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Creating Under Pressure: Effects of Divided Attention on the Improvised Output of Skilled Jazz Pianists

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A growing body of research suggests that jazz musicians concatenate stored auditory and motor patterns during improvisation. We hypothesized that this mechanism allows musicians to focus attention more flexibly during improvisation; for example, on interaction with other ensemble members. We tested this idea by analyzing the frequency of repeated melodic patterns in improvisations by artist-level pianists forced to attend to a secondary unrelated counting task. Indeed, we found that compared to their own improvisations performed in a baseline control condition, participants used significantly more repeated patterns when their attention was focused on the secondary task. This main effect was independent of whether participants played in a familiar or unfamiliar key and held true using various measurements for pattern use.

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Creativity research is typically focused on creative processes and products conceived without time constraints (Sternberg, Grigorenko, & Singer, 2004). Less research has been done in areas where the creative product is produced in real time. In music, the distinction is exemplified by composition and improvisation. A three-minute composition may take hours or days to create whereas a three-minute musical improvisation is created in exactly three minutes. In both areas the creative product is typically shaped by style, including frameworks for tonal and rhythmic structures. However, in improvisation it is necessary to produce this output very rapidly; in group improvisation, the musician may also need to attend to multiple external sources and shape the note choices accordingly.

The current study focuses on improvisational practices typical of soloists in the jazz style, in which the musicians improvise novel melodies in an interactive ensemble setting (Berliner, 1994). A typical jazz improvisation is shaped by the melody and chord structure of a given composition. The improviser creates novel melodies that reflect this structure both as related to harmonies and rhythmic feel in order to communicate with other accompanying musicians and the audience (Monson, 1996).

In order to successfully accomplish this task, the musician must perform and monitor multiple features of the performance, such as melody, harmony, rhythm, dynamics, articulation, and the playing of other musicians in the ensemble, simultaneously. Attending to all of these concurrent musical features is no easy task (Keller, 2001). Studies of divided attention show that performance decreases when attention must be divided amongst multiple tasks at once, especially when they are processed by similar mental resources (e.g., Klapp, 1979; Navon & Gopher, 1979; Pashler, 1994; Wickens, 2002). And yet, experienced musicians are somehow able to balance these competing demands during improvisation. This may be partly because, with practice, learned actions—even lengthy action sequences—can become automatized and stored as memorized patterns that require less active attention, freeing up additional resources in working memory (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). For example, in motor research, long action sequences have been shown to consist of concatenations of shorter memorized motion patterns known as Generalized Motor Programs—a basic building block of all movements (Park & Shea, 2005; Shea & Wulf, 2005). The importance of recurring sequences also extends to perceptual learning and information processing. For example, researchers who study language acquisition have reported that infants are able to decode patterns embedded within both natural and artificial languages (Saffran, 2003). These patterns are then used during language production in the form of motoric, sound, and meaning sequences that have been stored in memory to be reused later (Levelt, 2001).

Similarly, in the process of improvising, jazz musicians appear to use and re-use certain melodic patterns

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(Finkelman, 1997; Norgaard, 2014; Owens, 1974; Weisberg et al., 2004). A recent analysis of 48 improvised melodies recorded by alto saxophonist Charlie Parker revealed linked interval and rhythm patterns throughout his solos (Norgaard, 2014). Melodic patterns up to 30 notes in length reappeared in different solos, and 82.6% of all notes in the 48 improvisations analyzed started a four-interval pattern. These results align with a theoretical model introduced by Pressing (1988), who proposed that improvisers concatenate stored motor and auditory patterns during improvising.

Thus, it appears patterns are indeed used for the online creation of jazz improvisations. What is not clear is whether or not this strategy is used in order to ease attentional demands of improvisation. To examine this question the current study performed a cross-sectional investigation of the production of patterns across multiple improvisations within a single session under either high or low load attentional tasks (i.e., single- vs. dual-task, familiar vs. unfamiliar keys).

