Jazz Improvisation as a Model of the Creative Process: Heightened Perceptual Awareness and Sensitivity

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ABSTRACT

The process of creativity entails the production of novel and original work that takes into account the domain, the field, and the creator (Csikszentmihalyi, 1996). Here we report recent theoretical and empirical advances on jazz improvisation as a model for understanding the process of creativity. We propose a framework by which musicians can learn to become creative improvisers via simultaneous perceptual, cognitive, and social engagement. These learning processes translate to gaining active experience with musical structures (such as scales and chords), exposure to established works in the field, and ensemble improvisation with musical peers. Empirically we compare jazz musicians, classical musicians, and nonmusicians in a battery of psychophysical and EEG tasks. The psychophysical task (modified from Navarro Cebrian and Janata (2010)) entails perception and imagery of different musical scales, where participants' task is to judge whether the final pitch is too high, too low, or in tune. Jazz musicians show higher accuracy and a steeper psychometric function, suggesting heightened sensitivity to mistuned pitches given a tonal context. The EEG task (modified from Koelsch, Gunter, Friederici, and Schroger (2000)) compares expected, slightly unexpected, and highly unexpected chord progressions while participants rate the pleasantness of each chord progression. Given this explicit judgment task we see that the P300, an ERP component known to reflect explicit awareness and target processing, is enlarged during unexpected tonal harmonies for jazz musicians, and furthermore its amplitude is positively correlated with the length of musical training. Taken together, our central theme is that the process of improvisation requires heightened awareness of, and sensitivity to, tonal possibilities within a musical context, which allow the individual to generate novel sequences that are acceptable but original within the domain of jazz music.

I. BACKGROUND

A. Introduction

What characterizes the minds of exceptionally creative people, and how can we learn from them? Creativity is the ability to produce work that is novel (original, unexpected), high in quality, and appropriate (Sternberg, Lubart, Kaufman, & Pretz, 2005). To be deemed creative, a piece of work is defined relative to the field in which it lives, and thus must demonstrate some domain-specific knowledge on the part of its creator (Csikszentmihalyi, 1997). In the domain of music, improvisation is a form of spontaneous creative behavior that requires "novel combinations of ordinary mental processes" (Limb & Braun, 2008). Jazz musicians have been examined as a model of creativity due to the emphasis of improvisation in jazz musical performances (Limb & Braun, 2008; Pinho, de Manzano, Fransson, Eriksson, & Ullén, 2014). Functional MRI studies of jazz improvisation and other forms of spontaneous musical creativity generally show results in the frontal lobe, described in some reports as changes in functional connectivity and/or a tradeoff in activity between medial and dorsolateral prefrontal cortices (Berkowitz & Ansari, 2008; Donnay, Rankin, Lopez-Gonzalez, Jiradejvong, & Limb, 2014; Limb & Braun, 2008; Liu et al., 2012; Pinho et al., 2014). A thorough review of these and other neuroimaging results, however, suggested that these data patterns are somewhat inconclusive and sometimes in conflict between different studies, with evidence for creativity being supported by both activation and deactivation of the frontal lobe (Dietrich & Kanso, 2010).

B. The process of creativity

The complexity of fMRI results on creativity to date may arise from the diverse strategies that participants bring to bear when generating their creative output. The process of creativity by its very nature entails divergent thinking, which is commonly tested using divergent thinking tests (Runco, 1991), in which participants are given open-ended questions and tasked with generating as many responses as possible (Torrance, 1968). In contrast to most cognitive (convergent thinking) tests, divergent thinking tests yield no single correct answer. This poses a difficulty for the neuroscience of creativity, as it could be elusive to track down a single mental process of novel idea generation. One view of how novel ideas are generated comes from the theory of Blind Variation and Selective Retention (Campbell, 1960), in which organisms explore multiple candidates of possible ideas before selecting and implementing the most appropriate options. Time-sensitive measures of brain activity, when coupled with precise measures of each participant's given problem space and their resultant creative outputs, may test the hypothesis of exploration followed by selection in the creative process.

