps with a stress value <.39 "have less than 1% probability of having either no structure or a random configuration."

Third, a hierarchical cluster analysis (HCA) of the MDS coordinates was performed to partition the mapped points ("the statements") into clusters. Concept System Core uses Ward's algorithm to form clusters (Trochim, 1989). Basically this algorithm successively creates increasingly larger clusters. However, human judgment is necessary to monitor the clustering process and to determine the final cluster configuration. In the present GCM study, HCA started with an evaluation of a map that contained 20 clusters and sequentially analyzed maps with fewer clusters. Each consequent step focused on the merging of two clusters. The procedure stopped when a merge was not meaningful from a semantic point of view. In the course of analytic action, human judgment was informed by a "bridging analysis." This analysis helps to detect statements and areas on the map that are strongly related to each other. Bridging values (labeled "b") of statements range from 0 to 1 and help to interpret what content is associated with specific areas of the map. Statements with lower bridging values ("anchors") are generally better indicators of the meaning of their part of the map than statements with higher bridging values. Statements with higher bridging values ("bridges") can be regarded as connections between different areas on map. A cluster bridging value is the average bridging value of statements in a cluster. Lower cluster bridging values indicate better fit and consistency, which is the result of similar sorts across participants. Mean and median of the number of clusters sorted by the participants were used as post hoc expedients to validate the size of the final cluster map.

Ratings of statements helped to identify important characteristics of improvisational expertise (both on statement and cluster level).

Results

Generating Task

Sixteen experts generated 191 statements. These statements were analyzed with respect to content. Five statements were excluded from the set of statements, as their meaning was ambiguous. Six original statements covered more than one characteristic. Their subdivision led to 20 new statements (an increase of 14 statements). The new set of 200 statements was subjected to a pairwise comparison to identify semantically identical utterances. A consolidation of 46 original statements into 15 new statements reduced the set from 200 to a final set of 169 statements.

Sorting Task

Twenty-four experts sorted the 169 statements (M = 12.46 clusters; SD = 6.59; range: 2–25; Mdn: 11.50). MDS of the sort data resulted in a two-dimensional point map (see Supplemental Material [Appendix 1], first slide). The stress value for goodness of fit of the final representation with the original similarity matrix used as input was .33. This value slightly exceeds the average stress value of GCM studies reviewed in two meta-analytical studies (Rosas & Kane, 2012; Trochim, 1993), but falls within accepted ranges (Petrucci & Quinlan, 2007). It also does not exceed .39, which can be regarded a threshold for a 1% probability of having no structure.

The HCA of the MDS coordinates combined with a structured interpretation process resulted in a set of seven clusters (see Figure 1). The merging of clusters from 20 to 7 was a relatively straightforward process. The last meaningful merge of clusters was from 8 to 7. At that cluster level, the two clusters that fused into one contained both statements related to the concept "affect." One of the two merging clusters included statements like "a good improviser is someone who is sensitive to atmosphere, colors" (statement identification number #3), ". . . with a passion for music" (#105), and ". . . who keeps subconscious and conscious in balance" (#17). The other merging cluster consisted of similar statements such as ". . . who is sensitive" (#47), ". . . who is passionate" (#98), and ". . . who is balanced" (#26). A subsequent merge of clusters from 7 to 6 was regarded meaningless, as it would lead to a cluster that is large (n = 41) and conceptually broad ("self-regulation" and "creation"). Supplemental Material (Appendix 1) shows an animation of the hierarchical cluster-tree analysis from a 20- to the final 7-cluster solution. Supplemental Material (Appendix 2) shows descriptive statistics of the 7 clusters and the 169 statements. Table 1 is an excerpt from Supplemental Material (Appendix 2) and presents for each cluster three statements with the lowest bridging values.

The cluster central to the map focuses on self-regulatory aspects of improvisational expertise. Statements (n = 19) in this "self-regulation" cluster refer to knowledge, skills, and attitudes needed to start, go through, and end an improvisation. The cluster is about recognizing useful ideas, making musical connections, anticipation, playing, and not playing. Examples of statements are ". . . who draws musical connections quickly" (#69), ". . . who anticipates" (#150), and ". . . who is able to play nothing when he hears nothing" (#20). Some statements explicitly deal with monitoring the musical act (e.g., ". . . who can helicopter above one's own

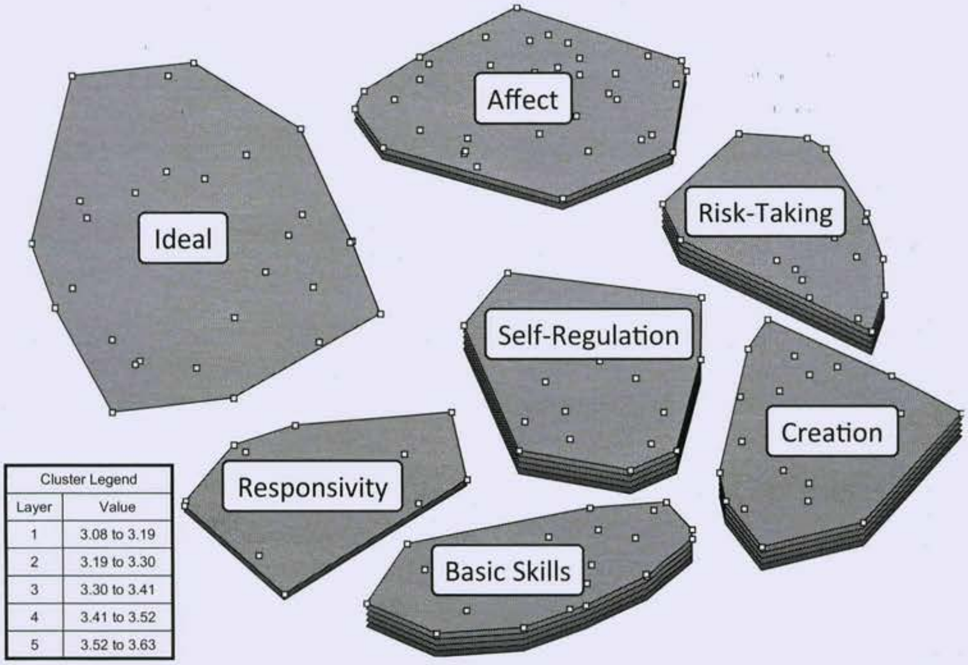

Figure 1. Cluster rating map.

music," #124) and reflection on musical action (e.g., "... who dares to listen to himself critically," #48). The cluster has a low average bridging value ($M = 0.09$), indicating that it is robust and an anchor to other clusters on the map, rather than a bridge between clusters.

Statements ($n = 26$) in the cluster "basic skills" refer to knowledge, skills, and attitudes, which are regarded elementary to improvisation. They include references to skills and abilities that count for musical performance in general and musical improvisation in particular. Examples of statements that refer to musical performance in general are "... who masters his instrument" (#169), "... with a highly developed sense of rhythm" (#23), and "... who has a large auditory memory" (#80). Some basic statements related to the improvisational act are "... who is able to structure" (#112), "... who makes use of the possibilities of his instrument" (#114), "... who can generate melodic and rhythmic ideas" (#61), "... who knows a lot of different solutions to one musical 'problem'" (#154), "... who can respond quickly to changes in all musical situations" (#86), and "... who is able to integrate tradition into his own style" (#115). Interestingly, the only utterance related to the development, maintenance, and adaption of improvisational expertise is positioned in this cluster (i.e., "... who studies in such a way that he is able to transform what he studied outside the frameworks he studied" [#167, $M = 3.38$, b = .31]). The cluster has a relatively low average bridging value ($M = 0.16$), indicating coherency and not being a "bridging cluster."

The cluster "affect" includes statements ($n = 36$) primarily aiming at the experience of feeling or emotion related to improvisational acting. Many statements in this cluster relate to musical proficiency in general. Examples are "... who is open-minded" (#129), "... who has fun" (#128), "... who has a degree of spontaneity, otherwise you shouldn't bother" (#132), "... who is flexible" (#67), "... who is sensitive" (#47), "... who can concentrate well" (#104), "... with degree of humor" (#41), "... with confidence" (#155), and "... who radiates identity; personality" (#44). The cluster has a relatively low average bridging value ($M = 0.18$), indicating coherence and robustness.

The cluster "risk-taking" involves statements ($n = 22$) related to managing personal and musical constraints. Examples of statements related to constraints are "... who looks for boundaries and pushes them" (#31), "... who does not consider frameworks limiting, but uses/misuses them for new forms and thoughts" (#62), "... who sets foot on stage with an open mind and with all ears, ready for the unexpected" (#73), "... who always tries to surpass oneself (pushing the envelope) and doesn't avoid leaving the beaten track" (#70), "... who knows his limitations and plays with them" (#14), and "... who is able to find freedom within constraints" (#101). An attitude frequently cited in statements belonging to this cluster is daring or guts. Examples are "... who dares taking risks and who is adventurous, but not reckless" (#27), "... who dares to fall flat on his face" (#151), "... who dares to make choices" (#145), "... who dares to follow his musical impulses" (#40), and "... who dares to create contrast" (#38). The cluster has an average bridging value of .30, meaning this cluster is relatively stable.

The cluster "creation" features statements ($n = 22$) related to the kernel of improvisation, which is creating music on the spot. Statements include concepts like form and construct and verbs like organizing, generating, composing, making, and responding. Examples of statements are "... who has an eye for form" (#108), "... who is able to organize musical thoughts, ideas on the spot. Someone who brings order to chaos" (#66), "... who is an instant composer" (#130), "... who is capable of picking up a musical idea, transforming it, and passing it on" (#54), "... who is able to create musical connections in real-time (so can also immediately

Table 1

Cluster Bridging Values, Cluster Ratings, Number of Statements Within a Cluster, and Per Cluster Three Statements With the Lowest Bridging Values

Cluster	Bridging	Rating	Count
Self-regulation	.09	3.63	19
. . . who draws musical connections quickly (#69)	.00	3.79	
. . . who understands that not playing is also playing (#51)	.00	3.79	
. . . who is able to play nothing when he hears nothing (#20)	.03	3.75	
Basic skills	.16	3.61	26
. . . who masters his instrument (#169)	.06	3.63	
. . . with a highly developed sense of rhythm (#23)	.06	4.04	
. . . who makes use of the possibilities of his instrument (#114)	.07	3.79	
Affect	.18	3.32	36
. . . who is passionate (#98)	.02	3.96	
. . . who is open-minded (#129)	.02	3.54	
. . . who has fun (#128)	.05	3.67	
Risk-taking	.30	3.59	22
. . . who does not consider frameworks limiting, but uses/misuses them for new forms and thoughts (#62)	.14	3.92	
. . . who always puts the music first, not his ego (#144)	.16	4.13	
. . . who dares taking risks and who is adventurous, but not reckless (#27)	.18	3.50	
Creation	.33	3.60	22
. . . with musical mastery; someone who is able to organize musical thoughts, ideas on the spot. Someone who brings order to chaos (#66)	.06	3.33	
. . . who doesn't like repetition, improvisation done (#136)	.12	2.50	
. . . who has developed musical intuition and can use it (#148)	.14	4.00	
Responsivity	.48	3.23	16
. . . who—whether or not starting from existing material—creates new music that is both comprehensible and surprising, both reassuring and disturbing (#89)	.20	3.29	
. . . who spontaneously thinks of and tells a coherent story (#82)	.20	3.67	
. . . who is able to play according to his/her interpretation of the essence of the music (#4)	.24	4.00	
Ideal	.70	3.08	28
. . . who manages to create conditions for himself that provide opportunities for the largest opportunity for inspiration (#74)	.36	3.67	
. . . who manages to immediately reach the audience, by starting his improvisation with certainty and authority (#118)	.40	2.96	
. . . who can work together (#92)	.43	3.50	

respond to mistakes of others)" (#159), and ". . . who is able to incorporate a mistake in his improvisation, sometimes even as springboard for unexpected developments" (#39). This cluster has an average bridging value of .33, indicating a relatively stable cluster.

The cluster "responsivity" highlights statements (n = 16) related to the nature of the improvisation. Statements in this cluster emphasize that the outcome of improvising should be characteristic, understandable, coherent, and meaningful, and should be based on a personalized knowledge base (one's own musical idiom), which is influenced by other music, art forms, and even ambient sound. Interaction with other musicians promotes this outcome. Examples of statements are ". . . who is able to tell a sensible musical story (i.e., give a sensible use of time), being able to utilize one or multiple types of musical or extramusical information" (#123), ". . . who explores/draws inspiration from music and other art forms" (#10), and ". . . who responds to fellow musicians" (#137). This cluster has an average bridging value of .48, indicating moderate consistency.

The cluster "ideal" comprises statements (n = 28) related to perceived idealized improvisational expertise. It includes statements like ". . . who deserves respect" (#88), ". . . who plays beautifully" (#87), ". . . who touches me emotionally" (#68), ". . . who surprises" (#16), and ". . . who fascinates me" (#75). This cluster has an average bridging value of .70, indicating low consistency.

Rating Task

The 24 experts rated the 169 statements 3.42 (SD = 0.44) on average. The highest average rating for a statement was 4.33 (SD = 1.13) and the lowest average rating was 1.21 (SD = 0.59). One statement had a median of 5, 1 statement had a median of 4.5, and 86 statements had a median of 4. Twenty-two statements had a modus of 5. Three statements (approximately 2% of the 169 statements) were rated as relatively unimportant (average rating <2.00). One hundred forty-six statements (approximately 86%) were regarded somewhat to very important (range: 2.00–3.99). Twenty statements (approximately 12%) were rated very to extremely important (≥4.00).

The 10 highest rated statements are presented in Table 2. The experts regard these statements very to extremely important. However, moderate standard deviations indicate the statements were not equally valued by the experts. The highest valued utterance in the "top 10" refers to a passion for music (M = 4.33, #105). Four out of 10 statements emphasize the importance of listening skills.

Table 2
Ten Highest Valued Statements

Rank	Number (#)	A good improviser is someone . . .	Cluster	*M*	*SD*	Range
1	105	. . . with a passion for music	3	4.33	1.129	1–5
2	77	. . . who has very good ears and listens with them/. . . who is able to listen very well/. . . with a good sense of hearing/. . . with a good set of ears/. . . who listens (well)	2	4.29	0.624	3–5
3	19	. . . who has a personal, recognizable voice	5	4.29	0.751	3–5
4	53	. . . who can listen attentively to the music surrounding him	5	4.25	0.737	3–5
5	65	. . . who can listen well to others	7	4.21	0.779	3–5
6	151	. . . who dares to fall flat on his face/. . . who is not afraid of making mistakes/. . . who dares to make mistakes	4	4.21	0.833	2–5
7	164	. . . with ideas	3	4.21	0.977	1–5
8	2	. . . who reacts to contributions of fellow musicians in an alert way, in exciting interaction	7	4.17	0.702	3–5
9	48	. . . who dares to listen to himself critically/. . . who is able to listen to himself	1	4.17	0.761	3–5
10	137	. . . who responds to fellow musicians/. . . who can respond to fellow musicians	6	4.17	0.761	3–5

Note. Cluster 1 = self-regulation; 2 = basic skills; 3 = affect; 4 = risk-taking; 5 = creation; 6 = responsivity; 7 = ideal.

They refer successively to good hearing ($M = 4.29$, #77), listening attentively to surrounding music ($M = 4.25$, #53), listening well to others ($M = 4.21$, #65), and listening critically/well to yourself ($M = 4.17$, #48). Two statements in the top 10 relate to musical interactivity and focus on the ability to respond to fellow musicians ($M = 4.17$, #2; $M = 4.17$, #137). The remaining statements in the ranking refer to having a personal voice ($M = 4.29$, #19), daring to make mistakes ($M = 4.21$; #151), and having ideas ($M = 4.21$, #164), respectively.

Average cluster ratings are presented in Table 1 and depicted as "layers" in the cluster rating map (see Figure 1). All clusters are regarded important ($M > 3.00$). The clusters "self-regulation," "basic skills," "creation," and "risk-taking" are rated relatively high. Relatively moderately rated are the clusters "affect" and "responsivity." The cluster "ideal" is relatively low-rated.

Discussion

This study explored expert views on improvisational expertise. Based on the individual input of 26 musical experts, a 7-cluster concept map of improvisational expertise was specified. This section first discusses the generated statements (research question 1), the cluster map (research questions 2 and 4), and a selection of highly ranked salient statements (research question 3). Subsequently, it considers implications for instruction. Finally, it presents limitations and shortcomings of the study and suggestions for future research.

Generated Statements

The experts generated a varied set of statements, which included utterances on knowledge, skills, attitudes, values, and personality traits related to improvisation in particular and music making in general. The statements covered psychomotor (technical skill), conative (will/drive), cognitive (knowledge/skill/memory), and affective (passion, risk taking) elements of improvisational behavior. Interestingly, the topic of expert learning and development was underexposed in the generated data. The data contained only one utterance that was directly related to expert learning (i.e., ". . . who studies in such a way that he is able to transform what he studied outside the frameworks he studied" [#167]). Apparently, the participants were not triggered to generate information on expert jazz musicians' deliberate practice (cf. Noice, Jeffrey, Noice, & Chaffin, 2008) and lifelong learning activities (cf. Smilde, 2012), both important expedients of expertise (Ericsson, 2006).

The varied set of statements enabled the experts to frame a broad holistic conception of improvisational expertise, which will be discussed in the next section.

Cluster Map

The seven clusters in the cluster map represent seven constituents of improvisational expertise. The cluster central to the map holds statements related to self-regulation, an acknowledged important element of expert behavior (Bandura, 1986; Creech et al., 2010; Zimmerman, 2000, 2006). According to Zimmerman (2006, p. 706) expertise entails self-regulating covert cognitive and affective processes, behavioral performance, and environmental setting during the cyclic phases "forethought," "performance," and "self-reflection." Interestingly, statements put together in the cluster "self-regulation" fit Zimmerman's theoretical framework.

An example of a high-valued self-regulatory statement related to *forethought phase* is "a good improviser is someone who anticipates" ($M = 3.71$, #150). According to Biasutti and Frezza (2009) anticipation "requires the ability to plan the improvisation and to have a comprehensive idea of the whole solo. It involves a 'plan,' an abstract homomorphism representing the essential structure of the performance." (p. 236). In a factor analytic study on improvisation processes, they identified anticipation as one of five factors. Norgaard (2011) found similar utterances in a qualitative study and summarized them as "sketch plans" for upcoming musical passages. A speculative model of mental improvisational processes proposed by Kenny and Gellrich (2002) differentiates between short-term anticipation (0.3–3.0 s), medium-term anticipation (3–12 s), and long-term anticipation (remainder of the improvisation).

Examples of self-regulatory statements given by the experts that are related to Zimmerman's *performance phase* are monitoring (e.g., ". . . who can helicopter above one's own music" [$M = 3.33$,

#124] and "... who knows what there is to know about the subject and therefore has an overview of what could be realized at a given moment, and what not" [M = 2.88, #22]) and steering (e.g., "... who strikes out and enforces a musical course during improvisation and simultaneously gives free rein to codetermining contributions of other musicians" [M = 3.71, #37]). These examples are about managing the improvisation process while it is taking place. As such they relate to Norgaard's (2011) concept of evaluative monitoring and Schön's (1983) concept of reflection in action. Monitoring statements are regarded important, but not extremely important by the experts. This might be related to the experts' belief that musical intuition is a very important constituent of improvisational expertise (cf. "... who realizes that beside knowledge and skill, intuition is an essential part of improvisation" [M = 3.67, #56]). Lower perceived values for conscious monitoring activities are not surprising, especially when intuition is defined as "understanding or knowing without conscious recourse to thought, observation, or reason" (Gallate & Keen, 2011, p. 683). To regard intuition as an impetus for improvisation is consistent with the notion that expert improvisation in music is largely automated and that no WM is necessary to create melodies (cf. Johnson-Laird, 1991, 2002). It also relates to states of flow in which musicians lose their self-consciousness and are left to intuition when improvising because there are no resources left in WM (Csikszentmihalyi & Rich, 1997; Dietrich, 2004). Interestingly, Baumeister et al. (2007) state that supervision by conscious processing (and thus a WM) is necessary to fashion creative melodies. Although it is under debate what conscious processing during improvisation exactly comprises, it is accepted that in the course of musical action states of consciousness alter (Dietrich, 2004; Fidlon, 2011). The statement "a good improviser is someone who keeps subconscious and conscious in balance" (#17 in cluster "affect") might emphasize this.

A highly valued example of a statement belonging to the *self-reflection phase* is the ability to listen critically/well to yourself (M = 4.17, #48). Critical listening, interpreted as a form of self-judgment (i.e., evaluation, attribution) and self-reaction after the improvisational act, can be seen as reflection on action (cf. Schön, 1983). According to McPherson, Nielsen, and Renwick (2013) a critical attitude toward musical skill is an important constituent of musical expertise. Critical listening serves this attitude.

The cluster "basic skills" includes statements related to the basics of music making in general and improvisation in particular. The group experts in this study consider general basic skills like a sense of hearing (M = 4.29, #77), a sense of rhythm (M = 4.04, #23), and instrumental mastery (M = 3.63, #169) as very important prerequisites for improvising. Interestingly, these items are also valued very high in studies on musicians' perceptions of general musical ability (Hallam, 2010; Hallam & Prince, 2003). The identification of a basic skills cluster is in line with findings of Biasutti and Frezza (2009) who extracted "basic skills" (e.g., singing in tune, pitch recognition) as an "ability" factor from a principal component analysis on improvisation abilities. In addition to the general basics, the experts in the present study also generated statements focusing on improvisation alone, such as "... who has a good feeling for musical tension" (M = 3.88, #119), "... who can adequately respond musically and instrument-technically to the melodic, harmonic, and rhythmic impulses and to changes in the (musical) environment in which he is situated" (M = 3.83, #55), "... who knows a lot of different solutions to one musical 'problem'" (M = 3.33, #154), and "... who knows the idiom in which he plays" (M = 3.38, #9). The latter two statements specifically refer to the improviser's knowledge base, an important constituent of improvisational expertise. Pressing (1998) conceives the knowledge base as an important tool for improvisation fluency. It is built into long-term memory and differs in richness and refinement between novices and experts (see also Johnson-Laird, 1991, 2002). Many statements generated by the experts refer to declarative and procedural knowledge, though not within the basic skills cluster. For instance, the statement "... who knows when to end his improvisation" (M = 3.67, #33) falls within the cluster "self-regulation." Interestingly, the statement that "a good improviser is someone who plays from knowledge" (M = 2.79, #36) is rated somewhat important, which might indicate a moderate aversion of experts to concepts like *cognition* and *knowledge*.

The cluster "affect" is a relatively large cluster, representing mainly attitudes and personality traits. As is the case with other clusters, statements in this cluster refer to musical expertise in general or improvisational expertise in particular. The cluster contains this study's highest-rated statement, namely that "a good improviser is someone with a passion for music" (M = 4.33, #105). This may state the obvious, but validates the notion that a "drive toward music" is an important factor for predicting a successful professional career in music (Bonneville-Roussy, Lavigne, & Vallerand, 2011; Manturzewska, 1990). Other "affect" statements relate to authenticity (M = 4.13, #96), fun (M = 3.67, #128), flexibility (M = 3.62, #67), personality (M = 3.61, #44), self-confidence (M = 3.54, #155), and open mindedness (M = 3.54, #129). Statements in this cluster that refer to "personality" and "authenticity" strongly relate to statements in the cluster "creation," like "personal voice."