Because a "pattern" can take many forms, we adopted multiple objective definitions for what constitutes a pattern. In particular, our definitions can be characterized by two main factors: type (pitch vs. interval) and iterations (two vs. four). First considering type, a pattern might consist of a memorized note sequence that has the exact same note configurations. We defined such configurations as *pitch patterns*. For example, using MIDI pitch labels in which middle C is 60, a five-note pitch pattern consisting of an ascending major scale starting on middle C is then iterations of the sequence 60, 62, 64, 65, 67 (C4, D4, E4, F4, G4). In contrast, a pattern might be based not on the same actual pitches but rather on the same melodic contour based on the distance between adjacent notes (measured in semitones). We defined these configurations as *interval patterns*. For example, the ascending scale pattern previously described would consist of the interval pattern +2, +2, +1, +2. Interval relationships have previously been used to assess patterns in jazz improvisation using a computer analysis paradigm (Norgaard, 2014; Weisberg et al., 2004).

Next considering iterations, patterns were defined more or less stringently by varying the number of recurrences (across improvisations within a session) required for a note sequence to be considered a pattern. For example, the interval sequence +2, +2, +1, +2 could be considered a pattern if it occurred at least twice (less stringent definition) or at least four times (more stringent definition).

Attention was manipulated using a dual-task paradigm in which musicians were either required to only produce a jazz improvisation (single-task condition) or to produce the improvisation while simultaneously performing a secondary task (dual-task condition), which required musicians to count a series of rhythmically unrelated "taps" applied to one shoulder while ignoring taps received on an opposing shoulder (Fidlon, 2011). This task is a tactile adaptation of counting tasks used in the visual (e.g., Wu, Kansaku, & Hallett, 2004) and auditory domains (e.g., Cohen & Poldrack, 2008), which have been shown to be effective in causing decrements to a primary task. As such, we theorize that counting taps should require similar attentional resources as those used to play the piano. If musicians do utilize stored patterns—either explicitly or implicitly—to help mitigate the cognitive demands of creating novel music in real time, we hypothesize that musicians will produce more patterns while attending to a simultaneous secondary task compared with their performances when no additional demands were imposed.

Finally, we examine whether familiarity of key influences the use of patterns. We ask whether musicians produce more patterns while playing in a self-identified familiar or unfamiliar key and whether or not this familiarity interacts with the presence or absence of a secondary task. On the one hand, it is possible that musicians may have a greater number of motor patterns stored in long-term memory for the familiar key as compared to the unfamiliar key. This greater number of available motor patterns may lead to a larger number of patterns being present in the performances in the familiar key than in the unfamiliar key. On the other hand, it is possible that the act of playing in the unfamiliar key itself may place higher attentional demands on the musician, similar to the dual-task condition. As a consequence, a musician might produce a greater number of patterns in the unfamiliar key as compared to the familiar key in order to reduce these demands.

Method

PARTICIPANTS

Twenty-five adult experienced and professionally active jazz pianists (21 males, 4 females; age range: 19-58 years; musical experience: $M = 32.2$ years, $SD = 14.2$ years) participated in the study. Participants were recruited through word of mouth and paid $50 for their participation. All participants provided informed consent and completed a brief preliminary interview in which they reported their musical experience and demographic information. Additionally, they identified their most comfortable key (hereafter "familiar") and least comfortable key (hereafter "unfamiliar") for improvising blues solos in a major key. Three participants' data

TABLE 1. *Participant Demographics* ($n = 22$)

	M	*SD*
Age	38.68	13.27
Experience playing piano	31.40	14.50
Experience playing jazz	20.77	13.27
Experience performing professionally	18.61	13.21

were excluded due to failure to follow the experimenter's instructions. Demographic and experience information is listed in Table 1.