C. Expectation and sensitivity as domain-specific knowledge

While the BVSR theory provides a domain-general account for the cognitive processes necessary for divergent thinking, expertise and domain-specific experience may cut down the process of blind variation. A seasoned creator, such as a well-trained jazz musician, may shortcut the variation process by efficient use of domain-specific tools such as perceptual imagery and musical expectation, which are informed by long-term knowledge and sensitivity to statistically frequent and probable events in their environment (Huron, 2006).

Additional support for expectation and imagery as domain-specific knowledge comes from jazz pedagogy, in which the cognitive components that comprise teaching improvisation are viewed not as unitary, but as involving anticipation, use of learned repertoire, emotive communication, feedback, and flow (Biasutti, 2015). In particular, the state of anticipation involves the interface between expectation and perceptual imagery, both of which are widely studied with well-established paradigms in music perception and cognition in behavioral (psychophysical) tests, and in time-sensitive measures of electrical brain activity (Janata & Paroo, 2006; Koelsch et al., 2000).

D. The Present Research

Here we apply psychophysical, electrophysiological, and psychometric tools from music perception and cognition research to clarify our understanding of creativity. Specifically, we examine the roles of divergent thinking, expectation, and perceptual imagery in jazz musicians as a model of creativity, compared with non-improvising musicians and nonmusician control groups. A major advantage of the following tests is that they offer specific, controlled stimuli to couple with neural measures, thus cutting down the problem space for a more rigorous understanding of jazz improvisation as a domain of creativity.

II. AIMS

A. Overall hypothesis

Here we combine psychophysical measures of auditory imagination and perception (Janata & Paroo, 2006), behavioral and electrophysiological measures of musical expectation (Koelsch et al., 2000), and domain-general measures of divergent thinking (Torrance, 1968), to test the hypothesis that spontaneous musical creativity depends on 1) heightened perceptual awareness and more accurate mental imagery, 2) increased sensitivity to and awareness of unexpected events, and 3) heightened domain-general divergent thinking abilities. We test this hypothesis using jazz musicians as a model of spontaneous musical creativity, compared with non-improvising musicians and non-musician controls.

III. METHOD

A. Subjects

Subjects were recruited from Wesleyan University or the Hartt School of Music in exchange for monetary compensation or partial course credit. Subjects gave informed consent as approved by the Institutional Review Boards of Wesleyan University and Hartford Hospital.

Table 1. Subject characteristics in Jazz musician, Control (non-jazz) musician, and Non-musician groups

	N	% Female	Age (years) M(SD)	Pitch Discrim (Hz) M(SD)	Raw IQ (Shipley, 1940) M(SD)	Training Onset (years) M(SD)	Training Duration (years) M(SD)
Jazz Musicians	17	11.8	20.1 (1.5)	4.1 (3.2)	17.5 (1.8)	7.9 (2.8)	8.7 (3.4)
Control Musicians	16	50.0	22.4 (5.9)	5.0 (2.2)	16.5 (1.6)	8.8 (3.4)	10.0 (4.6)
Non-musicians	24	62.5	19.0 (1.1)	14.4 (13.6)	16.6 (2.3)	9.3 (2.8)	2.1 (2.1)

B. Scale Imagery Task

Participants listened to scales (either major, harmonic minor, or blues) and judged whether the last note was modified in pitch. The scales were played using Max/MSP and each note lasted for 250 ms with an inter-onset interval of 600 ms. All 12 keys were used randomly throughout the experiment with starting notes of F#3 (184.997 Hz) through F4 (349.228 Hz). There were 108 trials total with a block of 36 trials for each scale block, for which the order was rotated for each participant. The last note alterations were ±0, 25, 50, 75 and 100 cents and these alterations were randomized within each scale block.

There were two conditions: perception and imagery. For the perception condition participants were asked to judge whether the last note was higher, lower, or the same as the expected pitch. In the imagery condition the two second-to-last notes of the scale were silent, and participants were asked to imagine these two notes in the silent gap and still judge the last note. For each condition there was a practice round of 10 trials during which participants received feedback on the screen and the experimenter monitored their accuracy to make sure they understood the task.

