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Abstract

This research investigates thinking processes of duos of jazz improvisers in performance. Of particular interest are cognitive processes related to creativity and to reasoning about time, since both activities are fundamental to improvisation. Data sources are the group members' retrospective verbal protocols, collected after the performance of each tune. One result of this work is that cognition related to reasoning about time and creativity varied little either within or across groups, regardless of the type of tune being played. This result is further investigated by examining some of the statements from the protocols themselves.

Introduction

This research examines the thinking processes of duos of jazz improvisers in performance. Of particular interest are cognitive processes related to creativity and to reasoning about time, since both activities are fundamental to improvisation. To produce the data used in this study, each member of the duo watched and listened to a tape of the duo's performance and recalled out loud what he had been thinking during it. The study addresses a gap in prior research by presenting an analysis of cognition during improvisation as reflected in verbal protocol data. Since this study is thought to be the first of its kind, an exploratory approach is taken.

A brief review of related work is followed by a presentation of exploratory questions concerning how performers reason about time and how they produce ideas for performance. The results of the study are then presented, followed by an analysis of the contents of selected statements in the protocols. The paper concludes with a discussion of implications for current theory and directions for future work.

Related Prior Research

Improvisation in jazz is said to involve "reworking precomposed material and design in relation to unanticipated ideas conceived, shaped, and transformed under the special conditions of performance, thereby adding unique features to every creation" (Berliner, 1994). While improvising has been compared to "real-time composing" (Kernfeld, 1988), the two differ in salient ways (Nettl, 1974). Composition refers to "the discontinuous process of creation and iteration (usually through notation) of musical ideas" (Sarath, 1996). Improvisation, by contrast, is a continuous and serial process. Composing involves distributing musical elements (such as notes) over a score that is to be played serially: the composer may add to, delete or edit any part of the composition at any time before its performance. Performance of a composition involves interpreting and articulating a written or memorized score. Performance of an improvisation involves *conceiving, articulating* and *remembering* an unwritten, evolving score (Berliner, 1994). While a misplaced note in a composition can be erased and rewritten; a misplayed note in improvisation cannot. Errors in improvisation therefore "must be accepted as part of the irrevocable chain of acoustical events, and contextually justified after the fact by reinforcement or development" (Pressing, 1984). As stated by Pressing (1984), "If erasing, painting over, or non-real-time editing exist, improvisation does not."

Temporal Cognitive Processes

Following Berliner's (1994) comments, improvisers must reason about time in order to *conceptualize* what is to be *articulated* in light of what they *remember* has been played (see Sarath, 1996 for further discussion). In comparison with a tune that is being composed as it is being played (i.e., a free tune), the performance of a well-learned tune (such as a jazz standard) may place fewer demands on remembering, since much of what needs to be recalled (e.g., chord changes) is easily accessible from long-term memory (Johnson-Laird, 2002). Similarly, conceptualization may also be easier for a jazz standard, since the path in front of the improviser is better known. A tentative hypothesis, then, is that players will spend more cognitive effort on remembering and planning ahead for a free tune than on a standard.

Creative Cognitive Processes

Creativity—the production of new ideas—is fundamental to improvisation, since it is not enough for improvisers to produce music that has already been composed: they must produce something that, to them at least, is new. There have been numerous proposed models of the cognitive processes involved in creative thinking (Sternberg, 1999) and on the factors that influence creative thinking (Welsh, 1973). These

theories typically include convergent and divergent processes, along with some mechanism that governs switching between them (Newell, 1962). The Geneplore model (Finke, Ward, & Smith, 1992) describes creative thinking as entailing divergent processes of generation and subsequent exploration of ideas (see Ward, Smith, & Finke, 1999 for a discussion). Evaluation (a convergent process) is discussed in Geneplore in terms of constraint satisfaction.

A jazz standard may afford more opportunities for divergent thinking than a free improvisation. Jazz standards are tunes with familiar structures and a long history of performance which players routinely draw upon. Their performance may enable the improviser to spend less time trying to recall the tune or, in the case of free improvisation, trying to determine the structure and content of the tune. Similarly, evaluation may be easier to accomplish for a jazz standard, since the player can easily recall what has been played and speculate reliably what is to be played.

Analytic Framework

The analytic framework for this study is used to define a set of temporal and creative processes. A scheme for classifying the contents of the protocols based on these definitions was developed so that independent coders could identify these processes in the protocols. This section provides the definitions of the processes; the method of their application is discussed in the subsequent section on "Study Design."