PROCEDURE

All participants were tested in a quiet university music department office. Participants improvised eight jazz solos over backing drum tracks under varying conditions. Backing tracks were played for the participants over loudspeakers and consisted of a solo drummer playing a jazz-feel 4/4 rhythm at a moderate tempo (quarter note = 180 bpm) for 60 measures (equivalent to five cycles, or "choruses," of the 12-bar blues form). All solos were performed on a Yamaha P-80 electronic keyboard using the "grand piano" patch. MIDI output from the keyboard was sent directly to a computer audio workstation. Before starting, participants were given an opportunity to familiarize themselves with the keyboard and to briefly listen to a sample drum track for the purpose of adjusting the keyboard and drum track volumes to comfortable levels. The experimenter then explained that some trials would include simultaneously completing a secondary task while improvising.

Training phase. Participants were familiarized with the secondary (Tapping) task through two practice trials. During secondary task trials, an experimenter stood behind the participant and held two pencils (one in each hand) approximately two inches above the participant's right and left shoulders. The experimenter then lightly tapped the participant on their right and left shoulders with the eraser-ends of the pencils during the participant's performance. Participants were instructed to count only the taps on the shoulder assigned (right or left) for that trial while still adhering to the blues form in the improvised solo. To ensure that neither participants nor experimenter could anticipate the timing of the taps, the experimenter followed a set of automated visual cues from a video monitor positioned in such a way as to not be visible to the participant. Five different cue videos were utilized, counterbalanced across trials. Each cue video contained between 12 and 19 tap cues per shoulder, spaced one to three seconds apart. All tap cues were arrhythmic with respect to the music. In the first practice trial, participants simply listened to the backing drum track, without playing, and counted taps on the assigned (right or left) shoulder. For the second practice trial, participants performed a 12-bar jazz blues melody in a major key repeatedly of their own choosing while counting taps on the assigned shoulder. After each trial, participants reported the number of taps they counted on the assigned shoulder. Additionally, they rated their confidence in the accuracy of their count on a 1-10 scale, with 1 defined as *totally guessing* and 10 as *100% sure*. For all trials, participants also reported their perceived level of effort (i.e., 1-10 scale with 1 defined as *easy* and 10 as *highly effortful*) and the level of stress experienced performing the task (i.e., 1-10 scale with 1 defined as *no stress* and 10 as *highly stressful*). After the participant was familiar with the tapping task, the Improvisation Phase began.

Improvisation phase. Participants improvised eight solos in total—four in the participant's familiar key and four solos in their unfamiliar key (as self-reported in the preliminary interview) over the 12-bar blues form in major. They were asked to play a melodic single-line improvisation in the right hand while accompanying themselves with chords in the left. Participants were free to choose their preferred variant of the blues chord progression as is common for jazz blues improvisations, though we instructed them to use a major rather than minor key progression. Within each key, two trials included simultaneously completing the secondary tapping task while the remaining two trials did not include the tapping task. The combination of these two variables (i.e., Key and Task) yielded four conditions: Familiar/Tapping; Familiar /No Tapping; Unfamiliar/Tapping; Unfamiliar/No Tapping. The task was counterbalanced across each key. As during the training phase, tap counts (where applicable), confidence ratings, stress ratings, and effort ratings were collected. At the completion of the final trial, participants were asked to recount any strategies they used to keep track of the tap count during tapping trials. Participants indicated that they found the Tapping condition manageable but difficult. Some indicated that they often started by focusing on the tap count but later in the improvisation abandoned the count. Other participants indicated they used specific strategies to keep track of the count and had no problem with the secondary task.

ANALYSIS

In order to assess pattern use, we analyzed the number of unique patterns in each trial as compared to all trials of that participant. The analysis only included the