The cluster "risk-taking" includes attitudes and personality traits. Unlike "affect," the statements in this cluster mainly focus on improvisational expertise. Although attitudes like having guts and daring are also important for nonimprovised musical performances (e.g., overcoming stage fright/performance anxiety), these are recognized constituents of improvisational expertise (Azzara, 2002; Berliner, 1994; Kenny & Gellrich, 2002). Interestingly, Vuust et al. (2010) found that undergraduate students in improvisational musical genres like jazz scored high on boredom susceptibility (a constituent of sensation seeking), which not only relates to statements like "... who dares to make mistakes" (M = 4.21, #151) and "... who dares taking risks and who is adventurous, but not reckless" (M = 3.50, #27), but also connects to utterances like "... who sets foot on stage with an open mind and with all ears, ready for the unexpected" (M = 3.83, #73) and "... who always plays as if there is no tomorrow; never plays on autopilot and who totally goes for it" (M = 3.96, #152).

The cluster "creation" includes many fundamental aspects of instant music making. The most highly rated statements refer to the aspect of novelty, an important constituent of creativity. Statements like "a good improviser is someone who has a personal, recognizable voice" (M = 4.29, #19) and "... who manages to keep one's own sound/voice in every music he or she creates" (M = 4.17, #162) underline novelty (McMillan, 1999). Interestingly, the statement "... who doesn't like repetition, improvisation done" (M = 2.50, #136) was rated relatively low, suggesting that improvisational performances may also include musical excerpts that have been played (or "created") before. This touches the discussion whether the improvisation of melodies is in essence a rule-based note-for-note creation (Johnson-Laird, 2002) or merely a formulaic process where note groups or "licks" are linked together (Norgaard, in press; Pressing, 1988).

The cluster "responsivity" consists of statements that reflect interaction. Interaction relates to the environment one performs in and includes other musicians, the audience, but also other "artificial" stimuli (Custodero, 2007). Although the consistency of this cluster is moderate due to the presence of statements that relate to other topics, the cluster includes a set of highly valued interaction-related statements, such as ". . . who responds to fellow musicians" (M = 4.17, #137) and ". . . who is good at communicating musically with fellow musicians" (M = 3.96, #103). These statements relate to collaboration skills, which according to Sawyer (2007) are important constituents of expertise.

Although the cluster "ideal" is not consistent and robust with regard to its content, it consists of some interesting statements that relate to both the process and the product of expert improvising. For instance, two statements refer to the aesthetics of the improvisational product and state that "a good improviser is someone who plays beautifully" (M = 2.67, #87) and ". . . who creates beauty" (M = 2.96, #135). The ratings indicate that these statements are regarded reasonably important by the experts. However, the musicians/teachers rated these items lower than the critics, which is an interesting finding that merits further investigation. Further, two statements relate to the profession and again received little credit. The first of these two statements says that "a good improviser is someone who during the arrangement of concerts: finishes compositions, emails band members about performances, gives a telephone interview for a local radio station, emails a high resolution picture to a jazz podium, reschedules music lessons, does the dishes, watches a performance of Art Pepper on YouTube, installs new software, submits compositions to 'BUMA,' and makes an appointment for car maintenance" (M = 2.00, #111). The second statement says that "a good improviser is someone who probably has a rough time financially" (M = 1.21, #93). Although these statements are regarded somewhat trivial (low ratings), they reflect the hectic and uncertain situation that imbues the musical profession (MacDonald & Wilson, 2005; MacDonald et al., 2012).

Salient Statements

In this section, the 10 most valued statements are discussed (see Table 2). It is notable that half of the statements account for musical expertise in general. These statements refer to passion (ranked no. 1) and listening (ranked no. 2, 4, 5, and 9). According to the experts, a good improviser is first and foremost someone with a passion for music (statement #105). This statement was elaborated on in the previous section. Four statements are related to the ability to listen well and refer to (a) the identification, rating, and modification of parameters of musical performance (statement #77), (b) the aptitude of "listening as engaged hearing" (statements #53 and #65), and (c) the skill to critically listen to yourself in/after the course of action (statement #48). The importance of these facets of listening is widely acknowledged in the domain of music (e.g., Lehmann, Sloboda, & Woody, 2007). A statement exclusively related to improvisational expertise relates to having "a personal, recognizable voice" (#19). According to McMillan (1999), the maturation of a personal voice or individual style is considered the final step toward improvisational expertise. Bailey (1992, p. 53) states that there is a tendency to skip this step, the result being that only a few expert musicians actually contribute to the innovation of musical styles. McMillan (1999) identifies three factors that influence the development of a personal voice, namely stylistic independence, musical relationships between players, and the ability to take risks. The last factor relates to the high-rated statement that a good improviser is someone who "dares to make mistakes" (#151). This statement belongs to the cluster "risk-taking" that was discussed in the previous section (see also Vuust et al., 2010). The experts further feel that a good improviser should be someone with ideas (#164). This is in line with Azzara (2002) who defines improvisation as "the spontaneous expression of musical ideas."

Implications for Instruction

Contemporary instructional design theories prescribe a whole-task sequencing approach for learning complex skills (Merrill, 2002; Van Merriënboer & Kirschner, 2013). Van Merriënboer and Kirschner (2013) define this as an approach in which the training immediately starts with learning tasks based on the simplest version of real-life tasks. The cluster map provides valuable information for the design of whole tasks. Elements of clusters that are regarded important for expert task performance, such as self-regulation, risk-taking, and affect, should be part of learning tasks right from the beginning. This whole-task approach is not new, as it was part of informal apprenticeship learning in former jazz communities like the ones described by Berliner (1994). However, it is at times lacking in present-day formal educational settings (cf. Mengelberg, 2012). Further, the statements within the cluster provide standards or criteria for task performance. An example of a standard is that a good improviser should surprise (M = 3.79, #16), which according to Boden (2010) is an important constituent of creativity (beside originality and effectiveness; see "Introduction"). Eisenberg and Thompson (2003) found that apart from creativity, complexity and technical goodness are important criteria to assess improvisational tasks. Especially the clusters basic skills, risk-taking, and creation provide important standards related to these criteria. The range of statements further shows that expert improvisation means being able to adapt to unfamiliar situations and to challenge existing stylistic rules. Formal education should prepare learners for such situations and should strive for gaining adaptive expertise (Hatano & Inagaki, 1986; Sawyer, 2007).

Limitations, Shortcomings, and Future Research

This study yielded a two-dimensional concept map, representing an expert view on improvisational expertise. A stress value of .33 was calculated, indicating acceptable map quality (Petrucci & Quinlan, 2007; Rosas & Kane, 2012; Trochim, 1993). However, a stress value larger than zero also indicates that not all experts clustered the statements identically, which can also be inferred from the range of clusters the experts produced. This study aimed to present a comprehensive view based on input of a variety of stakeholders in the field of jazz improvisation. In light of this, some variation in the individual clustering was not problematic. However, for future research it will be interesting to compare maps of categories of experts (i.e., musicians, teachers, critics, researchers) and examine whether this will result in increased cluster similarity within groups and subsequent lower stress values. Therefore, the number of participating experts would need to be extended.

A slightly different view between (groups of) experts on improvisational expertise can also be the result of a different interpretation of the concept expert (cf. Chi, 2006; Dreyfus & Dreyfus, 1980; Ericsson, 2006; Hoffman, 1998). A "good" or "expert" improviser might evoke the image of an eminent artist (Big-C creativity), a proficient craftsman (Pro-C creativity), or both (cf. Kaufman & Beghetto, 2009). In the present study, it was expected that the experts would refer to professionals recognized by the field (cf. Csikszentmihalyi & Rich, 1997). Future research on improvisational expertise might differentiate. Future research could also address generalizations of findings. Do experts in other improvisational fields, like classical music and hip hop, generate identical statements and clusters of statements? Research of Biasutti and Frezza (2009) suggests that improvisation experts in different genres have similar conceptions regarding improvisation. In a same vein, a replication of this study could be done in different countries around the world. The present study provided a Dutch perspective on improvisational expertise that ideally should be replicated for reasons of generalizability.

Conclusion

This study resulted in a comprehensive concept map on improvisational expertise, which represents a contemporary common view of a varied group of experts in the domain of jazz and improvised music. The map represents characteristics of expert improvisational behavior related to the improvisational act and puts self-regulation at the heart of improvisational expertise as an anchor to thematically categorized domain-specific knowledge, skills, attitudes, values, and personality traits. Interestingly, the study did not identify expert (lifelong) learning skills as an important constituent of improvisational expertise. This indicates that the experts were mainly focused on the kernel of improvisational expertise, which is instant music making.

For educators in the field of jazz improvisation, the concept map reveals interesting information for designing learning tasks and instructional support. Besides the knowledge, skills, and attitudes necessary to perform improvisational tasks, it exposes standards and criteria for assessing these tasks. Additionally, for all stakeholders in the field of jazz improvisation, this study presents a current holistic view of improvisational expertise, which might help to critically reflect on the evolution of the profession.

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Correction to Vassilakis (2013)

The book review titled "The Psychology of Music in Multimedia" by Pantelis N. Vassilakis (*Psychomusicology: Music, Mind, and Brain*, Vol. 23, No. 3, pp. 196–199. doi: 10.1037/pmu0000023), included a misspelled name in the text. On page 198, Mark Shevy's name was misspelled as Mark Chevy. The online version of this article has been corrected.

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Cognition and the Assessment of Interaction Episodes in Jazz Improvisation

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The purpose of this study was to examine the cognitive processes related to interaction episodes in jazz improvisation through the development, testing, and validation of a rubric for assessing interaction in jazz improvisation. Four questions guided this study: (a) is a rubric an effective method for assessing performance achievement at undergraduate, graduate, and professional levels? (b) what is the interjudge reliability of a rubric used to assess interaction in jazz improvisation? (c) which of the rubric criteria maximally differentiate 3 performance achievement levels (i.e., undergraduate, graduate, and professional)? and (d) does a cognitive task ordering of difficulty exist in assessing jazz interaction? The rubric consisted of 3 melodic interaction criteria, 2 harmonic interaction criteria, and 3 rhythmic interaction criteria. A total of 55 expert judges evaluated 55 distinct jazz improvisation performances. The results indicated a statistically significant multivariate analysis of variance effect across all 3 performance achievement levels on each rubric item. The standardized discriminant function coefficients suggested that the 3 performance achievement levels were maximally differentiated by a canonical variate with greater weightings from all 3 melodic interaction criteria (i.e., "Reaction to implied [melodic] musical suggestions," "Development of melodic musical ideas stemming from motivic interplay," and "Adaptation to melodic interplay [call and response]") and 1 rhythmic interaction criterion (i.e., "Coordination of rhythmical pulse [timing and synchronization]"). The results indicated a cognitive ordering of rater task difficulty: melodic interaction, rhythmic interaction, and harmonic interaction. A total of 66.33% of the variability was accounted for by performance achievement level, and interjudge reliability was estimated using Cronbach's alpha ($\alpha = .91$).

Keywords: assessment, cognition, jazz, improvisation, interaction

Interactive episodes are often considered to be the foremost contributor of excitement and complexity in a jazz performance (Berliner, 1994, 1997; Hodson, 2007; Monson, 1996). According to Monson, "Good jazz improvisation is sociable and interactive just like a conversation; a good player communicates with the other players in the band. If this doesn't happen, it's not good jazz" (p. 84). A difficulty in evaluating and measuring interaction episodes in jazz improvisation lies in judging the ensembles' overall performance achievement and creativity level (Collier, 1995). Research studies related to jazz improvisation creativity and performance achievement often exclude the variable of interaction due to the complexity of measuring performers' cognitive and decision-making processes (Ciorbia, 2009; Limb & Braun, 2008; Madura, 1995; May, 2003; Norgaard, 2011; Smith, 2009; Ward-Steinman, 2008). Other studies acknowledge the collaborative nature of jazz improvisation but maintain that temporal cognition is evident only in real-time improvisational performance (Johnson-Laird, 2002; Mendonca & Wallance, 2004; Pressing, 1984). An additional problem with the evaluation of interaction in musical performance lies in the perception of observed behaviors. Interaction within an improvising jazz ensemble may not always be detected by observable behaviors; in particular, the presence of subconscious cognitive and affective behaviors can potentially obscure the ability to perceive interaction by both the observer and the participants themselves (Seddon, 2005).

Further investigation into the cognitive processes of jazz interaction and performance achievement level is needed in order to broaden the scope of teaching and learning in jazz performance. The purpose of this study was to examine the cognitive processes related to interaction episodes in jazz improvisation through the development, testing, and validation of a rubric for assessing interaction in jazz performance. The research questions that guided this study include (a) is a rubric an effective method for assessing the performance achievement of interaction at undergraduate, graduate, and professional levels? (b) what is the interjudge reliability of a rubric used to assess interaction in jazz improvisation? (c) which of the rubric criteria maximally differentiate three performance achievement levels (i.e., undergraduate, graduate, and professional? and (d) does a cognitive task ordering of rater difficulty exist in assessing jazz interaction?

Interaction, Communication, and Jazz Performance

According to Sawyer (1992), nonverbal interaction in jazz performance is derived from a balance of conscious and unconscious processes acting simultaneously. More specifically, interaction includes the conscious response to syntactical elements of musical knowledge (i.e., sympathetic attunement) and/or an unconscious collaborative aesthetic judgment stemming from ensemble accordance (i.e., empathetic attunement) (Seddon, 2005). According to Seddon:

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> At one level this attunement is sympathetic, allowing for a cohesive performance revolving around sharing stocks of musical knowledge. At another level this attunement becomes empathetic, which is differentiated from sympathetic by collaborating musicians either consciously or subconsciously engaging in the psychological processes of decentring and introspection in order to become empathetically attuned. Once empathetically attuned, an atmosphere of trust allows for creative risk taking, which can result in the production of spontaneous musical utterances that may be regarded as examples of empathetic creativity (p. 58).

Empathetic attunement has also been described as ensemble groove or group flow (Berliner, 1994, 1997; Csikszentmihalyi, 1990, 1996; Kenny & Gellrich, 2002; Sawyer, 2006).

As Berliner (1994) explains, ". . . while attending to their own parts—assessing inventive material and selecting elements for development—performers must constantly exercise musical peripheral vision to make similar assessments about neighboring parts as they endeavor to predict their courses" (p. 364). Examples of such interaction include the subtle nuances and relationships between instruments in terms of synchronicity, reaction to the types of prevalent subdivisions being used (i.e., rhythmic density), adjustments to rhythmic patterns such as polyrhythms and on-beat/off-beat accents, adjustments to harmonic patterns of textural density and chord substitutions, reaction to the introduction of melodic fragments (i.e., melodic invention), and reaction to stylistic ideas engrained in the vocabulary of the jazz tradition (i.e., quotations, recurring vocabulary patterns, logical phrase construction, musical suggestion, and musical expectation) (pp. 348–379). Furthermore, Rinzler (1986) provides examples of various types of interaction that may occur specifically between a soloist and rhythm section: (a) call and response; (b) use of fills; (c) accenting the ends of formal units; (d) the harmonic or rhythmic repetition of a motive (common motive); and (e) response to the "peaks" of the soloist (pp. 156–157).

In addition to the "stocks of musical knowledge" that Berliner (1994) and Rinzler (1986) describe, a performer's degree of creativity is a factor in the level of attunement achieved (Sawyer, 2003). According to Rinzler, a performer may engage in three major degrees of creativity related to interaction: (a) the performers may produce music . . . with little or no creative impulse; (b) performers may produce music by creatively fulfilling their own individual musical function but not interacting with fellow musicians; and (c) performers may produce music by creatively interacting with the other musicians in the group (p. 156).

To assess interaction in a jazz performance from a pedagogical approach, one must consider several dimensions related to the musical development of the ensemble: (a) degree of obtained vocabulary (i.e., What subgenres of jazz are the students knowledgeable of? What standardized vocabulary have the students acquired?); (b) vocabulary development (i.e., Are the students able to connect multiple ideas throughout chord progressions? Are the students still developing their vocabulary over specific chord progressions?); (c) aural ability (i.e., Are the students able to recognize musical patterns and replicate them? Are the students able to interpret a musical idea? Are the students able to develop musical ideas from musical motives occurring within the ensemble?); and (d) level of response (i.e., Can the students listen and improvise simultaneously? To what degree can the students hear a phrase, internalize it, replicate it, apply it, and adapt it? How critically and in depth can the students hear? Can the student listen across the ensemble to multiple instrumentalists at one time? Does listening disrupt the flow of their performance?) By relating these dimensions to interaction episodes via a multidimensional rubric, the pedagogy and assessment of more elusive aspects of jazz improvisation may be enhanced. In addition, the analysis of such an assessment tool may provide further insight into what central factors contribute to the cognition and perception of interaction episodes at multiple achievement levels.

Jazz Pedagogy, Rubrics, and Music Performance Assessment

A frequent criticism of academic-based jazz improvisation pedagogy is the emphasis on syntactical technique-driven development at the sacrifice of creative improvisational thinking (Prouty, 2002). According to Prouty (2012), "In evaluating student performers, at least two main forces are at work, one of which is under control of jazz educators (the teaching of technique, e.g.), while the other largely is not (individual creativity)" (p. 68). Institutional demands have led educators to codify pedagogical methods that are easily measurable and quantified, such as cognitive ability-type testing of syntax and vocabulary development (Nicholson, 2005). This allows students the opportunity to construct, replicate, and perform an improvised solo using acquired syntax and vocabulary alone while demonstrating little creativity (Prouty, 2008). The subjective nature of assessing creative elements of jazz improvisation, such as ensemble interaction and communication, is proven difficult to assess in an objective concrete manner.

Current trends in higher education assessment are moving away from traditional cognitive-type tests and shifting more toward authentic assessments (Dochy, Gijbels, & Segers, 2006). Authentic assessments reflect more valid data about student competence through their engagement with meaningful tasks that demonstrate essential skills and knowledge (Darling-Hammond, & Snyder, 2000). In addition, authentic assessments aim at assessing higher order thinking processes and competencies as opposed to the factual knowledge of cognitive testing. This, in turn, has led to a strong interest in various types of performance assessments that capture more elusive aspects of learning (Jonsson & Svingby, 2007).

Rubrics offer a mechanism for assessing higher-order thinking by documenting students' developmental progress as well as providing clear levels of achievement to which they may aspire. A rubric is a form of a criteria-specific performance scale that divides a task into constituent parts and offers detailed descriptions of the performance levels for each part (Wesolowski, 2012). Research has demonstrated many benefits of the implementation of rubrics to the educational process. Research reports have shown evidence that rubrics (a) provide diagnostic feedback that can identify areas for improvement in instruction (Song, 2006); (b) serve instructional as well as evaluative purposes (Andrade & Du, 2005); (c) support teaching and student learning (Andrade & Du, 2005; Osana & Seymour, 2004; Reitmeier, Svendsen, & Vrchota, 2004; Schneider, 2006); and (d) reflect higher achievement and deeper learning by students who have rubrics to guide their work (Petkov & Petkova, 2006; Reitmeier et al., 2004). Student perception has been shown to reflect positively for their implementation. Graduate and undergraduate students value rubrics because they "clarify the targets for their work, allow them to regulate their progress, and make grades or marks transparent and fair" (Reddy & An-

Criteria	Beginning	Developing	Proficient	Accomplished
Melodic				
1. Development of melodic musical ideas stemming from motivic interplay	☐ 1 pt. Ensemble seldom develops melodic ideas and interaction extremely disrupts improvisa-tional fluency	☐ 2 pts. Ensemble sometimes develops melodic ideas and interaction moderately disrupts improvisational fluency	☐ 3 pts. Ensemble usually develops melodic ideas and interaction slightly disrupts improvisational fluency	☐ 4 pts. Ensemble develops melodic ideas with artistic awareness and interaction never disrupts improvisational fluency
2. Reaction to implied (melodic) musical suggestions	☐ 1 pt. Ensemble seldom develops implied musical suggestions and interaction extremely disrupts improvisa-tional fluency	☐ 2 pts. Ensemble sometimes develops implied musical suggestions and interaction moderately disrupts improvisational fluency	☐ 3 pts. Ensemble usually develops implied musical suggestions and interaction slightly disrupts improvisational fluency	☐ 4 pts. Ensemble develops implied musical suggestions with artistic awareness and interaction never disrupts improvisational fluency
3. Adaptation to melodic interplay (call and response)	☐ 1 pt. Ensemble seldom reacts to melodic figurations and interaction extremely disrupts improvisa-tional fluency	☐ 2 pts. Ensemble sometimes reacts to melodic figurations and interaction moderately disrupts improvisational fluency	☐ 3 pts. Ensemble usually reacts to melodic figurations and interaction slightly disrupts improvisational fluency	☐ 4 pts. Ensemble reacts to melodic figurations with artistic awareness and interaction never disrupts improvisational fluency
Harmonic				
4. Development of harmonic ideas stemming from harmonic interplay	☐ 1 pt. Ensemble seldom develops harmonic ideas and interaction extremely disrupts improvisa-tional fluency	☐ 2 pts. Ensemble sometimes develops harmonic ideas and interaction moderately disrupts improvisational fluency	☐ 3 pts. Ensemble usually develops harmonic ideas and interaction slightly disrupts improvisational fluency	☐ 4 pts. Ensemble develops harmonic ideas with artistic awareness and interaction never disrupts improvisational fluency
5. Adaptation to harmonic interplay	☐ 1 pt. Ensemble seldom reacts to harmonic substitutions and interaction extremely disrupts improvisa-tional fluency	☐ 2 pts. Ensemble sometimes reacts to harmonic substitutions and interaction moderately disrupts improvisational fluency	☐ 3 pts. Ensemble usually reacts to harmonic substitutions and interaction slightly disrupts improvisational fluency	☐ 4 pts. Ensemble reacts to harmonic substitutions with artistic awareness and interaction never disrupts improvisational fluency

Figure 1. Analytic rubric for assessing interaction in jazz improvisation.

drade, 2010). Instructors found that rubrics provide an objective basis for evaluation, more consistent, reliable, and efficient grades (Campbell, 2005), and facilitates a change in evaluation procedures from "subjective observations to specific performances" (Reitmeier et al., 2004, p. 18).

A primary difficulty with music performance assessment is managing its subjective nature (Radocy, 1986). Rubrics can be used to overcome its subjective nature and to help develop a set of guidelines for clearly assessing student work and thus to increase objectivity in the evaluation of performances (Wesolowski, 2012). In the field of music education, rubrics have been developed and empirically tested for the influence of certain variables on solo and small ensemble festival ratings (Bergee & Platt, 2003), effects of imagery-based instruction on musical expression (Woody, 2006), the relationships of keyboard ownership to performance ratings (Price, 2007), choral festival adjudication (Norris & Borst, 2007), undergraduate performance juries (Ciorba & Smith, 2009), and collegiate-applied studio instruction (Parkes, 2005). The implementation of statistically reliable and valid rubrics can serve as a valuable assessment tool for music educators to facilitate learning and improve teaching in the classroom as well as aid in the assessment of complex behaviors.