An improviser in performance must reason about past, present and likely or possible future events, resulting in three different processes related to *temporal* cognition. *Orientation* is the process of considering a current performance event. An example of orientation is the statement "The time is in 4," since the speaker is referring to the present moment. *Retrospection* is the process of recalling a previous performance event. The statement "He had just played in three so I did too" is an example of retrospection. *Prospection* (a term coined for this research) is the process of looking ahead; that is, of predicting or speculating about a future event in the performance. An example of prospection is the statement "I knew I was coming to the end of my solo so I looked up."

Three different types of *creative* cognition are considered here. Idea *generation* is said to occur when a musical idea (i.e., one that pertains to the performance) is recalled or created. An example is the statement "I was thinking about playing an open figure there." Idea *development* is said to occur when a player further develops a musical idea which has already been generated, either by the speaker or the other member of the group. An example is the statement "I was thinking of inverting the figure I played previously." Both idea generation and development are regarded as divergent processes. Finally, idea *evaluation* is said to occur when the speaker makes a statement about the value or worth of a musical idea. An example is the statement, "I remember liking what I played there." Idea evaluation is a process that leads to decisions about whether or not to pursue ideas, and is therefore convergent.

Research Questions The research questions concern the frequencies of occurrence of temporal and creative cognition within and among groups during the performances of various jazz tunes. Although some tentative hypotheses have been discussed, a broad range of questions are addressed. This decision is due to the exploratory nature of the study, one goal of which is to provide suggestions for further lines of research. The research questions explore (i) the defensibility of the assumption of between-group homogeneity; they also examine possible differences in creative and temporal cognition (ii) within a group for a particular tune and (iii) across tunes by the same group. Data from performances of a jazz standard and a free improvisation are used. An example of question (i) is, do the proportions of occurrence of the various types of temporal processes differ across the groups for the performance of a jazz standard? An example of question (ii) is, do the proportions of occurrence of the various types of temporal processes differ between the trumpet and bass player in the performance of a jazz standard? An example of question (iii) is, do the proportions of occurrence of the various types of temporal processes differ between the performance of a jazz standard and of a free improvisation for a particular group?

Study Design

The study employs the preceding three research questions to investigate the impact of different types of tunes on how members of professional jazz duos reason about time and think creatively.

Tune Choice The tunes which the duos were asked to perform were intended to vary in difficulty and familiarity. The first tune played, "I Got Rhythm," has been extensively recorded and is the origin of the so-called "Rhythm Changes," a set of widely-used chord changes in jazz (Berliner, 1994; Kernfeld, 1988). All participants were expected to be very familiar with this tune and comfortable in improvising on it. The second tune, "Willow Weep for Me," was chosen since it is not as familiar as "I Got Rhythm" and because it is typically played as a blues ballad. In case a duo did not know this tune well enough to play it without sheet music, a backup tune— "Blue Train"—was used. The third tune, "Giant Steps," is known for being a difficult tune, since the chord progressions are highly idiosyncratic and the tempo is fast. The backup tune for "Giant Steps" was "Cherokee," which is in part challenging because it is also typically played at a quick tempo. The fourth tune was a free improvisation. A free improvisation has no pre-determined structure other than the one which performers create.

Solicitation of Participants Groups of two players each were solicited through word-of-mouth contact with professional musicians working in the Albany, New York area. (Though the duo is a common configuration in jazz, the use of duos was also due to practical concerns of cost

and the availability of appropriate recording space.) The player of the lead instrument—a trumpet player in all cases—was first secured. The lead player then suggested the second member of the duo, someone with whom he played often. The groups were intended to be reasonably homogeneous in terms of musical experience and experience improvising. Accordingly, all participants were asked to describe their backgrounds. Because they would be asked to verbalize their thoughts, only players who had experience in teaching—and therefore talking about—improvisation were asked to take part in the study. Finally, they were then told that, during the study, they would be given three or four tunes to play, videotaped during the performance of each tune and then asked to recall their thinking while watching the videotape.

Procedure

The study was conducted at a local professional recording studio. Once a duo arrived, study personnel reviewed the study protocol with them. The duo's members next signed consent and contract forms, tuned their instruments and performed a sound check.