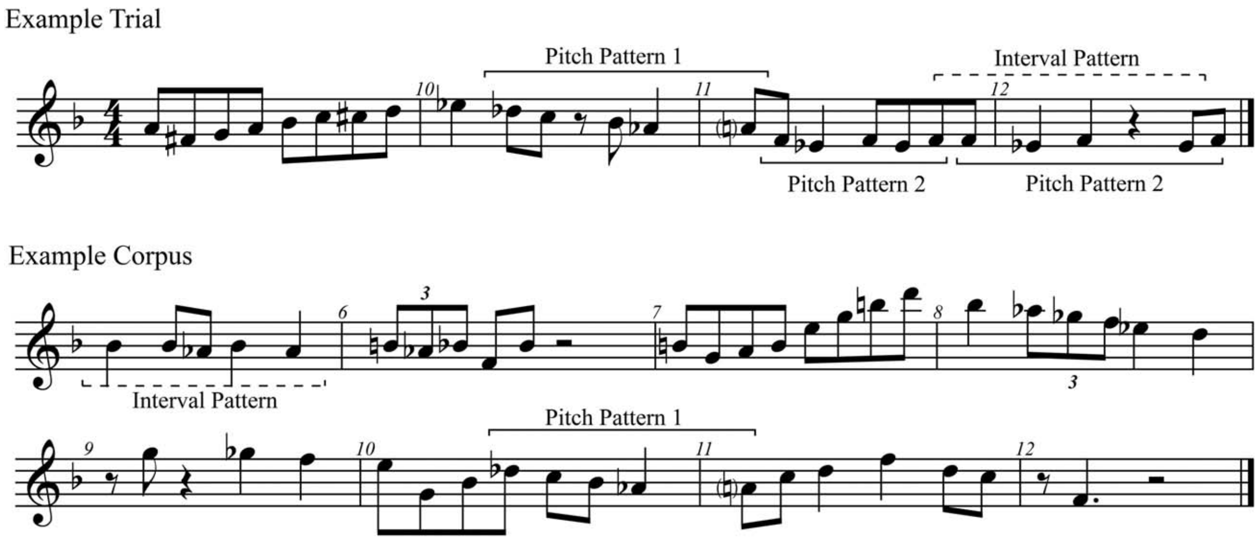

FIGURE 1. Example of trial and corpus (for illustration only). The pitch patterns are marked with a solid bracket and the interval pattern with a perforated bracket. Measure numbers correspond to the measure count within the blues form (1-12).

monophonic improvisation played in the right hand. In cases where the improvisation inadvertently included more than one note played simultaneously, the higher pitch was chosen for analysis. We used various criteria to identify patterns: Initially, we searched for exact repetitions of five-note melodic figures. We chose this length based on pattern-detection criteria employed in previous studies (Norgaard, 2014; Weisberg et al., 2004). For this analysis, a five-note pitch pattern was defined as a five-note melodic figure that occurred at least twice within the same trial and/or within other trials played by the same participant (hereby referred to as the participant corpus). Figure 1 shows a shortened trial and corpus for illustration purposes. Here the number of unique pitch patterns in the trial would be two, where one is repeated in the corpus (marked Pitch Pattern 1) and the other is repeated within the same trial (Pitch Pattern 2). In the second analysis, we applied a similar definition to melodic figures that contained identical interval patterns, regardless of the pitches used. In this analysis, five-pitch patterns were reanalyzed as four-interval patterns, and the direction (ascending/descending) and distance (in semitones) between adjacent notes was evaluated. For example, the five-pitch pattern in Figure 1 (Pitch Pattern 1: D♭, C, B♭, A♭, A) below would translate to the four-interval pattern -1, -2, -2, $+1$. This analysis therefore captures recurrences of the initial five-pitch patterns but adds transpositions of those patterns by including matching interval patterns. In Figure 1, the number of four-interval patterns in the trial is three as the pattern 0, -2, $+2$, -2 (marked Interval Pattern) is added to the two five-pitch patterns. In the third and fourth analysis, we again searched for pitch or interval patterns but applied a more stringent criterion of at least four occurrences within the trial and/or participant corpus for a figure to be counted as a pattern.