Method

Measure Development

The proposed measure for the assessment of interaction in jazz performance was a 4-point analytic rubric, using eight dimensions of evaluative criteria (see Figure 1). The levels were gleaned from Rinzler's (1986) outline of three major degrees of creativity and Berliner's (1994) description of how jazz ensemble members engage in nonverbal interaction during a performance. The language used in rubrics is considered to be one of the most important

Criteria	Beginning	Developing	Proficient	Accomplished
Rhythmic				
6. Coordination of rhythmical pulse (timing and synchroniza-tion)	☐ 1 pt. Ensemble seldom reacts to changes in timing and synchroniza-tion and interaction extremely disrupts improvisa-tional fluency	☐ 2 pts. Ensemble sometimes reacts to changes in timing and synchronization and interaction moderately disrupts improvisational fluency	☐ 3 pts. Ensemble usually reacts to changes in timing and synchronization and interaction slightly disrupts improvisational fluency	☐ 4 pts. Ensemble always reacts to changes in timing and synchronization with artistic awareness and interaction never disrupts improvisational fluency
7. Adaptation to rhythmic interplay (call and response)	☐ 1 pt. Ensemble seldom reacts to rhythmic figurations and interaction extremely disrupts improvisa-tional fluency	☐ 2 pts. Ensemble sometimes reacts to rhythmic figurations and interaction moderately disrupts improvisational fluency	☐ 3 pts. Ensemble usually reacts to rhythmic figurations and interaction slightly disrupts improvisational fluency	☐ 4 pts. Ensemble reacts to rhythmic figurations with artistic awareness and interaction never disrupts improvisational fluency
8. Adaptation to rhythmic density	☐ 1 pt. Ensemble seldom reacts to changes in rhythmic density and interaction extremely disrupts improvisa-tional fluency	☐ 2 pts. Ensemble sometimes reacts to changes in rhythmic density and interaction moderately disrupts improvisational fluency	☐ 3 pts. Ensemble usually reacts to changes in rhythmic density and interaction slightly disrupts improvisational fluency	☐ 4 pts. Ensemble reacts to changes in rhythmic density with artistic awareness and interaction never disrupts improvisational fluency

Figure 1. (*continued*)

factors for achieving reliable and valid large-scale assessments (Moni, Beswick, & Moni, 2005; Tierney & Simon, 2004). The complexity of this rubric is a consequence of the multifaceted nature of aurally examining interaction in jazz performances as well as the intricate process of engaging in interaction episodes in improvisational performance. The rubric was constructed to accommodate the population and advanced level of students being assessed (Green & Bowser, 2006). The rubric was piloted using freshman and sophomore undergraduate jazz major improvisational performances ($N = 10$), graduate jazz major improvisational performances ($N = 10$), and professional improvisation performances ($N = 10$). Undergraduate, graduate, and faculty members at three universities with accredited jazz programs provided the recordings. The selected recordings for the pilot study demonstrated a wide range of performance ability. The judging panel ($N = 5$) consisted of full-time jazz studies faculty members from varying universities who possess expertise in jazz performance and teaching. The panel was instructed to listen to the performances as many times as needed and to judge the ensemble using the specified measurement tool. Initial data were analyzed and feedback regarding the measurement tool was solicited from the panel. The rubric was revised and edited based on suggestions for clarity, practicality, redundancy, and continuity.

Subjects and Judges

Expert judges ($N = 55$) were selected based on their jazz education experience, jazz performance experience, academic background, and availability. The volunteer judges were drawn from a pool of professional musicians adept in the jazz idiom and university professors holding full-time positions in jazz studies departments. The judges represented diverse educational backgrounds, teaching expertise, and performing experiences. Before the evaluation, each judge viewed an instructional packet that outlined the premise of the research study and clearly defined the task expectations and degrees of proficiencies of the measurement instrument. The judges and recordings used in the pilot study were not used in the full-scale study.

Following the methodology of Smith (2009), each judge was provided two anchor examples representing a beginning level and an accomplished level of interaction in an improvisational performance. The anchor examples were offered to provide a reference point for judging criteria that spanned the range of the provided measurement tool. Each judge was then given one anonymous recording. The recordings were anonymous to control for judges' biases for performance level. The instrumentation of each recording was a jazz quartet, including a brass or woodwind soloist, piano, bass, and drums. Each recording was performed in a swing style using functional harmony with a standard song form or blues form as the improvisational vehicle. The recordings were randomly selected from a pool of noncommercially released undergraduate, graduate, and professional improvisational performances. The recorded performances averaged between 45 s and 1 min and 30 s. Each judge was instructed to evaluate the ensemble using the provided measurement tool within the range of skill illustrated by the two provided anchor recordings.

An a priori power analysis was conducted to estimate a sufficient sample size that would yield a medium to large effect size (i.e., .50–.80) with a power of .80 and alpha level of .05. The projected sample size ranged from 18 to 24 evaluations. A total of 55 expert judges evaluated 55 distinct jazz improvisation performances (i.e., undergraduate, $n = 17$; graduate, $n = 20$; professional, $n = 18$). This resulted in a 73% response rate.

Results

A one-way multivariate analysis of variance (MANOVA) was conducted to test the hypothesis that there would be significant mean differences between performance levels (i.e., undergraduate, graduate, and professional) and the eight criteria comprising the rubric. Before conducting the MANOVA, several assumptions were checked. Box's M value was interpreted as nonsignificant (104.93, $p = .32$), indicating that the covariance matricies were not significantly different; thus, the assumption of homoscedasticity was maintained (Huberty & Petroskey, 2000). The Shapiro–Wilk test of normality indicated that the population was distributed normally ($p > .05$) for each of the achievement levels. A series of Pearson correlations were performed between all of the dependent variables. Table 1 indicates that they were moderately correlated, ranging from .33 to .76 (Meyer, Gampst, & Guarino, 2006). Additionally, an evaluation of the Mahalanobis distances (α = .001) indicated no significant outliers, and a series of Levene's F tests satisfied the homogeneity of variance assumption. Fifty-five evaluators independently judged 55 distinct recordings; therefore, independence was assumed.

Table 2 presents the descriptive statistics for each rubric criterion and sum scores presented in this research study. A statistically significant MANOVA effect was obtained ($\lambda = .33$, $F_{(16,90)} = 4.10$, $p < .001$, $\eta^2 = .42$). The effect size .42 indicates that 42% of the variance was accounted for by performance achievement level. A series of one-way analysis of variance (ANOVA) on each of the eight dependent variables was conducted as a follow-up test to the MANOVA. All of the ANOVAs were statistically significant (See Table 3).

A series of Bonferroni-adjusted post hoc analyses were performed to examine individual mean difference comparisons across the three performance achievement levels and all eight rubric criteria. As seen in Table 4, the results revealed that all post hoc mean comparisons were statistically significant.

A canonical discriminant function analysis was conducted to test the hypothesis that some rubric criteria may maximally differentiate the three performance levels. Two eigenvalues and canonical variables were extracted; however, only the first extraction indicated significance. The first eigenvalue was equal to 1.73 and accounted for

Table 1
Pearson Correlations Associated With Ensemble Performance Ratings of the Rubric Criteria

Rubric criteria	1	2	3	4	5	6	7
Criterion 1	—						
Criterion 2	.68	—					
Criterion 3	.55	.34	—				
Criterion 4	.67	.52	.53	—			
Criterion 5	.51	.33	.50	.60	—		
Criterion 6	.43	.38	.47	.65	.48	—	
Criterion 7	.71	.57	.60	.73	.59	.53	—
Criterion 8	.76	.66	.56	.75	.54	.55	.70

Table 2
Descriptive Statistics for Rubric Criteria (N = *55)*

Rubric criteria	Mean	*SD*	Variance
Criterion 1	2.75	.87	.79
Criterion 2	2.67	.90	.82
Criterion 3	2.98	.76	.57
Criterion 4	3.22	.79	.62
Criterion 5	3.20	.65	.42
Criterion 6	3.15	.73	.53
Criterion 7	3.09	.78	.60
Criterion 8	3.02	.78	.61

40% of the model variance (Wilks $\lambda = .33$, $F_{(16,90)} = 4.10, p < .001$). As seen in Table 5, the standardized canonical discriminant function coefficients demonstrate that the three performance levels were maximally differentiated by one canonical variate with the greatest weight from all three melodic interaction criteria ("Reaction to implied [melodic] musical suggestions," [.51] "Development of melodic musical ideas stemming from motivic interplay," [.31] "Adaptation to melodic interplay" [.32]) and one rhythmic interaction criterion ("Coordination of rhythmical pulse" [.50]). Therefore, the results indicated a cognitive ordering of rater task difficulty: melodic interaction, rhythmic interaction, and harmonic interaction. Canonically derived group means were then estimated for the three performance levels. As hypothesized, the professional group was associated with the highest mean ($M = 6.57$, $SD = .88$), the graduate group was associated with the second highest mean ($M = 5.92$, $SD = .92$), and the undergraduate group was associated with the smallest mean ($M = 4.08$, $SD = 1.17$).

Interjudge reliability was calculated using Cronbach's alpha lower bound estimate of reliability. The result for all raters ($N = 55$) was .91. The high alpha reliabilities provide an indication that there was a significant level of internal consistency among the judges' scores and the variability of individual criteria within the rubric. A total of 66.33% of the variability was accounted for by performance achievement level.

Multicollinearity was assessed using variance inflation factor values. All values were under the recommended value of 10, indicating that the collinear variables (i.e., item responses) do not demonstrate redundancy with the dependent variables (i.e., rubric items) (Hair, Anderson, Tatham, & Black, 1995).

Table 4
Post Hoc Mean Comparisons (Bonferroni Adjusted)

Performance level	*N*	*M*	*SD*
Undergraduate	17	4.65	.90
Graduate	2	6.60	1.00
Professional	18	7.49	.84
Total	55	6.29	1.47

Note. $F_{(2,55)} = 43.44$; $p < .001$.

Discussion

The purpose of this study was to examine cognitive processes related to interaction episodes in jazz improvisation through the generation, testing, and validation of a rubric based on interaction episodes in jazz improvisation. The results of this study provide evidence that the prescribed rubric can be used effectively to evaluate interaction in jazz improvisation with significant reliability ($\alpha = .91$). Specifically, the rubric was able to discriminate between undergraduate, graduate, and professional achievement levels across each criterion outlined in the rubric. As hypothesized, the overall means across the three performance levels indicated that improvisers perform with greater attention to ensemble interaction and with greater improvisatory fluidity at higher performance levels. This indicated that the rubric has a high level of content validity. Strong content validity along with the moderate to strong correlations between the rubric criteria and significant reliabilities supports Fiske's (1983) argument that subjective performance-based activities can be effectively assessed in a holistic and objective manner.

The standardized discriminant function coefficients suggested that the three performance levels were maximally differentiated by a canonical variate with greater weightings from three items from the melodic criteria (i.e., "Reaction to implied (melodic) musical suggestions," "Development of melodic musical ideas stemming from motivic interplay," "Adaptation to melodic interplay [call and response]"), one item from the rhythmic criteria (i.e., "Coordination of rhythmical pulse [timing and synchronization]), and no items from the harmonic criteria. This implied a cognitive ordering of task difficulty with respect to the canonical variate: melodic interaction ($n = 3$), rhythmic interaction ($n = 1$), and harmonic interaction ($n = 0$). Moreover, this sheds some light on the

Table 3
One-Way ANOVAs With Rubric Criteria as Dependent Variables and Performance Level as Independent Variable

		Undergraduate		Graduate		Professional	
Rubric criteria	$F_{(16,90)}$	*M*	*SD*	*M*	*SD*	*M*	*SD*
Criterion 1	22.57	1.88	.60	2.95	.76	3.33	.59
Criterion 2	19.18	1.82	.53	2.90	.72	3.22	.81
Criterion 3	11.44	2.41	.62	3.05	.69	3.44	.62
Criterion 4	13.58	2.59	.87	3.30	.57	3.72	.46
Criterion 5	6.84	2.76	.56	3.35	.67	3.44	.51
Criterion 6	14.16	2.59	.62	3.15	.67	3.67	.49
Criterion 7	15.66	2.41	.62	3.25	.64	3.56	.62
Criterion 8	17.48	2.29	.69	3.25	.55	3.44	.62

Note. $N = 55$; $p < .001$.

Table 5
Discriminant Function Coefficients Associated With the MANOVA

Rubric criteria	Raw	Standard	Structure
Criterion 1	.66	.43	.71
Criterion 2	.72	.51	.65
Criterion 3	.50	.32	.50
Criterion 4	.09	.06	.55
Criterion 5	.01	.01	.38
Criterion 6	.83	.50	.55
Criterion 7	.08	.04	.59
Criterion 8	.07	.11	.61

Note. $N = 55$; eigenvalue was equal to 1.73 with a canonical correlation of .80. Raw = unstandardized coefficients; standard = standardized coefficients; structure = structure coefficients.

cognitive processes related to interaction in jazz improvisation at various achievement levels. These four items carried the most weight in the canonically derived group means. Although all items in the rubric were able to discriminate between the three performance achievement levels, the four highlighted items indicate where professional, graduate, and undergraduate soloists demonstrate the greatest differences. Therefore, one can speculate that these particular items may necessitate the most amounts of musical ability, adaptation, responsiveness, critical thinking, and/or creativity. A strong aural capacity is needed to engage in interaction at the melodic level. Interestingly, item number two (Reaction to implied [melodic] musical suggestions) carried the greatest weight in the canonical variate (.51). This item not only calls for a strong aural capacity, but also a strong foundation in jazz vocabulary, knowledge of repertoire, and stylistic convention. The only rhythmic item underscoring the canonical correlate was "Coordination of rhythmical pulse (timing and synchronization)." This strengthens Seddon's (2005) notion of empathetic attunement, where advanced levels of interaction move beyond vocabulary-based communication and into groove-oriented communication and accordance. Here, this is sense of "togetherness" can be evidenced in ensemble synchronization.

The suggested cognitive-task ordering provides a great amount of diagnostic and analytical value that may inform pedagogy and improve students' awareness in the aural and interactive aspects of jazz improvisation. Pedagogically, it may provide a framework for expectations of student improvisers. Undergraduates who strive to play at a professional level can focus on the four items with the greatest canonical weightings to increase their perceived ability to interact in the ensemble setting. A developed aural ability will allow students to melodically interact with the ensemble, and increased attention to ensemble synchronization (i.e., ensemble accordance) can improve the perception of interaction in the ensemble.

Bringing to light the construct validity of the measurement tool, one can only speculate on the relationship of listener perception to acoustical occurrence within the limitations of this study. The rubric identifies the cognitive rater task difficulty: melodic interaction, rhythmic interaction, and harmonic interaction. Arguably, harmonic interaction may not have been perceived, thus causing its subjacent position in the cognitive task ordering. Additionally, melodic interaction may be the most perceptually apparent form of interaction in jazz improvisation. Listeners' focus may be directed to melodic interplay due to the aural/oral nature and tradition of jazz stemming from the historical, pedagogical, and musicological significance of call and response. Future experimental studies that examine the connection between these variables and listeners' perception of interaction could potentially shed light on these perceptual and acoustical relationships. Furthermore, the perceived relationships between improvisation quality, interaction quality, and rater score are unclear. Raters may have potentially evaluated quality of the performance in lieu of occurring interactions. Experimental research that parses apart these relationships may lead to a clearer connection and understanding of the perception of ensemble interaction.

The development of valid and reliable assessment tools cannot only improve the teaching and learning processes, but can also provide insight into the more elusive aspects of musical behavior. Jazz improvisation and ensemble interaction are multifaceted and complex musical behaviors that use higher order thinking and creative competencies. The newly constructed assessment tool provided in this study may aid in the process of recognizing, diagnosing, and communicating new methods for improvement in an individual student's jazz improvisatory development, solo construction, and execution.

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Testing Cognitive Theories by Creating a Pattern-Based Probabilistic Algorithm for Melody and Rhythm in Jazz Improvisation

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Building on previous work, which suggests that jazz improvisers insert patterns stored in procedural memory, a probabilistic model based on patterns from a corpus of Charlie Parker solos was developed and implemented. In previous analysis, patterns were detected in the corpus in significant proportions; however, the results of a parallel control situation showed minimal patterns. The control improvisation was generated by software based on grammars and contours, coincident with the cognitive position that emphasizes learned rule-based procedures in improvisation, as opposed to stored patterns. The present pattern-based improvisations, using our model, have graphs that coincide significantly with the actual human improvisation. Though briefly described earlier (Norgaard, Montiel, & Spencer, 2013), the current article expands the theoretical foundation and adds methods for evaluating our algorithm using interval distributions and alternate corpora. Specifically, we show that the algorithm is capable of generating improvisations in fiddle and classical styles, demonstrating that the pattern-based algorithm is style independent. Our model shows much promise both for future research in the cognitive underpinnings of musical improvisation as well as for the development of software based on a stylistically appropriate concatenation of actual patterns.

Keywords: stochastic matrix, probability, music cognition, pattern-based software, jazz improvisation

Performance of preexisting music and musical improvisation both involve learned movements. However, during musical improvisation, the exact configuration of those movements is determined in the moment. How is this accomplished? What information is stored in the improviser's brain that enables this complex behavior? One theory posits memorized schemas form the basis for the improvised output (Pressing, 1988), while a competing theory emphasizes learned rules (Johnson-Laird, 2002). The current project further explores these questions through the implementation of a computer algorithm for improvisation based on the principle advocated by Pressing. We compare output from our model with the results of a jazz analysis study as well as with the output of a competing model that uses a rule-based algorithm to generate melodies in a jazz style. In addition, we show that our algorithm is capable of generating melodic output in other styles given a corpus in that style.

Pressing's (1988) model of the cognitive processes underlying improvisation is still widely cited (Burnard, 2002; Goldman, 2012; Hargreaves, 2012; MacDonald & Wilson, 2005). Pressing divided improvisations into concatenated note groupings. Each grouping is triggered by a creative intention in the form of a mental schema that contains a cognitive image of sound and corresponding motor realization. His theory implies that these mental schemas may derive from a stored library. Therefore, should his theory be accurate, improvisations by artist-level improvisers should contain repeated melodic and rhythmic figures as the improviser repeatedly accesses the same mental schema from the stored library. Importantly, Pressing's model is based on principles gathered from an extensive review of literature from diverse fields. Therefore, his theory is not tied to a particular style of improvisation but is applicable to any novel musical output created in real-time.

A competing theory of jazz improvisation emphasizes learned rules (Johnson-Laird, 2002). In support of his theoretical position, Johnson-Laird designed a rule-based algorithm that creates jazz bass lines based on contour, the underlying chord progression, and procedures related to the use of scales, chord tones, and passing tones. According to Johnson-Laird "instead of a list of fragments of rhythms, motifs, and so on, the algorithms described make use of rules" (2002, p. 440). Therefore, according to this view, there is no need for the improviser to store melodic material for later use. Johnson-Laird does acknowledge that longer patterns may be stored temporarily to be used later in the same solo but disputes they are reused in other contexts. Johnson-Laird's stated goal is specifically to model cognition during improvisation in which the use of working memory is minimal. Therefore he stresses that tonal and contour rules are adequate constraints for the computer model to select notes for jazz bass lines according to a given chord progression. Although these rules may contain constraints sufficient to generate bass lines in jazz styles, it is not clear that other improvised music would contain similarly parsimonious rules.

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Parts of this data was presented at The International Symposium for Performance Science, Vienna, 2013, and in the related proceedings. As the current work is an extension of previous work on jazz analysis, the first part of the Methods section in addition to Figures 5 and 7 were adapted from "How jazz musicians improvise: The central role of auditory and motor patterns," by M. Norgaard, 2014, *Music Perception.*

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Figure 1. Excerpt from Parker's solo on Back Home Blues mm. 31 to 33. Parker does not imply the Em7 and A7b9 chords in his solo line.

Therefore, Johnson-Laird's software model would have to be adapted to incorporate rules in other styles to show that this approach applies to other types of improvised music.

A previous study by one of the current authors explored the use of rules and patterns in jazz by analyzing a large corpus of improvisations by jazz great, Charlie Parker (Norgaard, 2014). The study found an extensive presence of patterns, lending support to Pressing's theory that improvisers develop a stored library of patterns serving as the basis for new improvisations. In that study, interval and rhythm patterns were investigated starting on each note position (see Method section below). Results showed that 82.6% of all notes in the corpus began a four-interval pattern and 57.6% began interval and rhythm patterns. Furthermore, patterns up to 49 intervals long were identified. Importantly, many of the longer interval patterns were distributed over several improvisations recorded at different times, even years apart. Specifically, of the 98 identified unique patterns of 15 intervals or longer, 61% occurred in two or more different solos, suggesting that these patterns were not just temporarily stored during the current improvisation as suggested by Johnson-Laird (2002).

Two fully implemented software packages represent the two theoretical approaches, ImPact (Ramalho, Rolland, & Ganascia, 1999) and Impro-Visor (Gillick, Keller, & Tang, 2010). Ramalho et al. describe how their software, ImPact, creates jazz bass lines by reusing fragments derived from six different recordings of bass lines performed by jazz bassist Ron Carter. The output is created by the bass player "Agent" but influenced by output from other simulated players in the form of a soloist, pianist, and drummer Agent. Using a multistage process, ImPact continuously segments a given chord progression into individual chords or groupings (e.g., ii-V) and then selects and adapts bass line fragments taken from the bank. The selection is influenced by concurrently applied structural rules such as "play diatonic scale in the ascending direction during this measure" (p. 112) or "play quieter during the current chord chunk" (p. 118). These abstract rules, called PACTs (Potential ACTions) are influenced by the current environment including the chords, "scenario events occurred so far, and the bass executor's own output" (p. 112).

Though their stated goal was not to model the thinking of human improvisers, two processes implemented by Ramalho et al. (1999) resemble processes identified in artist-level improvisers' descrip-

Figure 3. The first two measures of Parker's solo on Donna Lee. The numbers just above the notes refer to the intervals.

tions of their own thinking (Norgaard, 2011). In interviews concerning a solo just performed, expert improvisers described planning upcoming passages according to architectural features such as note density, register, and rhythmic content. These plans are similar to ImPact's implementation of PACTs that influence which fragments are inserted. Furthermore, ImPact is able to adapt retrieved fragments to the current context. If a fragment is selected because it fits several scenarios (e.g., "ascending" and "quiet" see above), this fragment can be adapted to the current harmonic context (e.g., if the stored fragment was originally played over a ii7–V7 but here needs to fit a ii7b5–V7 progression). This process of adapting stored melodic figures to the current context during improvisation was often mentioned by the expert improvisers in Norgaard's study.

Using ImPact to model human cognition presents problems related to cognitive load. Unlike Johnson-Laird's (2002) algorithm, which specifically models limited use of working memory, ImPact's use of multiple concurrent abstract rules and responsiveness to other players may only be possible within a computer environment. Human improvisers may be able to create material using subconscious automatic processes with minimal use of working memory (Berkowitz, 2010; Johnson-Laird, 2002; Limb & Braun, 2008; Pressing, 1988). Norgaard (2011) suggested that while architectural and interactive processes may be partially consciously controlled, the actual choosing of notes most likely can take place in an implicit process. This differentiation between controlled and implicit processes is not modeled in ImPact. Our current model attempts to model only the implicit process of choosing notes without regard for large structures and interaction with other players and audience.