Linear psychometric functions were fitted to yield the slope for imagery and perception conditions for each individual. General accuracy was compared in addition to slopes of psychometric functions between groups.

C. EEG Harmonic Expectation Task

Stimuli consisted of chord progressions that were either expected, slightly unexpected, or highly unexpected (figure 1). The participants were instructed to listen to each chord progression and rate their preference for it on a scale from 1-4, with the 1 being dislike and 4 being like. The trials were arranged in blocks of 60, and each participant completed at least 3 blocks (maximum 6 blocks). EEG was recorded using PyCorder software from a 64-channel BrainVision actiCHamp setup with electrodes corresponding to the international 10-20 EEG system. The recording was continuous with a raw sampling rate of 1000 Hz. EEG recording took place in a sound attenuated, electrically shielded booth.

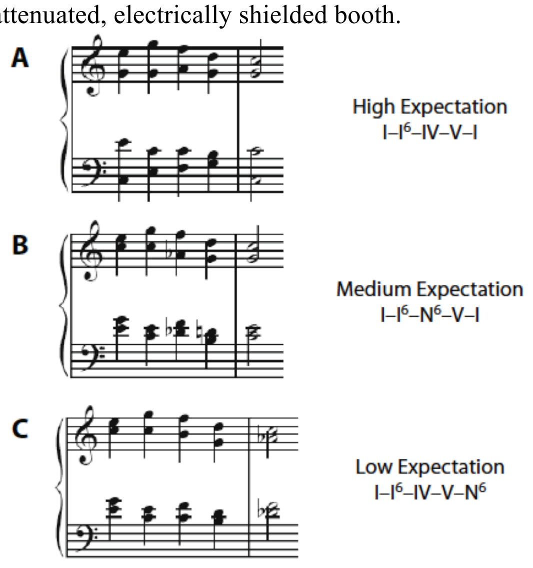

Figure 1. Example high, medium, and low expectation chord progressions.

Raw EEG data were imported to BrainVision Analyzer for analysis. Preprocessing included applying infinite impulse response filters with a low-pass cutoff of 30 Hz and a high-pass cutoff of .5 Hz. Raw data inspection was used to exclude data points with a higher gradient (>50uV/msec), high mins and max (>200uV), and extreme amplitudes (-200 to 200 uV). Ocular correction ICA was also done for each participant. The data were then segmented into chords and the trials were averaged and baseline corrected. We compared ERP traces for high, medium, and low expectation chords among the groups. We also plotted difference waves for medium minus high expectation and for low minus high expectation. Peaks for each subject were then exported from BrainVision Analyzer and analysed separately in SPSS.

D. Divergent Thinking Task

Participants responded to 6 open ended prompts for three minutes (Torrance, 1968). Participants were told that the task was a measure of general creativity and that they should try to give as many answers as they could. Participants' responses were coded for fluency and originality. Fluency was calculated as the number of unique responses. Responses from 16 control participants (nonmusicians) were used to create a baseline for originality. The participants were then scored for originality with unique responses receiving 3 points, responses that occurred once in the baseline receiving 2 points, and responses that occurred twice in the baseline receiving 1 point.

IV. RESULTS

A. Scale Imagery Task

A mixed factor ANOVA on the dependent variable of accuracy with the between-subjects factor of group (Jazz musicians, Non-jazz musicians, Non-musicians) and the within-subjects factor of task (perception vs. imagery) showed significant main effects of group ($F(2,33) = 22.8$, $p < .001$) and task ($F(1,33) = 21.0$, $p < .001$) but no task-by-group interaction ($F(2,33) = .65$, n.s.). A mixed-factor ANOVA on the dependent variable of slope, with the between-subjects factor of group and the within-subjects factor of task, showed a main effect of group ($F(2,33) = 11.2$, $p < .001$) and a main effect of task ($F(1,33) = 23.3$, $p < .001$) but no significant interaction between group and task ($F(2,33) = .027$, n.s.). These results, also shown in Figure 2, confirm that jazz and non-jazz musicians are more accurate at detecting mistuned scales in both perception and imagery.