Each member of the duo then entered a vocal (i.e., isolation) booth to practice giving concurrent and retrospective verbal protocols, using two tasks from the literature (Ericsson & Simon, 1993). In the third task they whistled or sang a short tune then recalled their thinking during the performance of the tune. Once these practice tasks had been completed to the player's and the experimenter's satisfaction, the players practiced operating the VCR that would assist them in giving the retrospective verbal protocol. The main part of the study then began.

The group first played "I Got Rhythm." They were asked to keep the performance to less than ten minutes and to take one solo each. A maximum length of ten minutes was chosen since that is the maximum length recommended in guidelines for conducting a retrospective verbal protocol (Ericsson & Simon, 1993). Once any questions had been answered, all personnel except two video camera operators left the main studio and the duo performed the tune. The videotape recorded the images and sound of the two performers, along with a display of the duration of the performance.

After the performance, each participant went to a vocal booth in order to watch and listen to a videotape of the performance and to deliver the protocol. (About two to three minutes usually elapsed between the end of the performance and the beginning of the protocol.) As is commonly done in verbal protocol-based studies, one experimenter remained with the participant in order to reiterate the instructions and to ask the participant to "keep talking" whenever there was silence for more than about ten seconds (Ericsson & Simon, 1993). While giving a protocol, each participant could control the videotape as necessary. All protocols were audio- and video-taped, so that it would be possible to hear and see what was on the videotape while the participant was speaking.

Once the protocol had been delivered, the participants returned to the performance area and prepared for the next performance. The above procedure was repeated for the tunes "Willow Weep for Me" and "Giant Steps." If the participants decided not to play a tune, the backup tune was played. For the fourth and final tune, participants were asked "to work out the composition of the tune as you play it." Again they were asked to keep the total length of the performance to less than 10 minutes. They were not asked to take solos, since doing so would have helped determine the structure of the performance.

Once the think-aloud protocol for the final tune had been given, participants were asked a series of questions about their background and their participation in the study. They were then paid and invited to discuss the study further in a relaxed atmosphere without being recorded. The total duration of each session was approximately two hours.

Results

Data are taken from the verbal protocols associated with the performances of "I Got Rhythm" (IGR) and a free improvisation (Free). Performances of these two tunes were chosen for initial analysis since they represent opposite ends of the spectrum of jazz performance. All the groups played IGR first and Free fourth.

Participants' protocols were first transcribed and segmented (Ericsson & Simon, 1993). All references to study participants in the protocols were masked so that it would not be possible for a reader to determine which protocol corresponded to which session or player. Segments pertaining to cognition during the actual performance of the tune were coded using the definitions for the types of temporal and creative cognition that are given above in the "Analytic Framework" section. Coders were provided with (i) the segmented and masked protocols and (ii) instructions on how to use the above definitions to code the protocols. Coding was done by two independent coders unfamiliar with the objectives of the research. The coders were trained first to identify creative processes, then applied the instructions to the protocols. The same procedure was then followed for temporal processes. A second coder coded approximately 10% of the data, and reliability as measured by Cohen's kappa (Cohen, 1960) was approximately 87%.

Counts of the various types of temporal and creative processes were then entered into contingency tables. For creative cognition, it was immediately obvious that there were too few instances of idea development to justify the use of the appropriate statistical test, the Chi-squared test for differences in proportions (Conover, 1999). All instances of idea development were therefore recoded as instances of idea generation, since, as discussed previously, both are processes of divergent thinking. All statistical tests were then performed on the tables at a 0.05 significance level. The observed significance level of a test is denoted p. Some of the contingency tables are shown below, with the following symbols used: for temporal cognition, O=orientation, P=prospection and R=retrospection; for

creative cognition, G=idea generation and E=idea evaluation.

Between-group Differences

A reasonable degree of homogeneity was desired among the groups in order to minimize the possibility of between-group confounding effects. Information on participants' backgrounds was collected, as discussed previously. Also, differences in groups' temporal and creative thinking processes for each tune were investigated using question (i), with the following results. For temporal thinking, no significant between-group differences were found among the groups for either IGR or Free.

For creative cognition, no significant differences were found among the groups for IGR, but a significant difference (p=0.0045) was found for Free. This result may be stated by saying that at least two of the proportions in some column were not equal to each other. Table 1 shows the data associated with Free.

Table 1: Creative Cognition, by Group for *Free*.

Group	G	E
One	33	37
Two	13	9
Three	68	26

The assumption of homogeneity may therefore be seen as reasonable for IGR but not for Free. Accordingly, the analysis will consider individual groups rather than pooling data across groups.