Impro-Visor (Gillick et al., 2010; Keller, 2012) is a full software implementation based on rules or grammars that is able to create solo lines in various styles given a chord progression. Gillick et al. generated grammars inspired by the solos of Charlie Parker, Lester Young, John Coltrane, and others by deriving rules related to contour, rhythm, chord tones, approach tones, and color tones. Using the rules embedded in the chosen grammar, the software creates an output based on a given chord progression without the use of stored melodic material. However, it is not known whether this software could generate grammars based on solos in nonjazz styles.

Our goal was to create a parsimonious model that, like Johnson-Laird's model (2002), uses simple computational processes but is

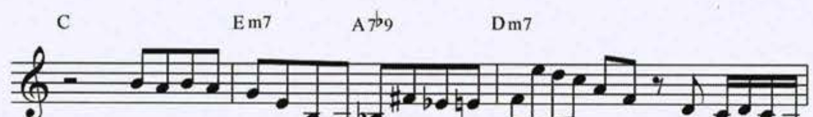

Figure 2. Excerpt from Parker's solo on Back Home Blues mm. 43 to 45. Parker clearly implies the Em7 and A7b9 in the solo line.

Table 1
Example Sequence Used to Illustrate the Melody Creation Algorithm

Pitch	C	D	E	F	G	Ab	Bb	B	Db	Eb	E	Gb
Midi pitch	60	62	64	65	67	68	70	71	73	75	76	78
Position	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	
Interval	2	2	*1*	2	*1*	2	*1*	2	2	*1*	2	

in line with Pressing's (1988) style-independent theoretical framework. We believe the pattern-based framework is supported by research on motor learning (Park & Shea, 2005; Shea & Wulf, 2005), language learning (Lew-Williams & Saffran, 2012; Saffran, 2003; Saffran, Pollak, Seibel, & Shkolnik, 2007), and pitch sequence acquisition (Saffran, Johnson, Aslin, & Newport, 1999), which emphasize the acquisition and storage of patterns. According to the classic Schema Theory, movements are based on generalized motor programs (GMP) that are concatenated and fitted to the current context (Park & Shea, 2005; Shea & Wulf, 2005). In the context of musical improvisation, each GMP could represent the instrument-specific movements necessary to play a short learned melodic figure. In highly skilled improvisers, GMPs would be linked to the corresponding auditory images (Baumann et al., 2007; Chen, Rae, & Watkins, 2012). Therefore improvisation would be a process of concatenating learned GMPs and their corresponding auditory images (Pressing, 1988). A full description of these processes is beyond the scope of this article (see Kenny & Gellrich, 2002; Norgaard, 2014; Pressing, 1988).

To create a parsimonious style-independent model, we initially focused only on the melodic aspect of improvisation. Computer models using either the rule- or pattern-based approach must weigh both melodic (horizontal) and chordal (vertical) considerations, as both influence experts' improvisations (Berliner, 1994; Norgaard, 2011). Specifically, improvisers may follow the logic of the horizontal line to create material that may or may not "fit" the actual chords. In a previous qualitative study, one participant described a phrase as having "no map behind that part" referring to the lack of attention to the underlying harmonic "map" (Norgaard, 2011, p. 120). In two musical examples taken from Parker's solo on Back Home Blues, he emphasizes the underlying chord structure in one but not the other. During this solo, Parker plays over the same 12-measure chord progression five times. Two examples show instances of his improvisation over the sixth through eighth measure of the 12-measure form. Though the notated chords played by the accompanying rhythm section are the same, Parker

Table 2
The Four-Interval Patterns on Each Note Position That Starts a Pattern Within the Sequence in Table 1 (Positions I, J, and K Do Not Start Four-Interval Patterns)

Position *a*	Position *b*	Position *c*	Position *d*	Position *e*	Position *f*	Position *g*	Position *h*
2	2	1	2	1	2	1	2
2	1	2	1	2	1	2	2
1	2	1	2	1	2	2	1
2	1	2	1	2	2	1	2

Table 3
The Five Unique Four-Interval Patterns From the Example Sequence Listed in Table 1

Pattern number	1	2	3	4	5
Pattern sequence	2	2	1	2	1
	2	1	2	1	2
	1	2	1	2	2
	2	1	2	2	1

Note. The patterns are listed vertically.

implies each chord in the solo line in one example but not in the other. In Figure 1, the chords E minor and A7b9 are mostly disregarded, as Parker uses a short diatonic scalar passage to connect two similar melodic ideas showing a horizontal focus. Although in the correct key, the notes do not spell out the E minor and A7b9 progression. In the second example (see Figure 2), however, Parker clearly outlines both the E minor and the A7b9 chords in his solo line by arpeggiating the E minor chord and by emphasizing the flat 9 (Bb) of the A7b9 chord.

Often computer algorithms for improvisation are based on strict vertical relationships between the improvised line and the underlying chords so the line clearly reflects each chord (Band-in-a-Box, 2013; Gillick et al., 2010; Johnson-Laird, 2002; Ramalho et al., 1999). In two of these models, grammars based directly on the underlying chord progression are used to create improvised material, thereby possibly overemphasizing vertical elements in improvisational thinking (Gillick et al., 2010; Johnson-Laird, 2002). To counter this bias, the current computer model emphasizes the horizontal aspect exclusively.

The basis of our model is a Markov chain used to string together a sequence of intervals and rhythms where each added note is depending on the four notes just played. Markov chains have been used in computational models of musical interaction (Pachet, 2003), virtuoso jazz passages played within longer solos (Pachet, 2012), and melody improvisation in modern Greek church chant (Mavromatis, 2005). These models are based on the Markov principle that the future state of a sequence depends only on the present state (Pachet, 2012). A Markov chain is based on what is known as a stochastic matrix. A stochastic matrix is a matrix that lists transitional probabilities where the sum of each row equals one. A stochastic matrix captures the randomness of a phenomenon and, to some point, controls it. Markov chains are iterations of the stochastic matrix applied to an initial situation where its memory is limited to the previous iteration. See the Method section

Table 4
The Matrix Lists How Many Times the Pattern Listed in the Top Row Follows the Pattern Listed in the First Column

Pattern number	1	2	3	4	5
1	0	1	0	0	0
2	0	0	2	0	0
3	0	1	0	1	0
4	0	0	0	0	1
5	1	0	0	0	0

Table 5
Stochastic Matrix Based on Table 4 in Which Each Row Adds Up to 1

Pattern number	1	2	3	4	5
1	0	1	0	0	0
2	0	0	1	0	0
3	0	0.5	0	0.5	0
4	0	0	0	0	1
5	1	0	0	0	0

Note. This matrix lists the probability that the pattern in the top row follows the pattern listed in the first column.

below for an example describing how this principle can apply to the creation of musical sequences.

In a notable recent example, Pachet (2012) described the use of the Markovian approach to model the creation of virtuoso passages as played by jazz improvisers. These passages, often referred to by musicians as "double timing," represent instances where the improviser must rely on implicit learned processes due to the short note durations. The improviser therefore has minimal conscious control of the output. As in the present work, Pachet's stated goal is a solution that "is analogous to the way human improvisers practice and improvise" (p. 130). Pachet used known virtuosic passages as training sets in combination with rule-based information representing chord/scale relationships, side-slipping (a style-specific technique to add variety to the passage), and chromatic passing tones. Our work detailed below is able to produce stylistically appropriate output solely based on our Markovian model without having to encode style-specific rules.

Our goal is to model musical improvisation in a parsimonious way that mirrors the cognitive principles used by human improvisers. Specifically our model aims to (1) use a simple mathematical process, (2) solely consider melodic horizontal information, and (3) use principles that are style independent. In future work, we plan to further develop our model also to consider a given chord structure. Our final goal is to create a software for improvisation in which both horizontal and vertical aspects interact in a manner that more accurately reflects the thinking of artist-level jazz improvisers.

Method

In the previous study, 48 improvisations by Charlie Parker served as a corpus for analysis (Norgaard, 2014). A master midi file containing transcriptions of all the improvisations was imported into the Matlab computer environment (Matlab, 2011; Smit, n.d.) and distances between pitches were converted to intervals. Then the frequency of five-note patterns was investigated by searching for four-interval patterns with an algorithm within Matlab that, starting with the first four intervals (+2, +2, +1, −1) (see Figure 3), looked for additional occurrences of this interval sequence elsewhere in the corpus. The result represents the number of times the interval pattern + 2, +2, +1, −1 occurs in the corpus. The program then went on to the interval pattern starting on the following note, F4 (+2, +1, −1, −2), and looked for the number of occurrences of this pattern. Note that, unlike previous research (Finkelman, 1997; Kenny, 1999; Owens, 1974), this study did not segment the solos into nonoverlapping patterns but looked for patterns starting on each note position. It follows that the patterns

Table 6
A List of Steps Used by Our Algorithm to Create Improvisations Where Interval and Rhythm Patterns Only Coincide if They Also Coincide in the Imported Corpus

1. Choose a beginning rhythmic pattern
2. Arbitrarily choose an interval pattern that is used in conjunction with the rhythmic pattern chosen at some point in the imported corpus
3. Loop through the following to reach the desired number of notes:
   a. Choose a rhythmic pattern:
      i. Using the stochastic matrix for pitch, find all interval patterns that can follow the last interval pattern chosen. This would be indicated by a nonzero cell in the row of the stochastic interval matrix corresponding to the last rhythmic pattern chosen.
      ii. Using the stochastic matrix for rhythm, find all rhythmic patterns that can follow the last rhythmic pattern chosen.
      iii. List all of the rhythmic patterns found in the previous step that at some point in the imported corpus coincide with one of the interval patterns found in step (i).
      iv. Using this list of rhythmic patterns, form a vector storing the probability that the last rhythmic pattern chosen will be followed by each of the patterns found in (iii).
      v. Divide each entry by the sum of the whole vector to turn it into a stochastic vector.
      vi. Pick a random number between zero and one. Compare this with a running total as you follow the entries in the vector. The pattern corresponding to the cell whose value pushes this total over the random number will be the new rhythmic pattern.
   b. Choose an interval pattern:
      i. Make a list of all of the interval patterns that can follow the last chosen interval pattern and coincide with the current rhythmic pattern (the one that was just chosen)
      ii. Make a stochastic vector of the probabilities of the last interval pattern following each of the potential successors in (i).
      iii. Choose an interval pattern in the same way a rhythmic pattern was chosen using the stochastic vector.
   c. Repeat until the desired number of notes has been found.

Figure 4. Example of an improvisation created by our melody algorithm.

therefore overlap with the preceding pattern. A similar procedure using beat onset times was used to investigate rhythm patterns.

Building on this previous work we decided to find a way of concatenating pitch patterns to generate improvisations based on the Markovian principle. The first step was to create a model for melody generation by using the Parker corpus as input. Initially a stochastic matrix was created that reflected the probabilities of the juxtaposition of the patterns in the corpus. Then an algorithm was programmed in Matlab that used these probabilities to create an output consisting of a series of intervals. In the algorithm, a change in pattern was determined by deleting the first interval of the previous pattern and adding a new interval. For example, a four-interval pattern (4, 3, −2, −1) might be followed by (3, −2, −1, 5), with the result that the concatenated interval sequence would be (4, 3, −2, −1, 5). In this case, the following pattern was contingent on the last four intervals of the preceding pattern.

To illustrate, we describe a small and contrived example of the melody-generating process with 5-note patterns. It is contrived because all of the intervals are ascending, which, even with five-note patterns, is not always the case. The five-note patterns will be presented as four-interval patterns, and in this example only intervals of "1" and "2" will be used (the semitone and the whole tone). However, the example should give a clear idea of how the algorithm functions. The example is as follows:

Taking the midi convention with middle C as 60, Table 1 lists a 12-note sample sequence.

Table 2 lists all four-interval patterns in the sequence. Note that there are only five *unique* patterns (see Table 3), as Pattern 1 appears on both position *a* and *h*, Pattern 2 appears on position *b* and *d*, and Pattern 3 appears on position *c* and *e*.

Then a 5 × 5 matrix was created, which lists how many times each pattern listed vertically is followed by the pattern listed horizontally (see Table 4). For example, Pattern 3 follows Pattern 2 on two occasions. Finally the 5 × 5 matrix is converted into a stochastic matrix, which represents the probabilities that a pattern follows the next embedded within the sequence (see Table 5).

This stochastic matrix is now used to create new sequences based on a process referred to as Random Walk (Pachet, 2012). The first pattern of the newly created sequence is selected randomly. The probability of each pattern following the previous

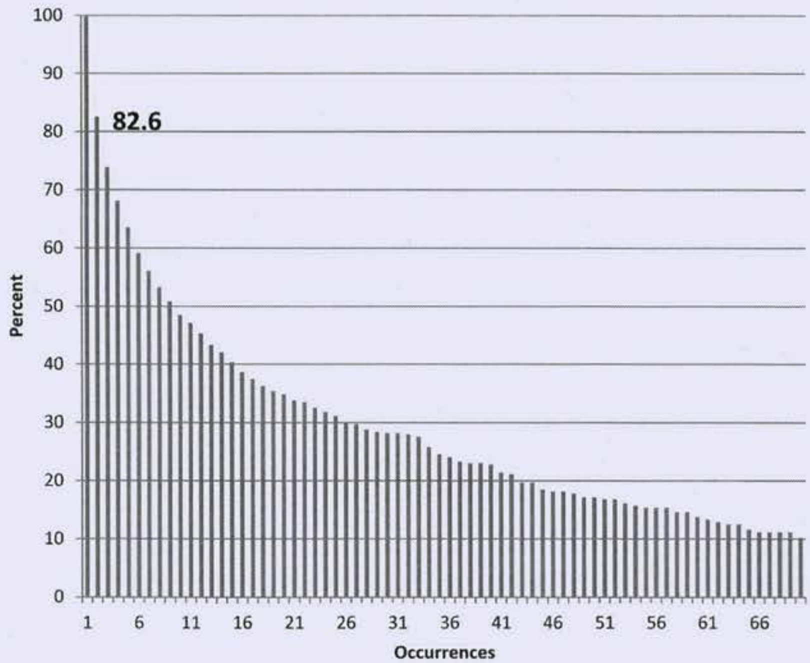

Figure 5. The percentage of notes that start a four-interval pattern as a function of the number of times the pattern occurs in the original Parker corpus (from Norgaard, M., *Music Perception*, 2014, 31. (c) 2014 by the Regents of the University of California. Published by the University of California Press.).

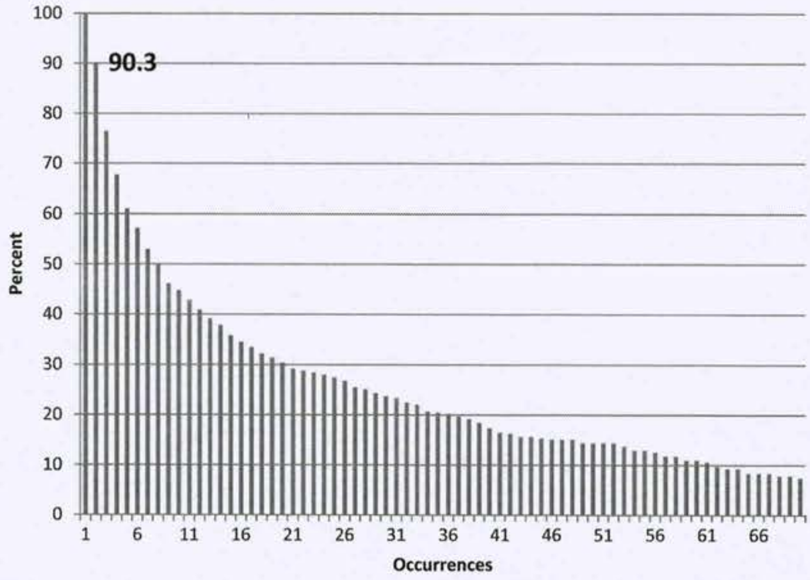

Figure 6. The percentage of notes that start a four-interval pattern as a function of the number of times the pattern occurs in an improvisation of similar length to the original Parker corpus created with our melody algorithm.

pattern chosen can now be found in the row of the stochastic matrix corresponding to the last pattern. For example, if the first pattern chosen was Pattern 2, then Pattern 3 would follow because the probability that Pattern 3 follows Pattern 2 is 1. Therefore, the concatenated sequence of intervals would be (2, 1, 2, 1, 2), taking the first four intervals from Pattern 2 and then adding the fourth interval from Pattern 3. Notice that even though four previous intervals are considered, only one additional interval was added in this step. In the following step, only the last four intervals representing Pattern 3 are considered. In this scenario, both Patterns 2

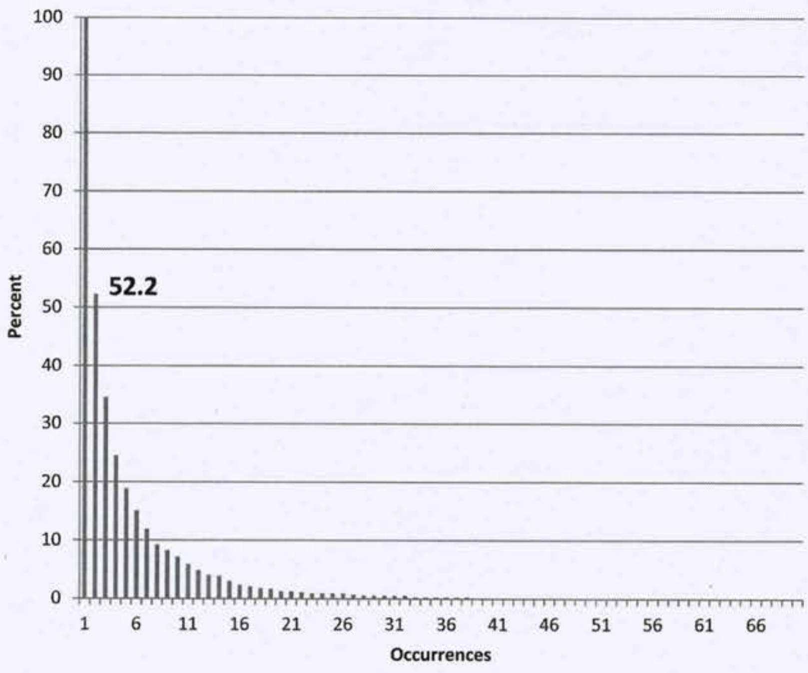

Figure 7. The percentage of notes that start a four-interval pattern as a function of the number of times the pattern occurs in the improvisations generated by Impro-Visor over the same chord progressions as the Parker corpus (from Norgaard, M., *Music Perception*, 2014, 31. (c) 2014 by the Regents of the University of California. Published by the University of California Press.).

and 4 can follow Pattern 3. Here, a random process is used to decide which of the two patterns will be added to the sequence. The decision is made by generating a random number and comparing that with a running sum of each entry in the row. Once the running sum is above the random number, that corresponding pattern is chosen, for example, if the random number generated is 0.6, Pattern 4 is chosen because the running sum is not >0.6 until the numbers up through column 4 is added ($0 + 0.5 + 0+0.5 = 1 \geq 0.6$). Our final sequence of concatenated patterns therefore is (2, 1, 2, 1, 2, 2) corresponding to patterns 2, 3, and 4. The actual corpus of Charlie Parker solos contained a sequence of 14,470 notes resulting in a stochastic matrix listing transitional probabilities of 1,671 patterns.

After obtaining positive results using the melody algorithm for the concatenation of the patterns, we decided to continue in the same vein for the treatment of rhythm. To keep these techniques as similar as possible, rhythmic patterns also spanned five notes. A rhythmic pattern was defined as a combination of four contiguous note durations and the time from each of these note onsets to the next. Initially, we tested this approach by superimposing separately generated rhythm and pitch improvisations into the same improvisation. This melody/rhythm algorithm created improvisations in which both pitch and rhythm patterns were present but where no relationship existed between the two parameters. In the latest working version of our algorithm, rhythmic and interval patterns are played concurrently only when they coincide at some point in the imported corpus. An outline of steps used by our algorithm is listed in Table 6.

Results

Figure 4 shows an example of an improvisation created with the melody algorithm. We evaluated the output of this algorithm using the same procedure used to investigate the use of patterns in the Charlie Parker corpus (Norgaard, 2014). Figure 5 shows the percentage of notes in the original Parker corpus that start a four-interval pattern as a function of the number of times the pattern occurs in the corpus. Naturally, all patterns by definition occur at least once in the corpus, which is why the first column is exactly 100%. If you define a pattern as a structure that occurs two or more times in the corpus, 82.6% of the notes in the corpus start a pattern as illustrated by the second column. About 30% of the notes in the corpus start a pattern that occurs ≥26 times, and so on. Remember,

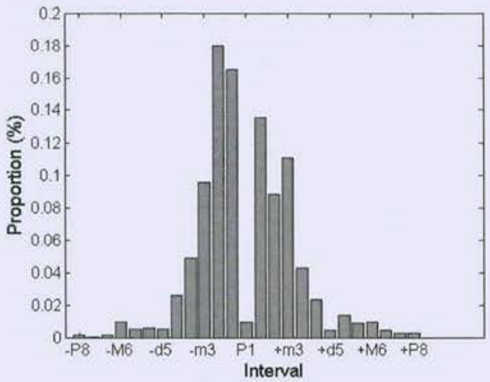

Figure 8. Interval distribution of the original Parker corpus.

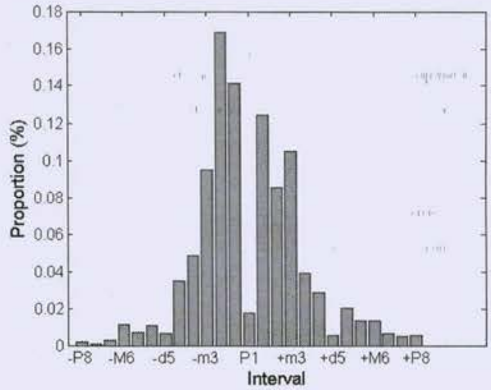

Figure 9. Interval distribution of an improvisation of similar length to the original Parker corpus created with our melody algorithm.

that patterns are investigated on each note position and therefore overlap (see above). Therefore a seven-interval pattern would contain four embedded four-interval patterns. Figure 5 is therefore a graphical representation of pattern use in general, not just the use of four-interval patterns. We used our melody algorithm to create an improvisation with approximately the same number of notes as the Parker corpus (about 15,000). Then we analyzed the number of four-interval patterns occurring on each note position (see Figure 6) using the same procedure used to create Figure 5. Notice the similarity between Figures 5 and 6 showing how our melody algorithm creates improvisations with pattern structures similar to that of the human improviser.

To compare our melody algorithm with the output from software using the rule-based approach, we investigated the frequency of four-interval patterns in a corpus created by Impro-Visor (Gillick et al., 2010; Keller, 2012). We used a build-in "Parker grammar" setting to create improvisations on the exact same chord progressions as the original Parker corpus. Figure 7 shows that this output from Impro-Visor has a much different structural pattern content than the Parker corpus and the improvisation generated by our melody algorithm.