B. EEG Harmonic Expectation Task

1) Behavioral Data. A mixed factor ANOVA with the within-subjects factor of expectation (high, medium, low) and the between-subjects factor of group (Jazz, Non-jazz including musicians and non-musicians) showed a main effect of expectation ($F(2,21) = 13.6$, $p < .001$) on preference ratings, as well as an interaction between expectation and group ($F(2,21) = 5.3$, $p = .014$). Preference ratings showed that jazz musicians prefer the medium expectation condition ($t(10) = 3.5$, $p = .005$) as compared to the non-jazz subjects (including non-jazz musicians and non-musicians) who prefer the high expectancy chords. While all groups showed lowest preference ratings for the low expectation condition, ratings for the low expectation condition was higher for the jazz musicians ($t(22) = 2.2$, $p = .03$), suggesting higher tolerance for unexpected events among the jazz group. This provides support for the notion that affect is aroused in music by slight violations of expectations (Meyer, 1956).

2) ERP Data. A mixed factor ANOVA on the dependent variable of ERP amplitude during the last chord, with the between-subjects factor of group and the within-subjects factor of expectancy (low vs. high) showed a significant main effect of expectancy and a significant interaction between expectancy and group for electrodes P2, P4, and PO4 between 410-480 ms and F8 and FT8 between 220 and 260 ms (See Table 2 for and F and p values).

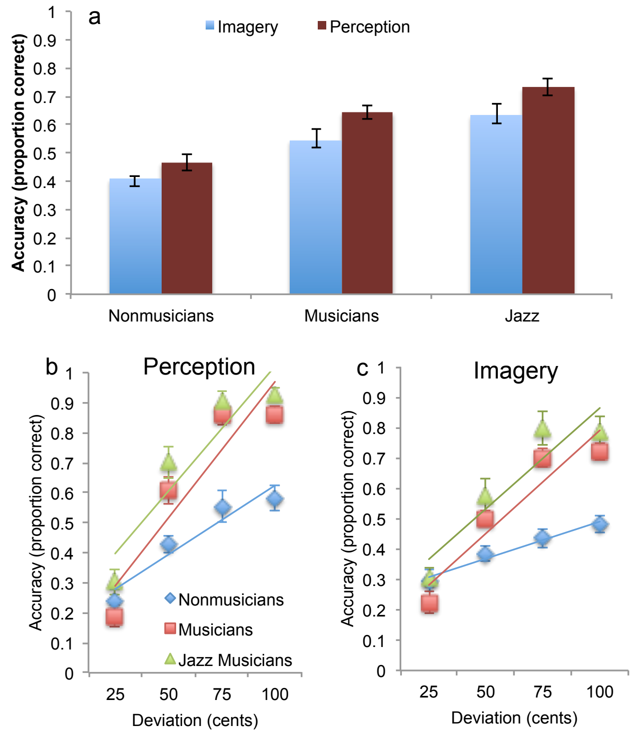

Figure 2. a. Accuracy on scale perception and imagery. b. Psychometric functions for scale perception task. c. Psychometric functions for scale imagery task.

Table 2. Analysis of the ERP data via mixed factor ANOVA

Electrode	Time (ms)	Main Effect of Expectancy	Expectancy x Group Interaction
P2	410-480	F(1,33) = 29.3, p<.001	F(1,33)=4.1, p<.05
P4	410-480	F(1,33)= 28.1, p<.001	F(1,33)=4.3, p<.05)
PO4	410-480	F(1,33)=22.4, p<.001	F(1,33)=4.4, p<.05
F8	220-260	F(1,33)=8.1, p<.01	F(1,33)=3.7, p<.05
FT8	220-260	F(1,3)=6.4 p<.05	F(1,33)=4.6, p<.05

C. Divergent Thinking Task

One-way ANOVAs on the dependent variable of fluency, with the factor of group (Jazz musicians, Non-jazz musicians, Non-musicians) showed significant main effects for questions 3 ($F(2,31) = 8.7$, $p <.01$), 4 ($F(2,31) = 7.3$, $p <.01$), 5 ($F(2,31) = 6.6$, $p <.01$), and 6 ($F(2,31) = 4.4$, $p <.05$). One-way ANOVAs on the dependent variable of originality showed significant main effects for questions 2 ($F(2,31) = 3.6$, p

= .04), 3 (F(2,31) = 13.1, p <.001), 4 (F(2,31) = 12.0, p <.001), 5 (F(2,31) = 8.7, p =.001), and 6 (F(2,31) = 5.5, p =.01). The jazz musicians scored the highest out of the three groups on questions 4, 5, and 6 for fluency and questions 3, 4, 5, and 6 for originality followed by musicians and then non-musicians.