Description of Performances

I Got Rhythm All groups structured their performances of IGR in approximately the same way, with the head (i.e., the introduction and first AABA chorus) and ending (i.e., the last AABA chorus) played more or less as discussed by Kernfeld (1995). In Groups One and Two, solos were two choruses long; in Group Three they were four choruses long. All performances were less than ten minutes long.

Free Improvisation For the free improvisation, participants were asked to "work out the composition of the tune as you play it." Groups in sessions one and two asked for some additional guidance but were given nothing more than a key and/or time signature. All performances were less than ten minutes long and had a stable time signature. It should be noted that, although all free tunes were spontaneously composed, all were clearly in the idiom of bebop jazz.

Temporal Processes

For question (ii), no significant differences in temporal cognition were evident between the participants in each group for IGR or Free. Table 2 shows the question (ii) data associated with Group One for IGR.

Table 2: Temporal Cognition for IGR, by Player in Group One.

Player	O	P	R
Trumpet	25	13	11
Bass	17	10	4

Similarly, for question (iii), no significant differences were evident across the two tunes as performed by each group. Table 3 shows the question (iii) data associated with Group One.

Table 3: Temporal Cognition for Group One, by Tune.

Tune	O	P	R
IGR	42	23	15
Free	30	21	21

Creative Processes

No significant differences were evident in creative cognition between the participants in each group for IGR or Free. So, in Group One, the proportion of segments from the trumpet player reflecting idea generation is not significantly different from the corresponding figure for the bass player. Table 4 shows the question (ii) data associated with Group One for IGR.

Table 4: Creative Cognition for IGR, by Player in Group One.

Player	G	E
Trumpet	18	16
Bass	8	6

No significant differences were evident across the two tunes as performed by each group. Table 5 shows the question (iii) data associated with Group One.

Table 5: Creative Cognition for Group One, by Tune.

Tune	G	E
IGR	26	22
Free	37	33

For both temporal and creative processes, the results suggest that—contrary to expectation—the same proportion of segments reflected each type of temporal or creative process. The same was true for differences within the same group across the two tunes. This result is particularly surprising, since groups were expected to approach IGR and Free quite differently; indeed, the recorded performances of the tunes by any given group, while sharing certain elements (e.g., stable key signature

and meter within each performance) nonetheless sound quite different, particularly in Group Three and to a lesser extent in Group One.

Content Analysis

The contents of the protocols from the performance of IGR by Group One are now analyzed in order to provide further insight into individual- and group-level creative and temporal cognition. These protocols were chosen because they are richer in content than those of the other groups and because it is appropriate to begin with an analysis of a simpler tune before moving to more complex ones. The statements examined here were those thought to provide the most insight into processes of collaboration, temporal reasoning and creativity. To aid the discussion, statements are labeled with their segment number from the protocols.

Collaboration Statements by one player about himself, the other player in the group and the group itself suggest how the duo collaborated. In IGR, the trumpet player (JH) explicitly mentioned trying to fit the melody and rhythm of his playing with that of the bass player (PT), as follows:

19. I'm just ah, I'm hearing melodies, I'm trying to play them, that I know will fit with what PT is playing.
24. I'm trying to keep, trying to keep a steady rhythm with PT, trying to make my eighth notes very steady.

JH also engaged in active listening following the completion of his own solo and the onset of PT's solo:

32. I'm kind of ah thinking after the thought and reacting to what he's playing.

Segments 19, 24 and 32 reflect JH trying to solve two types of problems related to collaboration. The first type, as in S24, is reasonably well-posed and technical. In this case, it involves keeping the rhythm of the tune. In contrast, the second requires the generation of new melodies: here, ones that "fit with" PT's playing. Segment 19 (S19) suggests that generation of the melodies occurred closely in time to their evaluation and performance. The use of the phrase "hearing melodies" would seem to indicate that the process is more one of retrieval rather than on-the-spot composition. Computational approaches to this type of thinking in jazz improvisation have sometimes involved retrieval and use of fragments or motifs (e.g., Ramalho, Rolland, & Ganascia, 1999) S32 is similar in spirit to S19, the distinction being that JH was not actually playing anything at that moment. The statements show that JH was actively listening to PT, analyzing PT's playing and attempting to use the results of this analysis to guide his own playing.