As our algorithm is based on patterns, we needed another way of evaluating the outputs that was not biased toward the basic principle of our own algorithm. Therefore, we analyzed the inter-

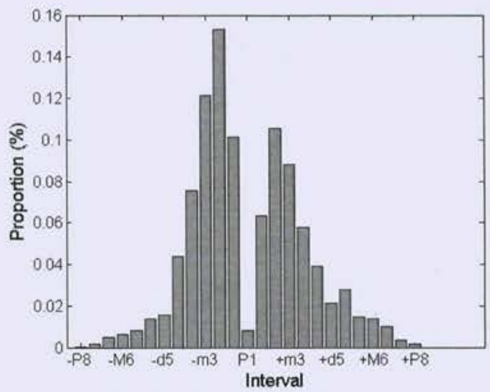

Figure 10. Interval distribution of the improvisations generated by Impro-Visor over the same chord progressions as the Parker corpus.

Figure 11. Excerpt from an improvisation created with a previous version of our algorithm in which pitch and rhythm patterns are created separately and then superimposed.

val distribution of the original Parker corpus (see Figure 8), the output from our melody algorithm (see Figure 9), and the output from Impro-Visor (see Figure 10) using the Midi Toolbox for Matlab (Eerola & Toiviainen, 2004). The interval distributions from the Parker corpus and our melody algorithm output are slightly more correlated (r = .997) than the interval distributions from the Parker corpus and Impro-Visor output (r = .923).

The final implementation of our algorithm creates improvisations in which the embedded interval and rhythm patterns are related. Before this final step, we designed an algorithm where pitch and rhythm improvisations were created separately and then superimposed (see Figure 11 for a sample). In the music created by the human improviser, patterns often include the same pitches and rhythms (Norgaard, 2014). For example, Charlie Parker often plays arpeggiated chords using a triplet rhythm. Therefore, the final implementation of our algorithm takes this relationship into account. Figure 12 shows an example of a complete improvisation created with this algorithm. Notice that at several points "quintessential" Parker patterns occur where pitch and rhythm is related. Examples include the melodic figure in measure 3, the ascending triplet arpeggio in measure 8, and the figure in measure 19 (see brackets in Figure 12). Also note that Parker's reliance of eighth and sixteenth notes is reflected in the example. As in standard jazz notation, the swing timing is not notated even though the midi file produced by the software included swung eighths.

To evaluate whether our final improvisation algorithm could create improvisations in a different style, we used as input a published collection of fiddle tune improvisations by Nashville fiddle player Aubrey Hanie (Norgaard, 1998). An excerpt of an improvisation created by our algorithm using this corpus is shown in Figure 13. Importantly, this improvisation was created without any modifications to our algorithm except the fiddle corpus was used as input. Note that the style-specific use of double stops of thirds, fifths, and sixths are reflected in the example showing that the relationship between pitch and rhythm in the corpus is reflected in the improvisation by our algorithm. These double stops occurred because the corpus includes instances where two notes have the same onset times and the interval between the notes is thirds, fifths, or sixths. The interval distribution of the fiddle corpus (see Figure 14) is comparable with the distribution in an improvisation created by our algorithm of similar length (see Figure 15). Note that the fiddle corpus used in this analysis was modified to only include the highest notes of all double stops. The interval distributions are highly correlated (r = .894) though slightly less so than the interval distributions for the Parker corpus. This may be due to the double stops in the original fiddle corpus or the fact that the

Figure 12. Example of a complete improvisation created by the most current implementation of our algorithm in which pitch and rhythm patterns only coincide if they also coincide somewhere in the corpus used as input. The three brackets denote examples of "quintessential" Parker figures.

Figure 13. Example of an improvisation created by our improvisation algorithm using as input a corpus of fiddle improvisations by Aubrey Hanie.

fiddle corpus was smaller (5,887 notes) than the Parker corpus (14,470 notes).

Finally, we investigated whether our algorithm was capable of incorporating embedded rules from a given corpus in the improvisations. For this purpose, we used a tonal corpus consisting of J.S. Bach's Partitas and Sonatas for solo violin, BWV 1001–1006. These pieces are not improvised; they are based on rules of traditional classical harmony. Our algorithm created improvisations in which selected parts appear to be based on tonal rules in which the line implies a cadential progression (see mm. 8–9 in Figure 16). This is only to illustrate that the algorithm by using a purely probabilistic process creates material that retains some of the rules embedded in the input.

Discussion

Here we outlined a software model that analyzes embedded probabilities of melodic and rhythmic patterns in an existing corpus of improvised solos and then produces a novel output that retains these probabilities. As mentioned in the beginning of this article, this is a work in progress, and future development will incorporate the vertical aspect, so that there is an interaction with a given chordal structure. Previous software that creates improvisations based on chord progressions may overemphasize the vertical element so that all notes strictly follow the chords (Band-in-a-Box, 2013; Gillick et al., 2010; Johnson-Laird, 2002; Pachet, 2012; Ramalho et al., 1999). Human improvisers at times follow the logic of the melodic line to create material that does not follow the underlying chords. In the future, we hope to create an improvisation algorithm that realistically balances the melodic and vertical elements similar to that of human improvisers.

One of the strengths of the current model is the parsimonious design. By simply relying on embedded probabilities, no style-specific rules were programmed into the algorithm. Therefore, the model was able to create novel output in the style of bebop jazz or folk fiddling by simply using transcriptions of improvisations in either style as the input corpus. Furthermore, the algorithm was able to create improvisations in the style of Bach by using his compositions as input. Importantly, these improvisations in various styles were created without changing the algorithm. This was made possible by the Markovian design used in the current model where the previous 4-interval and rhythm structures were used to predict a solution to the next pattern. Importantly, this pattern overlapped with the previous pattern so only one note was added in each iteration of the process. Previous designers of computer improvisation algorithms using Markov chains found it necessary to also encode stylistic dependent rules into the algorithm (Pachet, 2012). It is possible that these rules were necessary for the algorithm to work on given chord changes. In future work, we plan to augment our algorithm so it can create improvisations over a given chord progression while still programming no or few style-specific rules.

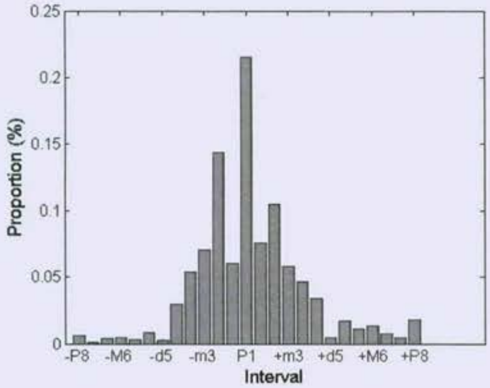

Figure 14. Interval distribution of the fiddle corpus (only highest notes of double stops considered).

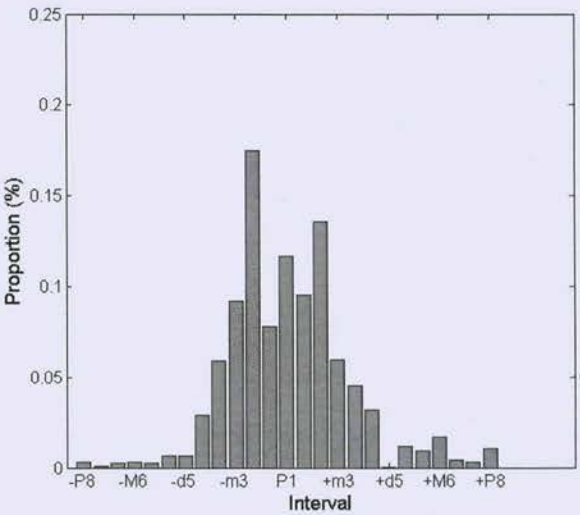

Figure 15. Interval distribution of improvisation by our final algorithm using the fiddle corpus as input (only highest notes of double stops considered). The improvisation was the same length as the fiddle corpus.

Figure 16. Improvisation created by our algorithm based on a corpus of Bach's Sonatas and Partitas for solo violin. The analysis shows that some tonal rules from the original corpus appear to be mirrored in the improvisation even though our algorithm is not based on rules.

The current work may serve as a possible model of the cognitive processes underlying human improvisation in which the use of patterns are central to the process. This would be compatible with Pressing's (1988) suggestion that note groupings based on stored mental schemas are concatenated during improvisation. Importantly, this model is not style specific, yet according to Pressing "specific enough to allow its use as a basis for the design of "improvising" computer programs" (p. 168). Pressing explains as follows:

> The fundamental nature of the improvisation process is considered to be the stringing together of a series of "event clusters" during each of which a continuation is chosen, based upon either the continuing of some existing stream of musical development (called here an event cluster class) by association of array entries, or the interruption of that stream by the choosing of a new set of array entries that act as constraints in the generation of a new stream (new event cluster class) (p. 168).

The current algorithm only models the continuation of ideas chosen based on the immediately preceding material. The interruption of the stream could happen owing to the underlying chords or other structural boundaries. Interruptions could also be due to external factors such as audience response or interaction with other musicians. Such factors may require the improviser to engage controlled processes in which conscious engagement is involved (Norgaard, 2011). These factors are not incorporated in the current model, which only attempts to model automatic implicit note generation, which may occur below consciousness (Johnson-Laird, 2002; Limb & Braun, 2008; Pressing, 1988).

We evaluated the current model by analyzing the structure of embedded patterns as compared with the original corpus, by comparing interval distributions, and by assessing whether the algorithm was capable of creating output in different styles. First, using a corpus of improvised jazz solos, we compared the output from our algorithm with an improvisation created by an algorithm based on grammar and contour (Gillick et al., 2010; Keller, 2012). We found that our software creates improvisations whose embedded structure of patterns resembles that of human improvisers to a larger extent than the competing software. It could be argued that if rule-based models were given a more elaborate set of rules, they might achieve better results. It is also possible that this type of evaluation unfairly favors our approach, as we are evaluating the models using our own model's main guiding principle, the use of patterns, as the dependent measure. Therefore, we also analyzed the interval distributions of the improvisations as compared with the original corpus. Again we found that our algorithm created improvisations that resembled the original human improvisations to a larger extent. Finally, we tested whether our algorithm was capable of creating improvisations in various styles using corpora of those styles as input. Although our initial results appear positive, it is important to note that this test did not evaluate whether the algorithm is capable of creating stylistically appropriate improvisations to a given chord progression, as this feature is not yet implemented. Future research could also evaluate the output of competing algorithms based on tonal structure, entropy, or other theoretical constructs[1] (Temperley, 2007). Furthermore, the output of artificially generated improvisations could be evaluated in experimental paradigms in which human experts in blind review rate output created by humans and software algorithms. Finally, expert players could evaluate the output from a motor perspective by testing whether the software produces performable sequences.

In summary, the described algorithm creates novel output using a parsimonious mathematical process in which patterns embedded in a given corpus are reused. This computer model is in line with the theoretical framework suggested by Pressing (1988) in which concatenated patterns are central to the process of improvisation independent of style. We believe our model mirrors the implicit process of note generation used by human improvisers and that the design could be augmented to incorporate constraints related to a given chord progression, larger architectural structures, and interaction with external factors.

[1] Here we emphasize the cognitive and mathematical perspective, yet our approach could benefit from some of the parallel developments in the music theoretic literature (e.g., Gjerdingen, 1989; Temperley, 2001). We hope this article may spark continued dialogue with music theorists and would welcome a full evaluation of our approach from that angle. As one of the anonymous reviewers pointed out, "while this paper could stand on its own as it is, the readers of Psychomusicology: Music, Mind & Brain have a strong interest in the human side, as opposed to the algorithmic, and understanding how an algorithm may come up short can be quite enlightening."

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Dialogue As a Way of Knowing: Understanding Solo Improvisation and Its Implications for an Education for Freedom

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Much has been written about the dialogical nature of group improvisation (Bailey, 1992; Berliner, 1994; Borgo, 2004; Fischlin & Heble, 2004). Dialogue sits nicely in a situation where many people are 'speaking' musically to each other around a common 'topic' or referent. But what about improvisation when it occurs outside the social setting of group playing? Is the act of solo improvisation a monologue given the absence of fellow 'speakers'? Building on research in cognitive studies (Sarath, 1996; Pressing, 1987; Gustavsen, 1999) as well as empirical research in the field of pedagogy of improvisation, this paper argues that the act of solo improvisation is inherently dialogical – a dialogue between musician and musical entity as 'Other' – and proposes that the existence of that dialogue is predicated on the art of listening. This art of listening will be discussed in light of two opposing directionalities or *listenings*: (1) *inner directionality* is expressed in the musician's audiating of her inner musical imaginings and translation of those imaginings into what the fingers play and (2) *outer directionality*: perception of and response to the emergent qualities of the musical idea (Gustavsen, 1999) as it manifests itself in the "sacred space" of play (Huizinga, 1949) between the musician and the improvisational continuum which constitutes the musical entity. Field research will be discussed which suggests that successful mastery of these two types of *listenings* in tandem is what allows the improviser to engage in dialogue with the musical entity, and affords the improviser a new 'way of knowing' the musical entity. The same research suggests that in the course of mastering these *listenings*, the improviser calls into play a number of socio-cognitive functions which, in turn, reflect multiple social positionings. These include: decision-making (authorship), divergent thinking and willingness to embrace the unknown (diversity and inclusion), risk-taking and problem-seeking (unsettling certainty), accountability and self-assessment (responsibility, integrity, and challenging assumptions). Herein, the dialogue of improvisation affords the improviser an 'epistemology of self'. Acknowledging solo improvisation as a way of knowing through dialogue may allow educators to construct models of engagement which can lead students toward personally meaningful dialogue between self and art. Additionally, an understanding of the socio-cognitive functions and social positioning traits inherent in acts of solo improvisation suggests that it could play an important role in education for freedom as envisioned by such thinkers as Maxine Greene and Paulo Freire, a freedom exemplified by conscious imagining of possibilities, creating and sharing meanings, and dialogue between self and other.

Keywords: solo improvisation, dialogue, music education

Deleuze (2006) wrote, "The phrase, *let's discuss it*, is an act of terror" (p. 313). The sentiment behind this statement is that discussion invites theorizing, talking about, and attempted conclusions of universalities. And because "improvisers, like it or not, leave their cherished realm of practice and become theorists the moment they open their mouths to speak" (Peters, 2009, p. 147), I will attempt to be diligent in this regard. I am an improviser and I am about to "open my mouth to speak" about solo improvisation. However, what I wish is to suggest not a "theory of" but rather a "philosophy of" solo improvisation that is grounded in the concrete, the observed, and offers a "method of progressing" (p. 150); a philosophy that begins by offering an understanding of the cognitive processes inherent in the act of solo improvisation and then, in light of that understanding, offers a possible conceptualization of solo improvisation's implications for an education for freedom as proposed by such thinkers as Paulo Freire and Maxine Greene. Given that I am an improvising musician and an educator, my end objective will be to spark creative dialogue in the field of improvisation pedagogy.

Much attention has been paid to the dialogical nature of group improvisation and the ways in which group improvisation fosters ways of being in the world outside of music-making (Bailey, 1992; Berliner, 1994; Borgo, 2004; Fischlin & Heble, 2004). Creative decision-making, risk-taking, and collaborative problem-solving, all inherent in group improvisation, have led educators and scholars to propose improvisation as a model for attaining ideals of critical pedagogy (Hickey, 2009, Hickey & Webster, 2001; Norgaard, 2011; Ross, 2011; Willox, Heble, Jackson, Walker, & Waterman, 2011). It has been suggested that the interaction be-

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tween individuals in group improvisation "erases a hierarchy of privileged points of view" and "definitiveness of meaning" (Kanellopolous, 2011, p. 124), opening pathways to appreciation of "other," and acceptance of personal responsibility in the collective task of meaning-making (Kanellopolous, 2011; Wright & Kanellopolous, 2010). However, I would suggest that the fact that group improvisation can be understood as dialogical and can foster deeply positive and humanistic group dynamics is, in a way, obvious and may relate more (although not exclusively) to the qualities of democratic group communication than to the essence of the improvisational act. To understand the dialogical (and hence, educational) possibilities of improvisation, we might do well to ask "Is the act of solo improvisation dialogical despite the absence of fellow 'speakers'?" Here, in solo improvisation, the inherent qualities and purest possibilities of improvisation, the authentically unique power of the improvisational act to develop habits of aesthetic consciousness, freedom, and responsibility, may become apparent to an extent, which might even influence the way in which we look at possibilities in collaborative improvisation.

Theories of Improvisation and Cognition

The question, "What do we do when we improvise?" has occupied (and continues to occupy) researchers in a wide variety of academic fields within and outside of the discipline of music. Whereas improvisation has played a perennial role in musical performance in world cultures, a renewed academic interest in theories of improvisation has been witnessed since Jazz entered the academy in the middle of the previous century. Since then, the field of ethnomusicology has produced entire volumes devoted to the exploration and explication of jazz musicians' self-reported experiences (Bailey, 1980; Berliner, 1994), understanding improvisation as social practice and cross-cultural dialogue (Fischlin & Heble, 2004), and investigating the various approaches and diverse sources available for the study of improvisation (Nettl & Russell, 1998). Music scholars have also turned to philosophy studies to deepen our understanding of the improvisational act (Kanellopolous, 2011; Peters, 2009).

For the purposes of this paper, I wish to preface my own discussion with a brief overview of several significant contemporary scholars who have presented theories of improvisation as it relates to mind and brain. Given that an overview of this sort cannot (and does not) claim to provide a definitive explication of the complexities and intricacies of these theorists' works, my purpose here is merely to attempt to situate my own research against the backdrop of these scholars and within the conversation that is already taking place in academic circles.

In the field of cognitive science, Pressing (1987) proposed a model in which improvisation is seen as a series of "events"—groupings of note clusters or phrases. Each event is triggered by an internal impulse, an envisioned schema, which is then executed through motor skills. New events are generated based on (a) previous events, (b) changes in the musical referent, (c) the musician's current musical goals, or (d) long-term memory. Pressing (1987) viewed the fundamental nature of improvising as decision-making and proposed that the improviser uses one of two methods of continuation in moving from event to event: association or interruption in relation to the immediately preceding event. Hence, Pressing viewed improvisation as a linear, sequential act, where E = event, E1 proceeding to E2 and so on, with variations instigated by the four considerations mentioned previously.

In the related field of consciousness studies, Sarath (1996) also appropriated the term "event." However, distinct from Pressing, Sarath defined event as a "perception of a musical object [external] and the resultant inference of implication from that object-perception" (p. 4) that is, inferring a dual-mode process. A central element of Sarath's model is the concept of "perception", or the improviser's relationship to, or perception of, the present moment. He notes the distinction between "inner directed temporality" (common in improvisation) and "expansive temporality" (common in composition) and, given this distinction, describes the creative process of the improviser as "moment to moment . . . generating an implication field at each time point, not based in an aggregate conception, but one in which each moment is perceived as self-contained and autonomous" (p. 4). Sarath proposed that "the inner-directedness of temporal conception may be significant as a possible mechanism for invoking higher or transcendent states of consciousness" (p. 12) in which the "personal self is subsumed within the unbounded self" (p. 14). Such a transcendent state, induced by virtue of "the folding of awareness back toward itself" (p. 12), is, according to Sarath, key to the spontaneous creativity afforded by improvisation.

Gustavsen (1999), in the field of psychology of improvisation, proposed a model that is based on the "art of listening" and reflecting upon dialectical attributes inherent in the improvisational continuum: moment/duration, difference/sameness, gratification/frustration, stimulation/stabilization, and closeness/distance. According to Gustavsen, an improviser must develop an ability to listen for the "emergent qualities" in phrases or musical events while at the same time grasping any musical situation in terms of its harmonic, melodic, textural, rhythmic, and periodic implications and be able to process this information in a flow that allows for flexibility and synthesis.

The above-mentioned art of listening, according to Gustavsen, is based on a highly developed aural sense, focus, and the ability to be continually self-reflective. According to Gustavsen, focus on the listening experience "emphasizes a radical acousmatic approach" in which isolated musical parameters are subordinate to the notion of emergent qualities (p. 3). He further suggested that the musician's interaction with the musical environment that he/she is "forming and being formed by" (p. 4) may be analogous to the individual interacting in social and physical environments and in complex and multidirected human relationships.

Although the models of Pressing and Sarath are insightful and make significant contributions to our understanding of the improvisational act, I believe there are additional aspects yet to be investigated. By connecting improvisation to human dialectics and placing focus ultimately on the quality of listening, Gustavsen, I would propose, has opened up the possibility to explore improvisation as an act uniquely grounded "in the world." He has conceived a holistic model of improvisation that addresses not only the cognitive aspects but (also) the dialectical aspects of the improvisational act, a model which, I believe, provides an entrance point into the results (and derivative philosophy) of my own study, which I hope will add to the rich conversation taking place in the academic literature.

A Case Study in Solo Improvisation

In 2009, I began an 18-month study to investigate a possible model for teaching jazz improvisation that would encourage the development of "personal voice." The study involved three participants, all of who were highly accomplished classical pianists pursuing studies in a music academy. As a self-prescribed pedagogical stance, I decided that no established jazz methodology would be used and no historical systems referred to until well into the process. I met with each student on a weekly or biweekly basis for from 1 to 3 h over the course of two to three semesters. All of the lessons were recorded and subsequently reviewed. Approximately half of each student's in-lesson improvisations were transcribed, played, and analyzed musically and in the pedagogical context of the lesson to reveal themes common to all participants. I also asked each participant to keep a journal and conducted exit interviews. All names used in this paper are pseudonyms.

Given this removal of predetermined methodologies, it became clear to me that my central role would be to listen and reflectively respond; in other words, I would position myself not as a teacher, but as an improviser. The participants were completely new to improvisation. I hoped that their responses would be pure in that they would be drawing on a deeply personal, idiosyncratic, and organic conception of music and musical expression. Therefore, I searched for generative themes[1] that were apparent with all participants, and in addition to documenting the process, I investigated these themes as clues to the following questions: What do we do when we improvise and how might improvisation be taught to facilitate the development of a personal voice?

Witnessing these students engaging in this new activity of improvising—listening to their playing and speaking with them—I was struck by how their engagement with the music appeared to reflect a dialogical relationship between improviser and musical entity. George, one of the participants, described it as, "It's like, ok . . .'he' speaks to me and then I answer him" (George, personal communication, June 12, 2010). The students' inner musical imaginings, as they became manifest in the improvisational space, were recognized as "other," blurring the boundaries of listener-performer, creating an "embodied dialogism" (Bogdan, 2001, p. 11). Through this dialogical relationship, the improviser was afforded the possibility of being surprised by something she heard and was encouraged to "pick up on" a musical idea just sounded and choose to let it lead her, and the improvisation, in a new direction. It was this dialogical reality that made the improvisation more than a private, self-referential language and that allowed me, as the facilitator, to enter the sacred space of play with my student (Huizinga, 1949). By virtue of my own dialogical (improvisatory) stance vis-à-vis the student, I was invited to become a member of this dialogue as a side participant, becoming aware of what the student was hearing in her head as it was played, and of how she was hearing the music's emergent qualities by how she responded to them. One might say that a puzzle was revealing itself with pieces that we both were hearing for the first time, the whole of which neither of us knew.