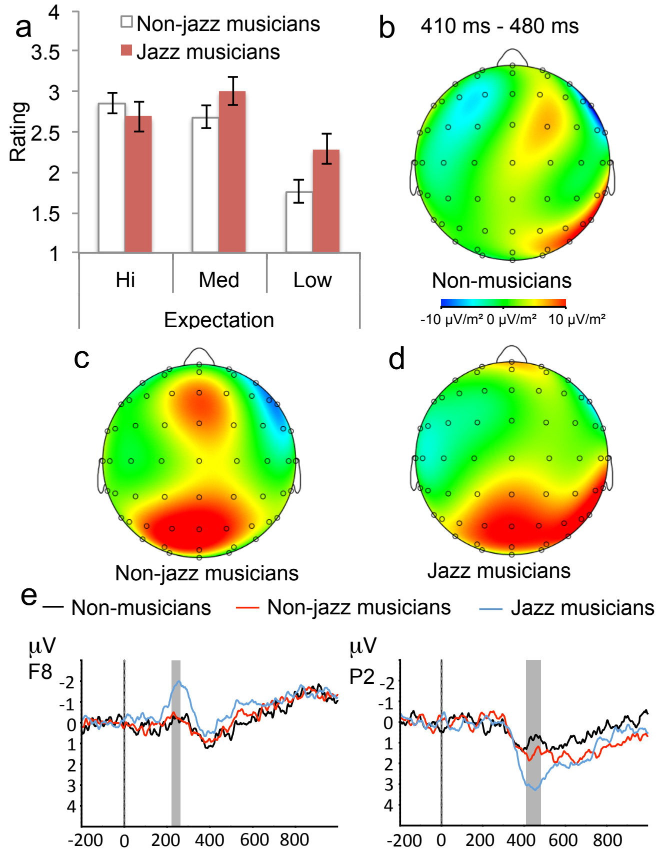

Figure 3. a. Behavioral ratings for high, medium, and low-expectation chord progressions. b-d. Topos plots of the 410-480 ms time window after the onset of the last chord in the low-expectation condition in non-musicians (b), non-jazz musicians (c), and jazz musicians (d). All color scales range from -10 to +10 µV. e. Difference waves (low minus high expectation) for last chords for right frontal (F8) and right parietal (P2) electrodes, showing enhanced early negativity and late positivity in jazz musicians.

V. DISCUSSION

Results from psychophysical, electrophysiological, and psychometric tasks converge to show superior auditory imagery and scale perception, heightened sensitivity to expectation, and higher domain-general creativity in Jazz musicians. These results provide support for the use of Jazz musicians as a model for creativity.

Psychometric functions show steeper slopes for both groups of musicians compared to non-musicians, suggesting that musical training in general enhances perceptual and imagery sensitivity. Auditory imagery is an important skill for musical performers of all genres, as musicians often have to be able to imagine an upcoming note or chord before it happens in order to craft their performance accordingly. Notably, these effects are observed despite similar baseline levels of performance on a pure tone pitch discrimination task (Table 1). By providing a musical context, the scale perception and imagery tasks assess a more central, memory-dependent strategy, and are thus more dependent on training compared to the lower-level pitch discrimination task.