Temporal Processes A number of statements by both players reflect reasoning about time, particularly about the group's movement through the structure of the tune. Once they were asked to play IGR, one of the things they discussed was whether or not to play the tag (an optional ending to the melody). JH decided that they would play the tag at the very end of the tune. As they neared the end of the tune (i.e., the last A section), JH recalled thinking

47. I'm, I'm thinking about how we're going to resolve the tune, how we're going to end it here.
48. I know we're going to put the tag on, which is what we're doing right now.

Similarly, at about the same point PT recalled thinking

41. Ah, we're coming up on the last eight, eight bars.
42. And we had talked about putting the the tag at the end, so I'm actually thinking, yeah we're going to put that tag on the end.

Successful completion of the tune was therefore in part dependent on both players recalling the need to play the tag at the end of the tune. Additionally, JH was thinking about how to resolve the tune, given the need to include the tag.

At numerous points in the performance, JH and PT each speculated about what might be played by the other person. For example, after the first chorus of JH's solo, PT thought

22. Now I'm, right now I tell you I'm thinking, is he taking another chorus?
23. There, so, he's taking two choruses.

These segments suggest that the *de facto* structure of the tune was in part determined during performance, thus requiring the performers to think explicitly about past, present and future events. For example, because JH had taken two choruses in his solo, PT did the same.

Creative Processes An interesting exchange occurred at the very end of the group's performance of IGR. As shown in S47-48 and S41-S42 (above), JH and PT recalled the agreement to play the tag and planned for it. JH made the following statements immediately after S48:

49. Now, I didn't, I also extended the tag.
50. I could have made that, I could have made that tag a few bars, uh one or two bars shorter. By not extending it, I I kind of doubled the time.
52. Ok, as I said I I I doubled the length here, just to see what PT would do, how he'd react.
53. And I held that note out because that gave PT an opportunity to decide for both of us how exactly that was going to end.
54. Um and then I just threw that little tag of those couple notes on the end uh expecting he might react off of that,...

JH therefore elaborated upon the tag by doubling the time, holding out a note and adding a couple of notes to the tag. Each generated idea was intended to result in PT generating an idea in reaction to it, which would of course require evaluation. PT's reaction was as follows:

43. And right there I'm thinking, should I put a tag after his little ending there, but I decided to just let him have the final word.

S54 (above) concludes with JH saying "and he chose not to. And that was his choice." This example therefore shows cycle of idea generation (by JH), evaluation of those ideas by (PT), and finally JH's evaluation of PT's evaluation.

Discussion and Conclusions

The statistical analysis suggests a great degree of stability in creative and temporal cognition across the various conditions. Groups may therefore have applied similar cognitive strategies, regardless of the conditions of performance. The analysis of the "I Got Rhythm" protocols for Group One provides additional insight into how improvisers collaborate while simultaneously abiding by constraints of an evolving musical structure and generating, evaluating and executing new ideas.

Temporal cognition is necessary when a tune's structure evolves in real time. A theory of improvisation, even for the performance of standard tunes, should therefore include explicit modeling of temporal reasoning (see Johnson-Laird, 2002 and Ramalho et al., 1999 for discussions on both sides of this issue). A key consideration is range of planning (Palmer, 1997), since the current study and others (Sarath, 1996) have suggested that improvisers engage in contingency-based reasoning during performance. This study used prompted retrospective verbal protocols as primary data sources. Data on physical movements (Palmer, 1997) and cues and communications (Brinner, 1995) of performers may be useful in triangulating the results.

Further work is needed in understanding the role of knowledge and experience in the production of new musical ideas. A large body of work (see Pressing, 1984) shows that skilled improvisers draw upon and adapt highly resilient motifs during performance. Some evidence (Berliner, 1994) suggests that the use of these motifs can be conscious, though this claim has not been rigorously tested.

The results show that some creative and temporal processes may themselves be highly collaborative. Indeed, as suggested by Pressing (1984), the nature of improvised performance demands that the all "acoustical events" must be folded into the performance. The protocols contained evidence of both routine and non-routine problems arising out of collaboration between duos.

Finally, as discussed by Johnson-Laird (1991, 2002), additional work is needed in expressing theories of improvisation as computer programs. The current study has provided some evidence that such programs should include mechanisms for reasoning about (i) evolving conceptions of musical structure (and therefore time), (ii) processes of creativity and (iii) how dependencies among group members are negotiated (e.g., Bongers, 1999; Walker, 1997) in order to deal with temporal constraints while thinking creatively (Ramalho et al., 1999). Such an approach ought to result in a theory of improvisation that seeks to explain how it occurs in a wide variety of domains.

Acknowledgements

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