The notion of dialogue with the "Other," which these students experienced, has been discussed in the literature. Bogdan (2001) referred to the act of solo musical performance as an "intrapsychic confrontation of the other within the self," a confrontation that creates a situation of "embodied listening as embodied dialogism" (p. 16). Quoting from Mikhail Bakhtin's, *A Theory of Dialogue*, Kanellopolous (2011) wrote, "The process of improvisation can be seen as the musical analogue of the unfinalizability of selfhood, that is, of otherness within a person, [of] her ability to be always another, unpredictable and free, to act and to remain the other and another to all others and even to herself" (p. 129). George described this as, "feeling like there's an added dimension of 'time,' somewhere that I can be in while I'm also in the dimension of playing-in-time. I can be the player and the observer at the same time—I don't know how! I can at once play and at the same listen to what I'm playing. It's like being in a whole different dimension" (George, personal communication, October 4, 2010).

Acknowledging the reality of "Other" at work in the solo improvisations of my students, it became apparent to me that listening was not only my primary tool but (also) the primary tool to be acquired by the student. Through my own dialogical approach, I attempted to aid the student in developing the ability to, at once, listen to her inner musical imaginings *(inner directionality)*, and, at the same time, be attentive to (to borrow from Gustavsen) the musical entity's emergent qualities (outer directionality); in other words, to engage in dialogue through listening and responding.

One may ask if, by virtue of the fact that the "listener" in each of these directionalities is the same person, I have not proposed an unnecessary dichotomy. I believe the key is in the fact that the student herself perceives the improvisational entity as "Other," opening the possibility (and necessity) to develop a dual listening perspective (i.e., dialogue). I might illustrate this with the following vignette, and George, the participant quoted above. George is having a conversation with his friend. A thought pops into George's mind that he wishes to share—for example, "I'm considering vacationing in Italy." He speaks this thought out loud to his friend. His friend responds by repeating the original thought, perhaps as a question—"You're considering vacationing in Italy?" Upon hearing his own thought externally embodied by his friend, George is now afforded (even encouraged) to thoughtfully consider new aspects of a thought that originated within himself. Perhaps he will choose to expand on the idea (he has more to say on the matter). Perhaps hearing the idea reflected back to him by his friend will cause George to change the subject or to question his own original intentions. And here is the key: Once externally embodied, George's thought is related to (by George) differently than when it was merely floating around in his head—it has become the material of dialogue.

Having identified this element of dialogue and its demands for a dual directionality of listening, I was then left with the following question: What tools does the student use (and might I help to develop) in mastering this quality of listening? I refer to the tools that I observed, integral to these students' processes, as "sociocognitive" tools. By using the term "sociocognitive," I wish to emphasize the "grounded" conception of improvisation that grows out of this study. And although it is possible that the type of

[1] I borrow this term from Freire (1970a), although, when viewed as strictly pedagogical, the themes presented here would more succinctly be labeled "emergent". However, given that my goal is to offer an explanation of solo improvisation in terms of dialogue and freedom, these same themes, from the start, are seen as generative—"contain the possibility of unfolding" (Freire, 1970a, p. 83).

"confrontation with the Other" (Bogdan, 2001, p. 3) that I witnessed contains elements of a transcendent state of consciousness, such as that proposed by Sarath, which aids in perceiving that which originates with oneself as "Other" (George himself has referred to this as "a whole different dimension"), what I wish to explore here is the reality of the student engaged in focused attentiveness to the "in-the-world" manifestation of voice, a voice that calls upon her to engage in dialogue. This focus will prove crucial to an understanding of the possibilities for critical pedagogy discussed in the second half of this paper.

Generative Themes

The sociocognitive tools that I observed as generative themes common to all participants included decision-making, divergent thinking and a willingness to embrace ambiguity, risk-taking and problem-seeking, and accountability and self-assessment.

Decision-Making

"That's what I'm hearing in my head."
(Rina, personal communication, March 15, 2011)

"I heard it arriving. I felt that it needed to happen right then."
(George, personal communication, August 10, 2010)

Whereas with most "tools" examined here I was able to draw conclusions on the basis of listening to and analyzing the improvisations produced (as well as through conversations with the participants), my interpretations regarding their decision-making processes needed to rely on my own observations, in real time, and the students' self-reporting. From those observations and conversations, the quality of decision-making of these students appeared to present itself as a holistic, I might even say existential, immediacy. The students themselves described decisions as being motivated by instantaneous recognition of musical manifestations sounding in the improvisational moment and response to those musical manifestations by means of organic inner reflection. Recalling our metaphor above, it appeared that the puzzle and the pieces were instantaneously revealed in the spontaneous present.

Divergent Thinking and Embracing Ambiguity

"As long as I was calculating in a system it didn't work, so . . . I just listened."
(Sarah, personal communication, October 29, 2010)

The unprescribed empty space in improvisation, always just around the corner, encourages diverse possibilities. Huovinen, Tenkanen, & Kuusinen (2010) concluded that when students and teachers are relieved of the burden to work and evaluate in terms of objective musical "rules", student players and their teacher-examiners recognized noticeable musical development and characterized the learning process as "moving from regularity, uniformity and determinate-ness toward more variable, heterogeneous and unanticipated musical play" (p. 95). I would suggest that the focus on improvisation as dialogue in this study significantly encouraged complex divergent thinking expressed, for example, in self-constructed modes and poly modes, exploitation of asymmetrical phrasing constructs, a dynamic embracing of ambiguity, and a continually expanding self-constructed improvisational "vocabulary."

Risk-Taking and Problem-Seeking

"Are you ever surprised when you improvise?!"
(Sarah, personal communication, September 17, 2010)

For all participants, a problem-seeking approach to the creative process of improvisation was exemplified by an exploratory nature, grappling with self-defined challenges and discovering personally viable solutions to those challenges. The willingness to embrace such an approach rested in the students' willingness to take risks. I would suggest, again, that the focus on dialogue, as opposed to assimilation of acceptable theoretical systems of improvisation, greatly enhanced the participants' openness to this way of approaching the task. Success in one self-chosen challenge was immediately apparent as a catalyst for continued self-challenging, often obviously pushing the student to the limits of her own abilities.

Risk-taking was also reflected in the students' responses to unexpected events such as unintended notes. The students' consistent willingness (and ability) to discover ways in which to use these unintended moments as integral and organic elements of their improvisations, allowing them to become guiding forces in discovery of new creative possibilities, proved to be a demonstration of the quality of their listening skills. It may also have demonstrated a devotion to dialogical positioning and recognition of their own "confrontation of the Other within the self" (Bogdan, 2001, p. 4).

Accountability and Self-Assessment

"Sometimes it's comfortable to have someone else there to tell you how you did! But ultimately, only you know what went through your head, how you responded to things, how much you were listening and how much you were thinking and how well you balanced the two."
(Sarah, personal communication, February 12, 2010)

"Sometimes I'm not happy with the results and I can't go back and change it. But when there's relaxation—deep listening and peacefulness—it's intoxicating."
(George, personal communication, April 22, 2011)

The "inherent and comprehensive indeterminacy" of improvisation as dialogue calls upon the improviser to take ultimate responsibility for the outcome (Kanellopolous, 2011, p. 119). There are no "roadmaps" for navigating musical choices. The rightness or wrongness of a choice lies in the perception of the improviser. Its belonging, its making sense, is a direct result of the measure of acceptance the improviser affords it, and the students of this study were encouraged to investigate their own personal definitions of right and wrong in their playing. There were no theoretical systems presented with ready-made answers to musical challenges. As in any dialogue, "speaking without a script" (Wright & Kanellopolous, 2010, p. 77) encouraged each student to assume personal responsibility and to engage in his or her own meaning-making and negotiation of differences in personally meaningful ways (Ross, 2011; Willox et al., 2011). In turn, this also had a profound effect on my own positioning. Judging the student's musical choices according to objective musical theories—or my own personal preferences—was not an option. Rather, I was challenged to listen intensely to the dialogue taking place and to attempt to hear each student's voice emerging through his or her choices. Recognizing the emergent qualities of that voice informed my own responses.

Recognition of accountability invites self-assessment (reflection). The participants were continually called upon to self-reflect on their performance. In turn, this forced them to confront deeply engrained musical assumptions and biases as well as self-perception stereotypes. In fact, as the students underwent a transformative experience, their own accountability and self-assessment often forced my own perspective and responses to change.

Solo improvisation, as highlighted above, does not rely on any inherent dialogical elements such as those found in group improvisation. Kanellopolous (2011) wrote, "Dialogue is understood as that quality of interaction (between people, texts, sentences, musical gestures, or principles of subjectivity itself) that is rooted in open-ended-ness, that does not wish to assume a privileged point of view, or a definitiveness of meaning and close-ness of sense" (p. 124). Although Kanellopolous was writing about group improvisation, I, for one, cannot witness a performance such as Keith Jarrett's "Solo Tribute" concert[2] and not recognize a truly astounding dialogical relationship revealed between artist and emergent music, a creating of meaning in a situation of indeterminacy and open-ended-ness. That being the case, what the preceding discussion has attempted to do is to reveal these same dialogical forces at play in the solo improvisations of these amateur improvisers—to situate that dialogical element at the heart of the improvisational act. This will prove central to an understanding of how solo improvisation might play a role in education for freedom and how educators might construct models of engagement that may lead students toward personally meaningful dialogue with self and other.

Implications for Education

I have explored two central concepts at work in solo improvisation: dialogue and listening. I have proposed several sociocognitive tools revealed as generative themes by these improvisers as they engaged with these concepts: decision-making, divergent thinking, risk-taking, problem-seeking, accountability, and self-assessment. Our question then is how is this dynamic reflective of the concept of freedom as envisioned by thinkers such as Paulo Freire and Maxine Greene.

Greene (1988) has described freedom as "the capacity to surpass the given and look at things as if they could be otherwise" (p. 3). A key element of this imagining is cultivating an awareness of what Greene calls "authorship" (p. 22), each individual's "writing of" the world and her place in that world, a world that Greene described as a "perpetual emergent" (p. 23). (The striking parallel use of language—Green's "perpetual emergent" and the improviser's work of engaging with the "emergent qualities" of the music—begs noting.) Therefore, education for freedom begins with the individual becoming empowered by recognition of authorship. As Greene wrote, acts of freedom "empower us to choose ourselves, to create our identities" (p. 51). By engaging in a continual reinterpreting of situations, one comes to "see oneself as a person in a new perspective" (p. 90). In other words, active and reflective dialogue with our world is seen as a "way of knowing" self and world (as "Other").

Freire (1970a) viewed this dialogue as a process of continually "recreating knowledge" (p. 51). As I engage in dialogue with the world—"name" and "rename" that world —I come to "know" myself and the world through "invention and reinvention" (p. 53). I come to view the world "not as a static reality, but as a reality in process, in transformation" (p. 64), and by doing so I recognize myself as a being "in the process of becoming"—as an "unfinished, uncompleted being in and with a likewise unfinished reality" (p. 65). For Freire, this dialogical character embodies a "practice of freedom" (p. 74).

There are two remarkable themes in Frere's notion of "dialogue as a practice of freedom" that I believe connect profoundly to our subject of solo improvisation as dialogue. The first is found in his continual use of the prefix "re": reinvent, re-create, rename. The image of perpetual transformation and discovery, an embracing of the "open-endedness" of reality, of myself, and of the dance that we engage in together, reflects deeply the ontological nature of solo improvisation as discussed previously. The second theme is the notion of contingency. In Frere's view of dialogue as a practice of freedom, the world and I are contingent on one and other—we continually transform and are transformed by each other, through praxis and through "action and reflection" (p. 47). This theme is at the heart of the conceptual understanding of solo improvisation that I have attempted to present.

The solo improviser, as we have envisioned her, is continually engaged in qualities that enable and encourage acts of freedom through her dialogue with the perpetually emerging musical entity. Through decision-making, our solo improviser embraces her role as "author" of an "emergent" world, an act that calls upon her to respond to situations with organic responses rather than preconceived assumptions or stereotypical clichés. Called upon to use extreme divergent thinking, our improviser engages in a unique relationship with the notions of diversity, inclusion, and negotiation of differences. By adopting a problem-seeking stance, she embraces the "open-ended-ness" of the dialogical relationship and an understanding that "knowledge emerges only through invention and reinvention" (Freire, 1970a, p. 53). Such a problem-seeking approach "unsettles certainties" and is "marked by the absence of fear" (Kanellopolous, 2011, p. 127), which is reflected in her willingness to take risks, knowing that the improvisational outcome is an unknown, an often surprising unveiling of self and "Other." Finally, our solo improviser recognizes the irreversibility of the improvisational moment and her own responsibility in creating and defining that moment. The resultant self-assessment and reflection speak to the integrity with which our solo improviser approaches the task of dialogue and the process of self-transformation, challenging engrained beliefs and stereotypes. Taken as a whole, our solo improviser's sociocognitive tools are revealed to contain sociocritical qualities by which she might become an individual capable of "creating that public space be-

[2] "Solo Tribute", a solo piano concert celebrating Keith Jarrett's 100th performance in Japan was videotaped live at Suntory Hall, Tokyo, on April 14, 1987 and released by RCA.

tween people where freedom might appear" (Greene, 1988, p. 15) even beyond musical engagements.

To return to the topic of listening discussed at the outset of this paper, and to understand its centrality in an education for freedom, I turn to Garrison's (1996) article, "A Deweyan Theory of Democratic Listening." Here, Garrison explains the relationship between listening and democratic education, which is intricately connected to education for freedom. His description of listening is highly reminiscent of our own descriptions of solo improvisation. For Garrison, to truly listen means to embrace a stance of "remaining open" and, as he noted, this "openness involves risk and vulnerability" (p. 433)—"listening is dangerous" (p. 450). To listen, we "must be willing to live with confusion and uncertainty about ourselves and the other person we are attempting to understand" (p. 433). Garrison proposed that true democratic listening needs to be accorded a central place within democratic education if that education is to be successful. I believe that the dual directionality of the listening act discussed previously, together with the sociocognitive tools inherent in solo improvisation, deeply reflect the qualities of listening discussed by Garrison in regard to democratic education.

Conclusions

At the outset, I wrote that, as an educator, my end objective would be to spark creative dialogue regarding improvisation pedagogy. Several questions grow out of this paper. Is there a transfer value from the solo improvisation concept discussed here to music education practices? Does the manner in which we presently engage in improvisation in our studios and rehearsal halls reflect the deeply humanistic and freedom-encouraging qualities afforded by the act as explored in this paper? How might a deeper understanding of solo improvisation aid us as educators to construct models for engagement, which may afford our students personally meaningful encounters with self and other? How might a deeper understanding of solo improvisation and its ability to develop qualities of freedom enable us to position it as a central value in critical pedagogy? I believe that all of these questions deserve further investigation.

This paper also raises larger questions as to the purposes of music education and the role of the teacher in possible new paradigms of the student-teacher relationship. The generative themes revealed in this study suggest that through a dialogical pedagogy of improvisation, the "music lesson" can play a significant role in students' development of qualities such as self-awareness, identity, and dialogical engagement with the world around us. Beyond the goals of comprehensive musicianship and technical proficiency, music educators can and should explore ways in which their own students' engagements with music encourage these deeply humanistic and democratic qualities.

The search for a way in which I might facilitate development of "personal voice" by these students of improvisation was predicated on the belief that (a) every student possesses such a voice, and (b) the end goal of education is not "learning and teaching" but "becoming" (Lave, 1996). In addition, as Freire has suggested, "becoming" does not happen in isolation but rather in relationship to the world. To be in the process of becoming means to be "in dialogue." For the student of improvisation, what it means to "be in dialogue" has been documented in the discussion of this study. For teachers such as myself, a significantly greater effort may be demanded, what Luke (1998) has called "getting over method" (p. 305). Freire (1970b) has called it being "converted to dialogue" (p. 406) and, as always, his choice of words begs interpretation. The term "conversion" naturally brings references to religion, religion being an all-pervasive outlook on the world and one's place in it. I would suggest that Freire, with this powerful choice of word, eluded to a transformation no less total; one that calls on us to step out of our world view of "expertise" and "method" into a realm of "becoming" and "unveiling," together with our students. In fact, to become such a dialogical teacher demands the same "tools" that our solo improviser used: organic and integrity-based decision-making, divergent thinking and a willingness to embrace ambiguity, risk-taking and problem-seeking, and accountability and self-assessment. However, most of all, it demands developing the "art of listening," and although we are all professionals in an aural discipline, perhaps it is time to admit that we may also need training in the art of listening.

In keeping with my original intentions of presenting a conceptual philosophy of solo improvisation grounded in the concrete and the observed, I would like to close with a quote from one of my research participants, from a letter that he wrote to me at the end of our work together. As a conclusion to the preceding discussion, I believe this quote reflects the deep connection between solo improvisation as dialogue and education for freedom. . . .

"You have taught me to listen . . . to act . . . to give."
(George, written correspondence, August 10th, 2011)

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A First Look at the Role of Domain-General Cognitive and Creative Abilities in Jazz Improvisation

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The present study explored the associations among several cognitive and creative abilities and expert ratings of jazz improvisational quality. Ten male undergraduate jazz students (8 performance majors, 2 education majors; 5 winds, 3 strings, 1 piano, and 1 drum) performed a video-recorded improvisation with a trio and completed measures of divergent thinking, working memory, and fluid intelligence. Performances were rated for creative quality by 3 expert raters. Students also answered questions regarding their musical background and subjective experience of improvisation. As expected, cumulative practice hours substantially predicted improvisational creativity. Results for the cognitive variables showed mostly negative correlations with improvisation; however, divergent thinking strongly predicted performance quality. We consider these results in the context of the literature on expertise and creativity.

Keywords: improvisation, intelligence, divergent thinking, expertise, working memory capacity

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Conventional wisdom holds that "practice makes perfect," a notion supported by decades of empirical research with eminent musicians (Ericsson, Krampe, & Tesch-Römer, 1993; Howe, Davidson, & Sloboda, 1998). *Deliberate* practice, "a very specific activity designed for an individual by a skilled teacher explicitly to improve performance" (Krampe & Ericsson, 1996, p. 333), is widely accepted as necessary to achieve mastery in a domain. But some researchers are beginning to question whether practice alone is sufficient (Hambrick et al., in press; Meinz & Hambrick, 2010). An emerging literature suggests that domain-general abilities, such as fluid reasoning and working memory capacity (WMC), supplement domain-specific abilities to enhance musical performance quality.

Meinz and Hambrick (2010), for example, explored the contribution of WMC to sight-reading performance in a sample of classically trained pianists. Participants sight-read six unfamiliar songs—later judged by two expert raters—and completed measures of WMC and a questionnaire regarding their musical background. Cumulative lifetime practice hours explained half of the sight-reading variance. WMC accounted for an additional 8% of variance beyond practice, however, suggesting that practice is necessary but not sufficient to achieve musical expertise.

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Regarding the creative quality of instrumental improvisation, De Dreu, Nijstad, Baas, Wolsink, and Roskes (2012) recorded three improvisations and assessed subjects' WMC. Two professional cellists rated the performances for overall creativity. The researchers expected the creative quality of high WMC participants to be sustained or increased across trials, presuming that these individuals could maintain focused attention and inhibit the proactive interference from earlier improvisations. As expected, WMC predicted the creative quality of improvisations across time. Domain-general cognitive abilities thus seem important to both musical improvisation and sight-reading performance.

But why might domain-general cognitive abilities improve improvisation? According to Pressing's (1988) framework—perhaps the most influential model of jazz improvisation—improvisation involves the continuous generation and evaluation of melodic ideas in real time. Such a demanding task should recruit general cognitive resources to manage the many simultaneous processes required. Other models of improvisation have attempted to integrate the apparent interplay between divergent and convergent modes of improvisational thought (Webster, 1990). Although these models imply a role of general abilities in improvisation, few empirical studies have examined the contribution of such abilities in jazz performance. In the present research, we thus explored the associations among jazz improvisation quality, deliberate practice, and general cognitive and creative abilities.

Method

Participants

Ten male jazz students from the University of North Carolina at Greensboro volunteered to participate in the study (eight performance majors, two education majors; saxophone = three, guitar = two, trumpet = one, trombone = one, bass = one, piano = one, drums = one). Students varied in their year of academic progress. A trio of jazz performance majors (piano, bass, and drums) was

Table 1
Correlations and Descriptive Statistics

Variable	*M*	*SD*	Minimum, maximum	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1. Practice (week)	14.20	8.70	5, 30	1																							
2. Improv: Rater 1	4.20	1.81	1, 7	.73	1																						
3. Improv: Rater 2	4.10	1.59	1, 7	.55	.79	1																					
4. Improv: Rater 3	3.40	1.17	2, 6	.63	.79	.86	1																				
5. Improv: Avg.	0.00	.93	−1.63, 1.86	.68	.92	.94	94	1																			
6. DT: Rater 1	2.00	.66	1, 3	.36	.36	.20	.42	.35	1																		
7. DT: Rater 2	1.90	.99	1, 4	.47	.62	.63	.70	.70	.83	1																	
8. DT: Rater 3	1.80	.78	1, 3	.52	.57	.63	.57	.63	.63	.82	1																
9. DT: Avg.	0.00	.91	−1.14, 1.71	.49	.57	.53	.62	.61	.89	.96	.89	1															
10. WMC: SSPAN	34.00	5.97	26, 42	−.15	−.11	−.47	−.52	−.39	.00	−.23	−.40	−.23	1														
11. WMC: OSPAN	67.36	5.52	59, 75	−.14	−.51	−.75	−.70	−.70	.12	−.27	−.06	−.07	.28	1													
12. WMC: Avg.	0.00	.80	−1.43, .73	−.18	−.39	−.77	−.76	−.68	.07	−.31	−.29	−.19	.80	.80	1												
13. Gf: Letters	11.44	1.87	10, 15	−.21	−.36	−.31	−.52	−.42	−.23	−.31	−.32	−.31	.67	.11	.49	1											
14. Gf: Numbers	9.88	2.02	7, 13	.01	.00	−.29	−.07	−.13	.35	.17	.35	.32	.11	.48	.37	−.21	1										
15. Gf: CFIQ	7.66	1.50	6, 10	−.25	−.54	−.83	−.71	−.74	−.07	−.55	−.56	−.43	.68	.67	.84	.41	.23	1									
16. Gf: Avg.	0.00	.65	−.92, .89	−.22	−.43	−.73	−.66	−.66	.02	−.35	−.27	−.21	.75	.64	.87	.61	.51	.83	1								
17. ITQ: Control	5.00	1.05	3, 6	.31	.75	.79	.62	.78	.15	.53	.66	.49	−.22	−.56	−.49	−.21	.15	−.69	−.38	1							
18. ITQ: Conscious	4.20	1.61	2, 6	−.29	−.58	−.56	−.63	−.63	.00	−.40	−.13	−.19	.24	.68	.58	.33	.14	.69	.59	−.45	1						
19. ITQ: Decide	3.10	1.44	1, 6	.21	.00	−.34	−.41	−.27	.00	−.22	−.27	−.18	.78	.35	.71	.71	−.11	.56	.59	−.29	.27	1					
20. ITQ: Plan	3.50	1.71	2, 7	.26	−.07	−.18	−.33	−.15	−.48	−.55	−.24	−.46	.45	.23	.43	.34	.07	.47	.45	.00	.32	.55	1				
21. ITQ: Emotion	5.00	1.49	3, 7	.00	−.08	.04	.00	−.01	.11	.22	.09	.15	−.02	.04	.00	−.23	.00	.03	−.10	−.14	−.04	−.30	−.17	1			
22. ITQ: Previous	3.90	1.44	2, 6	.38	.68	.67	.67	.72	.00	.37	.36	.27	−.58	−.53	−.69	−.63	−.12	−.83	−.80	.58	−.79	−.41	−.24	−.15	1		
23. ITQ: Group	5.20	.78	4, 7	.43	.43	.42	.50	.48	.21	.45	.07	.26	.10	−.51	−.25	−.07	−.20	−.23	−.25	.13	−.64	−.01	−.16	.56	.21	1	
24. ITQ: Rehearse	3.90	1.85	1, 6	.21	.53	.71	.48	.61	−.09	.23	.13	.10	.03	−.77	−.46	.07	−.51	−.38	−.41	.56	.28	−.07	.12	.20	.20	.47	1

Note. $n = 10$. ITQ items are listed in the order they appear in the Appendix. WMC = working memory capacity; SSPAN = symmetry span; OSPAN = operation span; DT = divergent thinking; Gf = fluid intelligence; ITQ = Improvisational Thinking Questionnaire.

paid to assist with the study by serving as a backing band. We provided a catered lunch to compensate students for their participation.