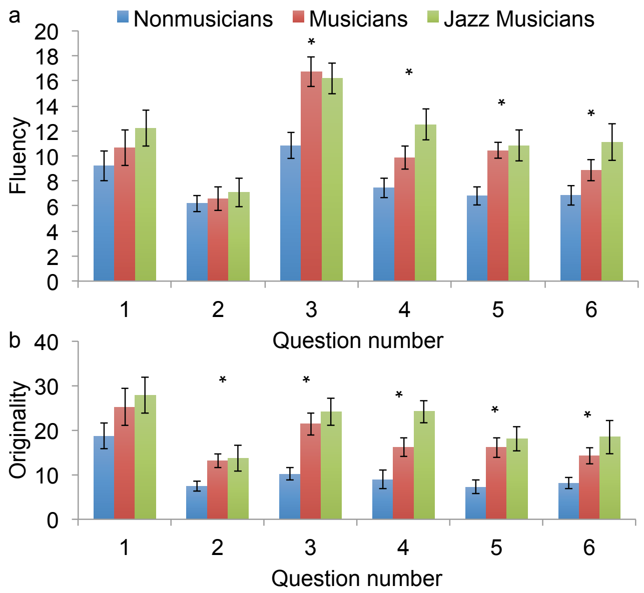

Figure 4. Results from divergent thinking task scored for (a) fluency and (b) originality. * = p < .05 (one-way ANOVAs).

Behavioral results for the EEG chord progression ratings task differ from previous studies (Loui & Wessel, 2007), which showed that musicians and non-musicians have similar preferences. Here, Jazz musicians' preference for the medium expectation chords as opposed to the high expectations chords may be due to the nature of Jazz where the rules are more free and meant to be broken in some instances of improvisation. The significantly higher rating of the low expectancy chords also suggests that Jazz musicians are more tolerant to chords that sound out of place. This may be explained by the experimental nature of jazz improvisation, where it is customary to embellish performances by violating expectations. In contrast to contemporary classical musical training, jazz improvisers are encouraged to play notes and chords that seem out of place, as many Jazz musicians use chords that seem out of place as a transition to a new tonal landscape or musical idea.

ERP results show interactions between group and expectation in right-hemisphere electrodes (table 2). This suggests that the different groups respond to the unexpected chords differently. Difference waves clearly show that Jazz musicians have larger Early Right Anterior Negativity (ERAN) and P3 (figure 3e). Interestingly, both the early negativity and the P3 components are right-lateralized in Jazz musicians, with the P3 especially more in the right posterior electrodes for the Jazz musicians and the left posterior and frontocentral electrodes for the Non-jazz musicians (figure 3b-d). This could be supported by neuropsychological findings on hemispheric asymmetry (Ivry & Robertson, 1997) as well as fMRI work on creative musical sequence generation (Villarreal et al., 2013), where the right hemisphere is shown to subserve holistic perception and creative thought. Together these results indicate that Jazz musicians have an enhanced sensitivity to harmonic expectation compared to the Non-jazz musician group and the Non-musician group. These findings are in contrast to no differences in low-level perceptual abilities and age of onset or number of years of musical training between non-jazz musicians and jazz musicians (as shown in the control pitch discrimination tasks), and no differences in IQ among the three groups.

The Jazz musicians' high performance on the DTT on 4/6 questions compared to Non-jazz musicians and Non-musicians indicates that Jazz musicians have a general advantage in creativity that transcends the domain of music. We believe that questions 1 and 2 may not have captured significant differences among the three groups because 1) the questions were especially ambiguous and resulted in extremely divergent answers, and 2) possible order effects as participants might have needed time to engage themselves fully in the task of divergent thinking. Nevertheless, the differences between the Jazz musicians and other two groups for the rest of the questions is striking given that there are no differences in IQ among the three groups.

VI. CONCLUSION

Jazz musicians in our present sample scored higher on domain-general creativity tasks. Psychophysical and electrophysiological measures suggest that they also possess heightened perceptual awareness of and sensitivity to unexpected events within a musical context. Taken together, results from domain-specific as well as domain-general tasks suggest that creativity entails being open to unexpected events within one's domain, as well as being more fluent and original in idea generation. The present results validate the use of jazz improvisation as a model system for understanding creativity, and further suggest that systematic violations of domain-specific expectations may provide a time-sensitive measure of the rapid and flexible real-time creative process.

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