Procedure

The study took place in a large ensemble room in the music department of the University of North Carolina at Greensboro. After performing an improvisation, students were asked to complete several cognitive tasks and a questionnaire. All measures were administered electronically using E-Prime.

Improvisation. Performances were recorded with a digital video camera. Students were presented with the instrumental lead sheet from *I Hear a Rhapsody* by George Fragos, Jack Baker, and Dick Gasparre. All students claimed to have never previously performed this piece. After a practice trial (1 min), they played the melody with the trio once and then improvised over two complete iterations of the song (2 min). Performance videos were later scored using the consensual assessment technique (Amabile, 1982) by three associate professors of jazz studies at separate institutions. Each performance video was scored on a 7-point scale for creativity (i.e., a holistic score of the improvisation quality; Appendix A). Videos were uploaded to a Web site dedicated to the study along with a link to a Qualtrics survey used for scoring.

Divergent thinking task. After the recorded performance, students completed a 3-min divergent thinking task—a classic measure of verbal creativity that predicts real-world creative achievement (Plucker, 1999; Torrance, 1988). The aim of this task is to generate unusual and uncommon uses for an everyday object (i.e., a brick). Students received instructions to "be creative" and "to come up with something clever, humorous, original, compelling, or interesting." Three research assistants, all unaware of the jazz performance and cognitive ability scores of the subjects, scored each response independently on a 1 (*not at all creative*) to 5 (*very creative*) scale, using combined criteria of novelty, remoteness, and cleverness (Silvia et al., 2008).

Cognitive tasks. Students were then given three fluid intelligence (Gf) tests that assessed inductive reasoning: (1) a letter sets task (Ekstrom, French, Harman, & Dermen, 1976), (2) the matrices task from the Cattell Culture Fair Intelligence Test (Cattell & Cattell, 1961/2008), and (3) a number series task (Thurstone, 1938). These tasks appear in our past research on intelligence and creativity (Beaty & Silvia, 2012, 2013; Silvia & Beaty, 2012). Students also completed two WMC measures: operation span (OSPAN; Unsworth, Heitz, Shrock, & Engle, 2005) and symmetry span (SSPAN; Kane et al., 2004). Both tasks measure participants' ability to hold to-be-recalled information in memory (OSPAN: 3–7 letters; SSPAN: 2–5 locations in a matrix) while answering a series of questions (OSPAN: verifying equations; SSPAN: verifying symmetry of patterns).

Questionnaires. We administered two questionnaires to assess musical history and beliefs about improvisation. The musical history questionnaire included items borrowed from Ericsson et al. (1993) to assess deliberate practice and musical background. An Improvisational Thinking Questionnaire was developed by us to

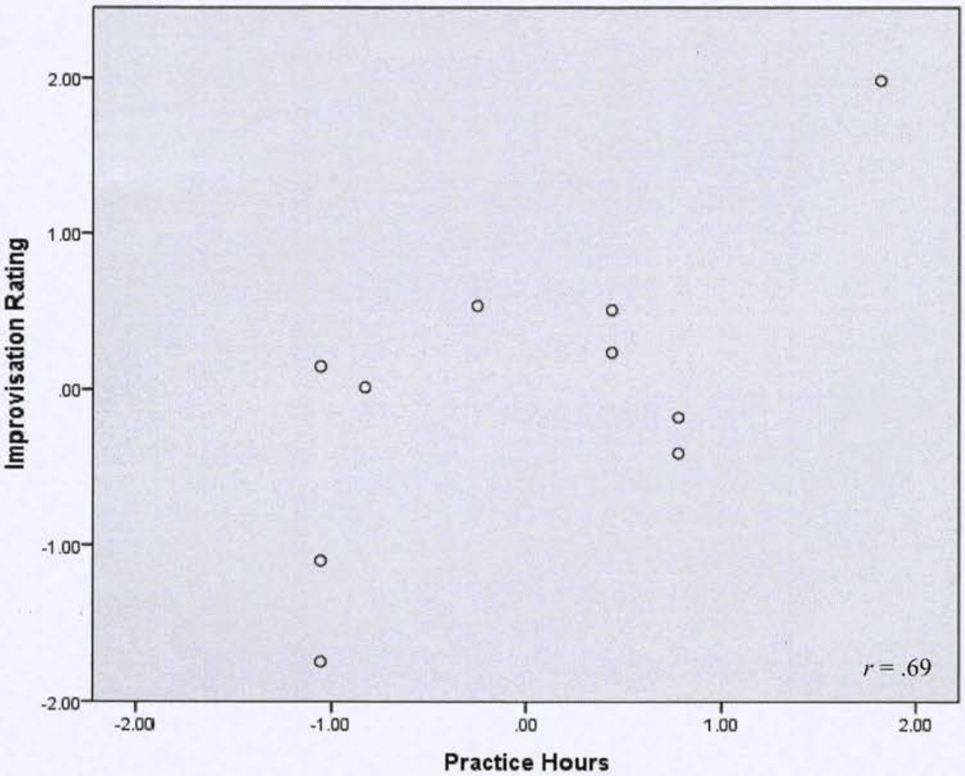

Figure 1. Relationship between the standardized composite improvisation ratings and standardized annual practice hours.

evaluate student beliefs about improvisation (Appendix B; e.g., "To what extent do you feel that you are in control of the direction of your playing?"). Students responded to each item on a 7-point scale (1 = *not at all*, 7 = *very much*).

Results

Table 1 displays correlations and descriptive statistics. Ratings of improvisational quality and divergent thinking were each averaged to form separate composite variables for analysis. Likewise, we averaged the scores among the Gf and WMC tasks. Due to time constraints, one student was unable to complete the WMC tasks, and another student was unable to complete both the WMC and Gf tasks. Interrater reliability was high for both improvisation (α = .91) and divergent thinking (α = .94). Self-reported weekly deliberate-practice hours were multiplied by 52 to estimate a total number of practice hours per year (Meinz & Hambrick, 2010). Because of the small sample size, we report effect sizes rather than p values and inferential tests (Kline, 2004). Using the r metric, effect sizes of .10, .30, and .50 are considered benchmarks for small, medium, and large effects (Cohen, 1988), respectively.

Improvisation and Cognitive Abilities

To what extent were expertise and cognitive abilities associated with improvisation quality? As expected, deliberate practice was strongly correlated with the composite performance scores (r = .69; Figure 1). Correlations of improvisation quality with WMC and Gf, the cognitive measures, were negative. We thus estimated a regression model with practice hours and Gf predicting improvisation quality. This model showed a large main effect of practice (β = .56) and negative effect of Gf (β = −.53, R^2 = .73; Figure 2). A similar model was estimated for practice and WMC: practice's effect was positive (β = .55) and working memory's effect was negative (β = −.59, R^2 = .79; Figure 3). In sum, these analyses suggest a negative relation between general cognitive abilities and improvisation scores.

Improvisation and Divergent Thinking

We then considered the role of general creative abilities in performance quality. The correlation between improvisation and the composite divergent thinking average was large (r = .63; Table 1). We thus estimated a regression model predicting improvisation quality with divergent thinking and practice hours. A moderate positive effect was found for divergent thinking (β = .36), and a large effect was found for practice hours (β = .50; Figure 4). This model explained more than half of the variance in improvisation scores (R^2 = .57).

Improvisational Thinking Questionnaire

Performance on the cognitive measures was substantially associated with items describing controlled aspects of the Im-

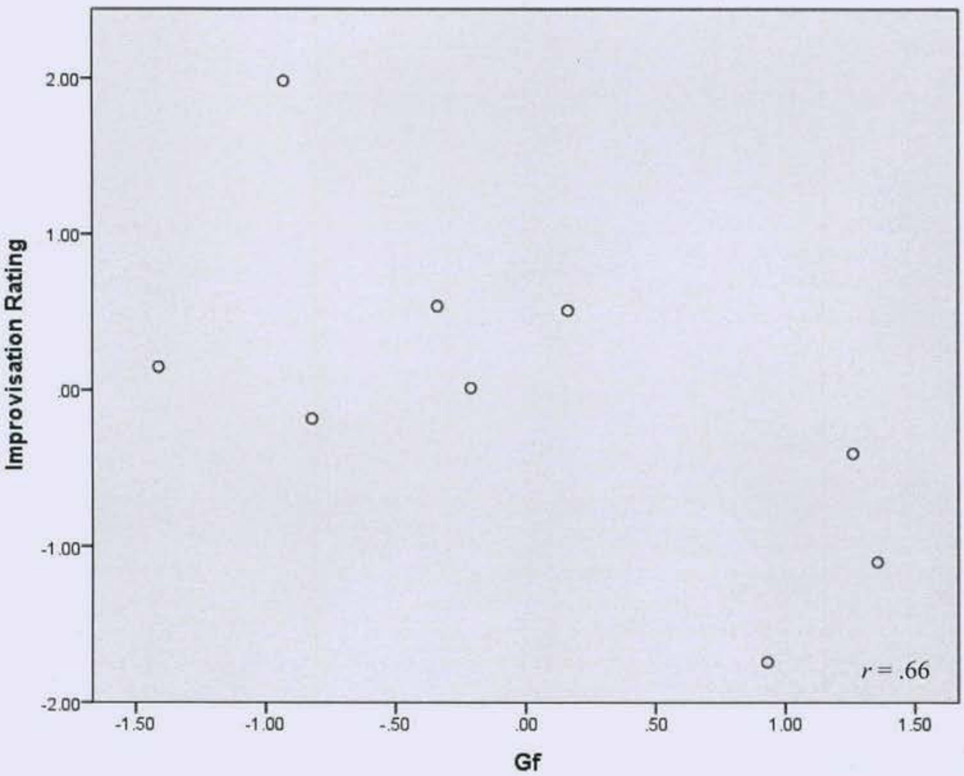

Figure 2. Relationship between standardized composite improvisation ratings and standardized composite Gf scores.

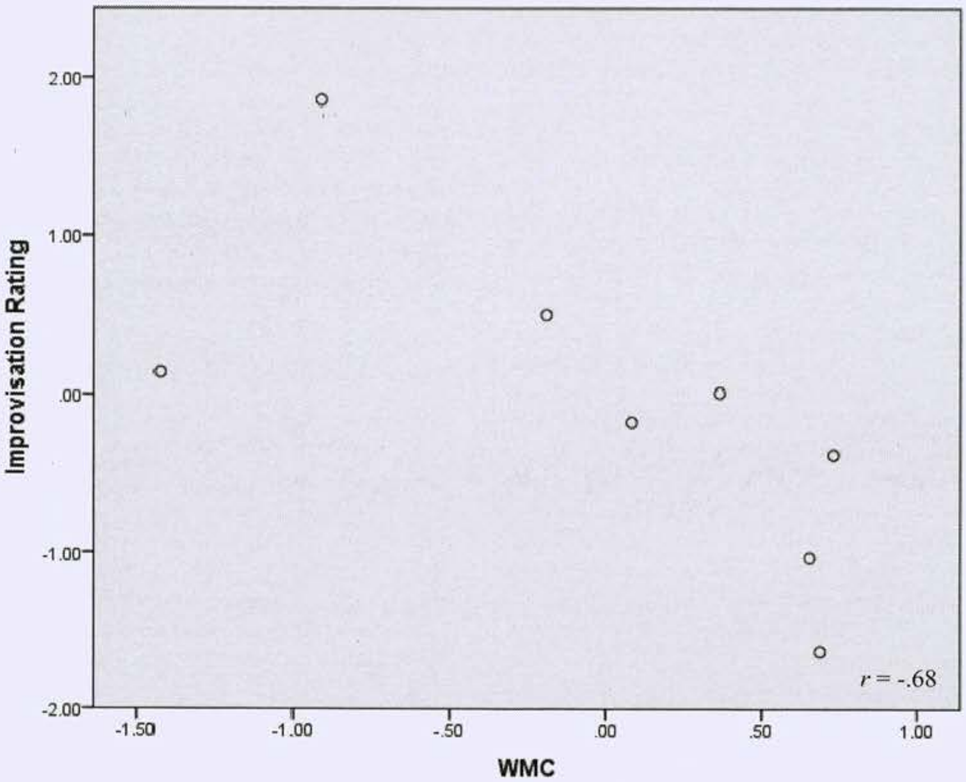

Figure 3. Relationship between standardized composite improvisation ratings and standardized composite WMC scores.

provisational Thinking Questionnaire (Appendix B): WMC predicted self-reported conscious direction of improvisation (i.e., item 2; $r = .66$), as well as musical decision making (i.e., item 3; $r = .72$). The degree to which students reported incorporating previously improvised melodic material in their playing was positively related to improvisation performance scores (i.e., item 6; $r = .72$) and negatively related to variables associated with cognitive ability (WMC, $r = -.81$; Gf, $r = -.77$) and conscious direction of improvisation ($r = -.79$). Overall, self-reported experiences of improvisation appeared to covary with both general cognitive abilities and expert ratings of performance.

Discussion

In the present study, we examined the role of general abilities to explore whether acquired expertise is sufficient for jazz improvisation quality. Verbal creativity—assessed via divergent thinking—was highly correlated with improvisational creativity ($r = .63$), and it predicted experts' performance ratings in a regression model controlling for practice hours ($\beta = .36$). We also found that Gf and WMC were *negatively* associated with expert ratings of improvisation quality. Although these results were surprising and inconsistent with previous findings (De Dreu et al., 2012), there is reason to believe they were influenced by a few important characteristics of the data; for example, the variance in performance on the cognitive measures was exceedingly restricted.

Furthermore, we conducted a follow-up analysis with the divergent thinking and cognitive ability data. Using large data sets from our institution's undergraduates who participated in previous studies of creativity and cognitive ability, we compared the musicians' performance with the norm sample on all measures of interest (i.e., divergent thinking, Gf, and WMC). Musicians were a full standard deviation higher on all of the cognitive measures, replicating previous research showing an advantage of musicians compared with nonmusicians on measures of cognitive ability (Bidelman, Hutka, & Moreno, 2013; Hansen, Wallentin, & Vuust, in press). This was not the case for divergent thinking, however: musicians performed less than a quarter of a standard deviation better than our normed sample. We are thus less certain about the findings for Gf and WMC and leave it to future research to further explore this issue.

Limitations and Future Directions

The present research offers preliminary data on the understudied field of musical improvisation. Due to the small sample, our analyses focused on effect sizes, and less on conventional significance tests. We also focused on musicians' ability to sight-improvise—using lead sheets to improvise with unfamiliar chord changes. Future work should assess musicians' ability to improvise within more familiar contexts, and further examine how general abilities influence improvisational quality with a larger and more diverse sample. Although deliberate practice is certainly necessary to achieve musical expertise, this study and

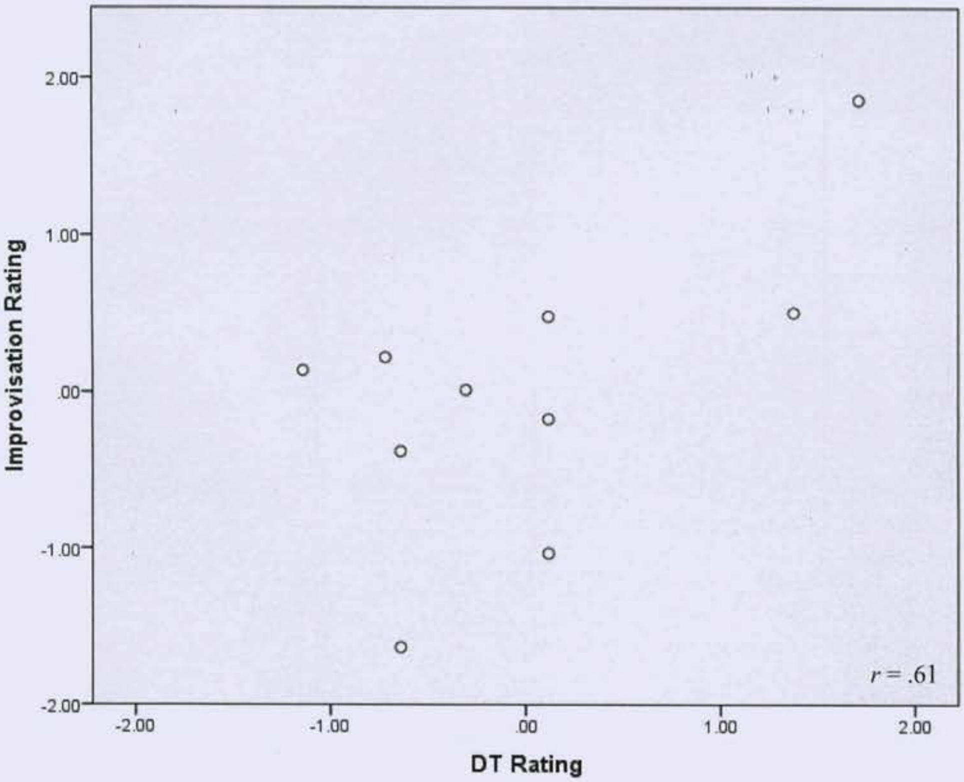

Figure 4. Relationship between standardized composite improvisation ratings and standardized composite divergent thinking scores.

others suggest that researchers should take a new look at the longstanding notion that practice alone is sufficient.

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Appendix A

Rater Instructions

We are primarily interested in assessing the creative quality of students' improvisation within the context of a novel harmonic structure. After viewing the videos, we ask that you rate the performances on a 7-point scale, where 1 is the lowest possible score and 7 is the highest. You may consider as many elements of the performance that come to mind (melodic development, intonation, etc.), but simply factor these into one overall, holistic score.

Appendix B

Improvisational Thinking Questionnaire Items

1. To what extent do you feel that you are in control of the direction of your playing?
2. To what extent are your improvisations guided by conscious thinking?
3. To what extent do you make decisions about what you are going to play before you play it?
4. To what extent do you plan what you will play right before you play it?
5. To what extent are your improvisations guided by feeling or emotion?
6. To what extent are previously learned melody lines or licks present in your solo?
7. To what extent do you feel that other musicians in an ensemble influence your improvisation?
8. How often do you mentally rehearse or improvise without your instrument?

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Researching Musical Improvisation: Questions and Challenges

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This article considers the art of jazz improvisation from the perspective of how it is defined and the challenges it poses to researchers exploring its cognitive basis. Questions on the nature of improvisation, the difference between student and professional improvisers, and the effect of context on improvisation were posed to expert jazz musicians and educators. An interdisciplinary approach to exploring the improvising brain scientifically and aesthetically will benefit these lines of inquiry.

Keywords: musical improvisation, music education, testing aesthetics

Exploring the art of musical improvisation through psychological research raises interesting and difficult challenges. By necessity scientists deconstruct an aesthetic and creative experience to describe the underlying cognitive and behavioral mechanisms that give rise to it. Taking a reductive approach to art can feel intuitively misguided, as it involves analyzing a certain kind of intuition and the beauty that can emerge when the rules of formal structure are broken. Nevertheless, researchers document, analyze, and propose models of improvisation; their work contributes to studies of creativity, divergent thinking, performance skill, aesthetics, and musical communication.

Compared with most other musical performance tasks, jazz improvisation has received relatively little attention from psychologists (Gabrielsson, 2003), but the following methodology is commonly used. A musician improvises with or without accompaniment. Video, audio, and/or neural imaging tools capture the performance, and the solo is often notated after the fact (Bengtsson, Csíkszentmihályi, & Ullén, 2007; Berkowitz & Ansari, 2008; Brophy, 2005; Limb & Braun, 2008; Mendonça & Wallace, 2004; Norgaard, 2011). The musician is frequently asked to comment on the improvisation to answer the question, "What were you thinking?" Experts may rate the solo's quality to help find correlations between improvisational skill and other cognitive abilities, or to examine stages of improvisation.

Results of these studies and the articles presented here tell us that the jazz improviser starts with some degree of short- or long-range plan for a solo, engages self-monitoring and self-evaluation during it, and can alter the plan midsolo as new information and ideas arrive. Postimprovisation he may perform a rapid analysis of how the solo he intended to play compared with the one he executed. These cognitive processes might be consciously driven only part of the time, as Bruno Nettl (1998) reminds us, "In improvisation, one must face the likelihood that some of the material may be precisely intended while other passages are thrown in without specific thought, possibly to permit the performer to think of 'what to do next'" (p. 13).

On the receiving end of the solo is the listener, who often cannot tell whether pure improvisation has actually taken place (as opposed to a solo drawn entirely from the improviser's long-term memory). Oblivious to the soloist's aesthetic intention, listeners' experiences of jazz improvisation, multiplied many times over the course of a musician's career, accumulate to forge his reputation and earning potential. For the professional jazz performer, improvisational skill is the coin of the realm. The great jazz soloist becomes legendary while the less adept remains obscure. Jazz aficionados, many of whom are untrained in music theory, will nevertheless have opinions on what constitutes an effective solo; researchers will work to discover how these aesthetic criteria develop, and what they are based on (Brattico, Bogert, & Jacobsen, 2013; Nieminen, Istók, Brattico, Tervaniemi, & Huotilainen, 2011; Repp, 1997; see also Wöllner, 2013).

Authors featured in the present special issue explored questions of improvisation from many angles. Perhaps all would agree that what we know is incomplete; we can still debate much of what is known. For the psychologist: what constitutes musical improvisation and how do we know when it is happening? For the music educator: what makes a performer a skilled improviser or for that matter, what constitutes "good" improvisation? Can the skill be taught and if so, are there cognitive or personality traits that might predict which student is likely to become a good improviser? How does feedback from the audience or musical accompanist shape a running improvisation? These questions were posed to guest editor Peter Vuust (Aarhus University, Denmark)—an accomplished jazz musician and neuroscientist—and educators from Berklee College of Music, one of the world's foremost institutes advancing the art for more than five decades.[1,2]

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[1] Berklee College of Music was founded in 1945 as the Schillinger House of Music by Lawrence Berk to offer itinerant musicians training in jazz and other contemporary musical styles. Berk was a student of Joseph Schillinger, developer of the Schillinger System of Musical Composition—a method of organizing musical elements using a mathematical approach. Although his name is somewhat obscure today (undeservedly

What Is Improvisation?

Improvisation is found in practically all styles of music but is most commonly associated with jazz. It is distinct from playing from a score or from memory, and knowing it when we hear it is a nontrivial concern for researchers. Norgaard (2011) defines jazz improvisation as "the development and expression of musical ideas in the moment" (p. 109). Although expression of ideas is apparent, their development is not. During a solo, it is possible and indeed likely that only some of the ideas are entirely new. Vuust describes the challenge of creating new ideas after becoming accustomed to a solo he recorded. "I always think of [a solo] as something completely new, I'm trying to express myself, but if you have been listening to yourself too much, it can actually be difficult to get out of." The researcher will often have to rely on self-report to know the difference between novel and familiar phrases, particularly if the soloist is improvising over a standard melody.

We can also ask to what degree stringing together familiar phrases in a novel way constitutes improvisation and if it is cognitively equivalent to *pure* improvisation at the level of melodic intervals. It is perhaps unavoidable that improvisation will consist of some phrases previously composed by the soloist and some composed by others. Professor John Baboian (Department of Guitar, Berklee College of Music) states:

> In the midst of my playing, Charlie Parker's ideas are inevitably going to show up because I did serious listening to Charlie Parker, and everybody else. I always tell my students, "There was only one truly great, original artist. It was Gork the Cave Man who took a rock, threw it against the cave wall, and said, 'Ah ha! Music!'"

Vuust reminds us that jazz players differ. "Some players fall very much into the same patterns; they actually compose solos." Others such as jazz pianist Keith Jarrett are different. "Every time he gets into something familiar, he twists the phrase in a new direction." Kari Juusela (dean of the Professional Writing and Music Technology Division, Berklee College of Music, and cellist) notes, "The difference between composition and improvisation is the ability to edit." Whether she relies on novel or familiar phrases, the improviser is uniquely challenged in that once her ideas are expressed before a live audience, she has no opportunity to take them back. This simple fact makes improvisation highly demanding of the performer's cognitive and emotional resources, making the task especially intriguing to researchers.

Learning and Teaching Improvisation

Advanced jazz students are so fluent in music theory that they can improvise by seamlessly expressing themselves according to a set of rules. According to Juusela:

> It is almost recursive in a way. They don't have to stop to evaluate what they've done, there won't be a hesitation with technique, and they won't get lost in the form. A good *professional* improviser will surprise you. That is the creativity side of it.

Juusela says that the professional has accumulated an arsenal of "personal clichés," that is, phrases that work. "You have this huge box of Legos and so you can decide what to build with it."

Similar to an extemporaneous speaker, many of those well versed in a topic can easily string together new ideas that were expressed in a different form elsewhere. Mental dexterity readily prompts new sentences when the speaker is on familiar ground. Compared with the seasoned veteran, the less experienced jazz improviser must rely more heavily on the rules of discourse until the "topic" becomes over learned.

Musicians adopt tricks to learn and enhance their creativity. Vuust learned to play one note at the onset of a solo and "really try to make it sound beautiful." An improvisational idea may suddenly develop from the tone. Another trick is to wait out the first chorus before delving into a more fully realized idea. "The more pauses you make in the beginning, the more the solo will create itself."

"Improvisation is essentially spontaneous composition. Composition is essentially written-down improvisation. They are the same thing." Baboian commented that if a student practiced composition enough, he could learn to improvise. However, he acknowledges, "You can always teach the theory behind [improvisation], but some people just have more of a creative spirit than others." To become a good improviser, Baboian lists two qualities a student must possess: craftsmanship (i.e., the ability to move fluidly around the instrument) and the capacity to hear phrases that "go beyond the norm."

Juusela agrees that the personality trait of risk-taking, manifest in a willingness to not use phrases from the standard repertoire, or at least to do unusual things to these phrases, is on the list of qualities found in the best improvisers.

> They know that a chord progression is going on underneath, and they're playing within that framework, but they're not "locked in" to it. Those people who play chord to chord—they are the "student-sounding" players, to me.

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so), Schillinger taught and influenced many of the biggest names in popular music, including George Gershwin, Benny Goodman, Tommy Dorsey, and Glenn Miller. Over the years the Berklee faculty roster has included prominent jazz musicians such as: Herb Pomeroy, Alan Dawson, Gary Burton, Danilo Perez, Pat Metheny, Terri Lynn Carrington, and Joe Lovano. See Warren Brodsky's (2003) essay "Joseph Schillinger (1895–1943): Music Science Promethean" in *American Music, 21*(1), pp. 45–73.

[2] Peter Vuust holds a PhD in neuroscience and BSc degrees in mathematics, French, and music. He is currently an associate professor at The Royal Academy of Music Aarhus, Denmark. As bass player and leader of the Peter Vuust Quartet, he is a well-known figure in the Danish jazz world, with five CDs and numerous tours to his credit. The quartet's latest CD, *September Song*, was released on Imogena records in 2013. http://www.petervuust.dk

Kari Juusela is a Finnish/American composer, performer (cello), and educator and Dean of the Professional Writing and Music Technology Division at Berklee College of Music. He holds a D.M.A. degree from the University of Maryland and is an Executive Board Member of the Society of Composers. His compositions and performances have earned him international awards and recognition. http://www.societyofcomposers.org/members/KariHenrikJuusela

John Baboian is a guitarist, composer, and educator, and professor at Berklee College of Music. He holds a B.M. degree in music education from Berklee and an M.M. in jazz studies from New England Conservatory, Boston. He has performed throughout the world with a wide range of jazz and pop artists. His compositions and arrangements have been heard on national television programs, including The Sopranos, All My Children, and Walker, TX Ranger. He currently records with the All-Berklee-Faculty band "Be-Bop Guitars." http://www.berklee.edu/people/john-baboian

It is not immediately apparent that a given personality trait is driving an exceptional solo (although Vuust notes that this could be tested). Rock and jazz musicians score higher than classical musicians in tests measuring the sensation-seeking trait (Vuust et al., 2010), and this may be correlated with a willingness to make mistakes in the moment. Juusela says that what might appear to be risk-taking behavior could actually be the player's eccentric style or relatively poor theoretical knowledge. Is a great soloist "a really good theorist because he can see the connections between all these things, like seeing the forest above the trees" or "just someone who throws caution to the wind?" The (rare) great improvisers who lack formal musical training are very intriguing. "How could they possibly be playing within the rules if they don't know what they are?"

Vuust emphasizes that being an effective communicator, including a propensity to listen to others, is a prominent trait of any good soloist. He describes two kinds of listeners, or ears: the "analytical ear" can accurately describe chords and dissect their composite pitches (Wallentin, Nielsen, Friis-Olivarius, Vuust, & Vuust, 2010), but the "interactive ear" can listen intuitively to other musicians and say, "OK, he's trying to communicate *this* kind of emotion." The ideal jazz student possesses both, but Vuust notes that without the interactive ear, a student cannot hope to become a highly regarded improviser.

The Effect of Context

If the improvised solo is a conversation with other band mates, it is dependent on the caliber of the musicians. Baboian comments:

> The hipper the band and the more able they are to interact with what I'm about to do, the more liberties and freedom I can take. When I'm playing with students who are still working things out, the more obvious I have to make things so that they don't get lost in the form. It takes away some of my creative elements and I have to play a little bit more down the center.

Audience expectation, venue size, and appetite for novelty also shape the improvisation (Brand, Sloboda, Saul, & Hathaway, 2012). Baboian continues:

> When I'm improvising at the local American Legion Hall for somebody's wedding, [the solo] is going to be different than if I'm improvising on my quartet gig at Ryles Jazz Club. One [solo] is going to be intentionally less creative than the other.

When he is playing unaccompanied before an audience, Baboian is more likely to play worked-out ideas that were composed prior to their execution, ". . . so that I don't sound like I'm fumbling for notes, but that have enough creative elements that I don't sound like what I played yesterday."

The audience for live jazz performance is typically knowledgeable and experienced. Burland and Pitts (2010) surveyed an Edinburgh Jazz and Blues Festival audience and found that during performances, jazz listeners compared their memories of musical pieces with the live renditions they were experiencing. The authors speculated that jazz listening was a "more involved experience" than classical music listening because the audience was "keen to enter into the participatory spirit of live jazz and to add to their already substantial memories of high quality performances enjoyed in a sociable atmosphere" (p. 131).

Cultural norms influence improvisation (Pressing, 1998) and musical evolution (Nettl, 2006), just as they influence speech patterns. Vuust reports that when he listens to his own recordings from decades ago, he recognizes phrases that he still uses but others that he would no longer play. The difference between what persists and what falls out of favor may be similar to the "accent of society"—prosodic norms. Just as the annoying "Valley Girl" prosody of the 1980s (statements delivered with a rising pitch inflection to sound like questions) slowly disappeared from the North American English-speaking soundscape, so might certain jazz phrases not destined to become classic. (See Nettl, 2006, for a commentary on consistency of musical styles, or evolutionary musicology.)

This article presents some of the challenges faced by researchers exploring the cognitive and behavioral processes underpinning jazz and other musical improvisation. Questions of how to define improvisation from the psychological perspective, how best to teach it and who is likely to learn it well, and how context and listeners affect the improviser, are just a few of the many that will be explored anew as findings come in. Researchers are encouraged to take an interdisciplinary approach to account for, among the factors discussed here, variables such as musical instrument and voice, age, gender, familiarity with the piece, and so forth constraining the skill. The Improvising Brain Symposium provided a forum for researchers, educators, and musicians to share observations and ideas. Given the complexity of the task, their findings and future research on improvisation will inform related investigative work in the broader fields of music education, neuroscience, and psychomusicology for some time.

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Conference Report: The Improvising Brain Symposium, 2013

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The Improvising Brain Symposium was held at Georgia State University in April 2012. The event attracted researchers, educators and students interested and involved in the research of the brain during music cognition and improvisation. This summary provides an overview of the symposium and details from the keynote address. It also summarizes additional research presented at the symposium that was not submitted for publication.

Keywords: Improvising brain symposium, brain, research, improvisation, brain imaging

More than 50 researchers, educators, and graduate students in the disciplines of music education and music cognition gathered to discuss recent developments in the area of musical improvisation. The Improvising Brain Symposium (IBS) was held at Georgia State University (GSU) and Loudermilk Convention Center, in downtown Atlanta, GA, April 7 to 9, 2013. The event was organized by chair Dr. Martin Norgaard (GSU School of Music), supported by the GSU School of Music, GSU Neuroscience Institute, Center for Collaborative and International Arts (CENCIA), GSU Research Foundation, and Yamaha Corporation of America. The symposium featured an introductory summary of empirical research on the improvising brain, a keynote speaker, 18 research presentations, 11 poster presentations, a string master class, and a live research study. Jazz violinist Christian Howes and the Kevin Bale trio performed a jazz concert for attendees. The performance was recorded and notated by Dr. Norgaard and his research team who later interviewed the musicians on their improvisational choices. Dr. Robert Zatorre's (Montreal Neurological Institute, McGill University) first keynote address set the stage for much of the research presented at the symposium. His discussion of developments of technology and his descriptions of brain activity, as understood through brain imagery (e.g., Zatorre, 2012), while engaging in music listening and performance added historical and theoretical context for the presentations that followed. He closed the symposium with a lecture on brain, behavior, and music. The purpose of this report is to provide a summary of research presentations that will not be published elsewhere in this edition.

This report highlights a sampling of work presented at the IBS and is organized under two main themes (1) neurocognitive functions in musical improvisation, and (2) implications for music education. For additional information on the topics presented below and presentations from researchers not covered in this summary, visit the official Improvising Brain Symposium Web site (http://www.cas.gsu.edu/theimprovisingbrain/).

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The Improvising Brain

An overarching theme of much of the research presented was identifying and modeling brain activity related to musical improvisation. James Fidlon (University of Texas at Austin) opened the event with an overview of empirical research on the improvising brain. Fidlon recognized that many researchers have identified improvisation as a cultural phenomenon because of the interaction between mind and body, making empirical study difficult. However, he identified the cognitive and physical processes that have been successfully measured in empirical research. He described improvisation as a complex skill in which creativity, decision-making, sensory motor processing, expert performance abilities, and spontaneous behavior occur simultaneously. He outlined the tools and methodology currently used in improvisation research, including physiological data (brain imaging, neural activation), behavioral data (music performance notation), and qualitative data such as self-report and expert evaluation.

Augusto Monk (University of Toronto, Canada) presented a model of improvisational intelligence derived from the multidimensional cognitive processes underlying the task. To explore the strategies involved, Monk interviewed 10 professional musicians after they each performed a solo improvisation, in a nonidiomatic format (free of musical restraints and implications, making all elemental choices available). He proposed that in improvisational contexts outside of standard tonal jazz, musicians simultaneously activate mental processes he labeled *residual*, *emergent*, and *monitoring*, with monitoring acting as the mediator between the other two. The model described how memory, attention, listening, and problem solving interact in a running creative task. Monk presented schematics illustrating this complex process and proposing connective links between cognitive processes and functions that may be, consciously or not, activated during improvisation.

Many presenters endorsed the 10-year rule for expert performance (Csikszentmihalyi, 1996; Piirto, 2004) as a prerequisite for comfortable and effective improvisation. Richard Hass (Rowan University) explained how learned expertise influences improvisers' tonal selection in expected and unexpected harmonic contexts. He tested the hypothesis that organization, encoding, and retrieval of knowledge and skill allow trained musicians (nonkeyboard players) to improvise on a keyboard more effectively than nonmusicians. The 23 undergraduate student participants (9 experienced improvisers) improvised on keyboard to a normal blues progression in C Major and an altered progression. To help illustrate how music cognition is probabilistic and increases with experience, Haas introduced a computer program that he and fellow researchers developed. The program actually calculated the probability of notes to be played during the given progression, based on meter, harmony, voicing, and pitch. As hypothesized, the trained improvisers performed more notes within familiar and unfamiliar harmonic contexts than did nonmusicians. Not only did they perform more notes, but also their choices were also more comparable with the "probable" (more contextually appropriate) notes generated by the computer program. Even though the musicians performed much better during the study, the majority of them admitted in poststudy interviews that they did not feel that their improvisational skills transferred from their primary instruments to keyboard.

Robin Wilkins presented research conducted at Wake Forest Medical Center that applied network science—a "rapidly emerging analysis method for investigating complex systems, such as the brain"—to music listening. The lecture, entitled *A New Method for Investigating the Complexity of Musical Experiences in the Brain*, described the brain in terms of a network, and presented findings on how musical form affects this complex system. Twenty-one adults with diverse musical tastes and backgrounds listened to different genres of music during a functional magnetic resonance imaging (fMRI) procedure. Listeners were presented with musical samples from popular, rock, r&b/hip-hop, classical, country, and an unfamiliar genre (Chinese opera). Although participants' musical preferences spanned a wide range, the physiological results were more homogeneous. Researchers identified correlations between regions of brain activity and musical genre, particularly in the visual and auditory centers. Wilkins proposed that differences in compositional complexity among musical genres are reflected in brain connectivity.

In a second presentation, Wilkins elaborated on her study of musical experiences in the brain. The fMRI scans revealed similarities among participants' initial reactions to music genres, but the degree of activation showed a correlation with participants' (self-reported) musical preferences. Wilkins observed reduced hippocampal activity during presentations of genres participants identified as liking, suggesting that less coding and fewer neural connections are used when listening to familiar or preferred musical forms. The results of both studies corroborate network science and the mapping of brain connectivity as successful tools for measuring music's impact on the brain.

Implications for Music Education

Many researchers at the symposium presented work on the improvising brain that contributed to the discipline of music education. Tamara Thies's (University of Vermont) presentation began with a glance at Ken Robinson's work on creativity in school. Citing evidence that formal schooling discourages and ultimately diminishes children's creativity (Robinson, 2011), Thies focused on music educators' responsibility to counteract this observation through teaching improvisational skills. She quoted neurological studies postulating that self-monitoring diminishes during musical improvisation, in comparison with when the performer plays or reads memorized music. Thies presented a case study of seventh grade jazz band students and their teacher's techniques for teaching and facilitating improvisation. Based on the results of the study, she suggested that a pleasant nonthreatening atmosphere with opportunities for daily improvisation, modeled by teacher and student, promotes effective learning and creativity. The use of humor, metaphors, encouragement of engagement, and fostering a home-like environment, was identified as influencing students' comfort level. The importance of easing students' fears of making mistakes and acknowledging risk factors support earlier findings from Thies and others who investigate the correlations between educational environment and improvisational skills.

Amy Engelsdorfer (Luther College) listed several reasons for students' hesitance to improvise, including lack of a palette from which to draw, feelings of engaging in a foreign activity, and the fear of being wrong. Her presentation provided insight into how to create a comfortable environment advancing improvisation that guides music students through exercises of relaxation, meditation, and music making. Using three *Deep Listening Pieces* by Pauline Oliveros (Oliveros, 2005), students in Engelsdorfer's workshops (undergraduate music majors, mostly inexperienced in improvisation) learn to silently meditate, absorb, and vocalize the sounds around them, spontaneously create sounds, imitate the sounds of others, and improvise in small groups based on tones from other group members. Throughout the process, students become less afraid to express their musical instincts. Engelsdorfer attributes this development to a framework for improvisation that is effective when built from the bottom up. Her pre- and postworkshop surveys show large increases in student courage, comfort, and confidence during improvisation. A video of her using this method with a group of undergraduates illustrated the increase in their comfort levels and abilities.

Final Remarks

This report summarizes only a portion of the research and topics presented during this engaging and instructive symposium. Lectures and posters on related topics included new technologies to create, predict, and notate improvisation; rubrics for accurately adjudicating college jazz performance; the effect of practice on improvisation; and a commentary on how jazz resisted the feminist movement.

The study of brain network systems, music's effect on these systems, and the resulting behaviors (e.g., physical, emotional) has proven to be appropriate and applicable to musicians, neuroscientists, and educators. Just days before the IBS, President Obama announced the BRAIN (Brain Research through Advancing Innovative Neurotechnologies) Initiative allotting $100M to advancing research into brain function—from individual neurons to entire circuits and their interactions (Markoff & Gorman, 2013). Researchers believe that deeper knowledge of circuit function will lead to a better understanding of how the brain produces complex thoughts and behaviors, including musical improvisation, and provide insight into devastating diseases such as Parkinson's, Alzheimer's, and autism. Additional resources for investigating the brain as a complex and dynamic system will fuel current research efforts in the cognitive neuroscience of music, and the findings will advance our understanding of musical improvisation.

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Dissertation Abstracts Related to Improvisation

Motor Control of Rapid Rhythmic Movements in Skilled Drummers

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Supervised by Shingo Oda

The aim of my doctoral research was to investigate the motor control of rapid rhythmic movements in skilled drummers. This research was summarized in my thesis, which contained 9 chapters. In chapter 1, we described the research background on the motor control of skilled musical playing and proposed the significance of studying expert drummers. In chapter 2, we reviewed previous literature on the motor control of rapid rhythmic movements and summarized the methods for analysis. In chapter 3, we showed that the use of drumstick enhanced the stability of intertap interval during rapid tapping performance (S. Fujii and S. Oda, 2009, Effects of stick use on rapid unimanual tapping in drummers, Perceptual and Motor Skills, Vol. 108 (3), pp. 962–970). In chapter 4, we showed that skilled drummers had reduced tapping-speed asymmetry compared with nondrummers (S. Fujii and S. Oda, 2006, Tapping speed asymmetry in drummers for single-hand tapping with a stick, Perceptual and Motor Skills, Vol. 103 (1), pp. 265–272). In chapter 5, we showed that drummers had lower level of muscle cocontraction compared with nondrummers (S. Fujii, K. Kudo, M. Shinya, T. Ohtsuki, & S. Oda, 2009, Wrist muscle activity during rapid unimanual tapping with a drumstick in drummers and non-drummers, Motor Control, Vol. 13 (3), pp. 237–250). In chapter 6, we focused on the world's fastest drummer and measured his pattern of wrist muscle activity during 10-Hz unimanual-tapping movements (S. Fujii, K. Kudo, T. Ohtsuki, & S. Oda, 2009, Tapping performance and underlying wrist muscle activity of non-drummers, drummers, and the world's fastest drummer, Neuroscience Letters, Vol. 459 (2), pp. 69–73). In chapter 7, we showed that the use of drumstick improved bimanual coordination performance (S. Fujii & S. Oda, 2009, Effects of stick use on bimanual coordination performance during rapid alternate tapping in drummers, Motor Control, Vol. 13 (3), pp. 331–341). In chapter 8, we showed that the reduction of detuning parameter (i.e., symmetry-breaking parameter) in the nonlinear dynamical system model successfully described the difference in skill level during bimanual drumming movements (S. Fujii, K. Kudo, T. Ohtsuki, & S. Oda, 2010, Intrinsic constraint of asymmetry acting as a control parameter on rapid, rhythmic bimanual coordination: A study of professional drummers and non-drummers, Journal of Neurophysiology, Vol. 104 (4), pp. 2178–2186). In chapter 9, we summarized the results and discussed the motor control mechanisms of rapid rhythmic movements in skilled drummers.

The Statistical Learning of Musical Expectancy

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This project investigated the statistical learning of musical expectancy. As a secondary goal, the effects of the perceptual properties of tone set familiarity (Western vs. Bohlen-Pierce) and textural complexity (melody vs. harmony) on the robustness of that learning process were assessed. A series of five experiments were conducted, varying in terms of these perceptual properties, the grammatical structure used to generate musical sequences, and the methods used to measure musical expectancy. Results indicated that expectancies can indeed be developed following statistical learning, particularly for materials composed from familiar tone sets. Moreover, some expectancy effects were observed in the absence of the ability to successfully discriminate between grammatical and ungrammatical items. The effect of these results on our current understanding of expectancy formation is discussed, as is the appropriateness of the behavioral methods used in this research.

Improv Ed: Changing Thoughts About Learning

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Improvisation has long been regarded an integral element of artistic work, but has received less attention for ways it may inform education and learning. This dissertation explores understandings central to improvisation, interrogates how they are embodied in music (Western classical music, jazz, and African drumming) and theatrical practices, and uses them to problematize values in curricular design and modes of classroom instruction. Improvisation is presented as a means of confronting indeterminacy and negotiating change, concepts that are discussed first in philosophical and anthropological contexts. These theoretical frameworks serve to foreground notions of performance and agency, particularly as they are actualized in creativity and play. Jazz (as well as its adoption in Knowledge Management) and Process Drama are offered as practices that use open-ended interactive structures to highlight creative collaboration. These artistic forms of engagement are shown to integrate features central to cognitive and social development, and should therefore be regarded as fundamental elements of educational praxis. It is argued that improvisation-based curricula display the following features: they foster learner creativity and aesthetic sensitivity, promote democratic interaction, and validate student subjectivities. These dynamics, which foreground dialogic encounter, are considered to be of particular importance in language arts. The applied use of improvisation in the classroom is shown to complement leading theories and pedagogical approaches in education, resonating strongly with situated cognition, constructivism, and the works of Vygotsky, Dewey, and Lave and Wenger. Improvisation is proposed as a generative and transformative alternative to the reproductive and impersonal nature of standardized curricula.