All pattern searches were implemented in Matlab using a custom algorithm that went through the following steps: To find pitch patterns in a given trial, the computer would evaluate the first five-note figure consisting of the notes A4, F♯4, G4, A4, B♭4 in the example listed in Figure 1. Since this figure does not appear again in the trial or the corpus, it is not counted as a pattern. The algorithm then considers the five-note sequence that starts on note 2 (F♯ in Figure 1). The same is true for the next seven notes until the melodic figure starting on the second note in the second measure. This same figure also appears in the sixth measure of the corpus and is therefore considered a pattern (marked Pitch Pattern 1). In this way, the algorithm evaluated each possible pitch pattern in the trial as compared to the rest of the possible pitch patterns produced in both the trial and entire corpus. For this analysis, timing was generally disregarded. However, in order to focus on notes that the participant may have conceived of as connected into a pattern, melodic figures that contained notes or rests longer than four beats were not counted as patterns (Norgaard, 2014).

In order to compare trials with a different number of notes we adopted a method used in corpus linguistics that allows for the comparison of texts of different length (Covington & McFall, 2010). Figure 1 only contains 24 notes. In the current study, the trials contained between 153 and 484 notes ($M = 295.6$, $SD = 63.8$) even though participants played over the same number of choruses in each trial. The number of notes used appeared to be influenced by the musical key the trial was played in. In a repeated measures ANOVA using a 2 × 2 design with the factors Key (Familiar vs. Unfamiliar) and Task (Tapping vs. No Tapping), we found a significant main effect for Key, $F(1, 21) = 35.28$, $p = .000$, $\eta_p^2 = .63$, but no main effect for Task, $F(1, 21) = 3.08$, $p = .09$, $\eta_p^2 = .13$, and no significant interaction, $F(1, 21) = 0.11$, $p = .74$, $\eta_p^2 = .005$. Since participants played significantly more notes in the familiar key trials compared to the unfamiliar key, we had to adjust the pattern finding algorithm. We adapted a method used in corpus linguistics to calculate the type-token ratio using a moving window average (Covington & McFall, 2010). Here we created a computer algorithm that evaluated the number of patterns per 100 notes and then averaged the results. In other words, the computer started by analyzing whether the figure starting on the first, second, third. . . . hundredth note was a pattern as outlined above. It repeated this analysis starting on the second note to note number 101. Finally it calculated the mean of these separate analyses. This number then represents the number of patterns per 100 notes in each trial (accidental patterns across trial boundaries were not considered) and is therefore independent of the total number of notes in the trial. The computerized analysis was validated by constructing an artificial trial set with known values that was then analyzed in the same batch procedure as the actual data.

Results

VALIDITY OF MANIPULATIONS

In order to examine whether participants' familiarity with the musical key of their improvisations influenced their ability to perform the counting task, we evaluated the accuracy of the tap count and the participants' confidence in the reported count. Confidence ratings added additional context to our evaluation of secondary task performance: A low confidence rating might reveal an accurate count as a lucky guess whereas a high confidence rating paired with an accurate count might be indicative of a participant's ability to focus a greater amount of attention on the tapping task. To evaluate counting accuracy, the absolute value of the counting error (i.e., the amount by which the participant over or underestimated the number of taps) was calculated for each trial. The mean counting error and confidence ratings then were calculated for both of the trials in the Familiar and Unfamiliar Keys separately. Paired samples t-tests revealed that there was no difference in the counting error between the Familiar ($M = 5.50$, $SD = 2.92$) and Unfamiliar Keys [$M = 5.71$, $SD = 2.91$; $t(21) = -0.39$, $p = .700$; see Figure 2A]. A difference was, however, found between participants' confidence ratings for the Familiar ($M = 4.45$, $SD = 2.24$) and Unfamiliar Keys [$M = 3.11$, $SD = 2.04$; $t(21) = 3.53$, $p = .002$; see Figure 2B]. This implies that participants were less confident in their ability to perform the counting task while performing in the unfamiliar key although this did not appear to affect their actual performance on the task. Furthermore, no correlations were found between the mean counting error or confidence rating and the number of patterns produced in any of the tapping conditions.

We also analyzed the stress ratings from participants after each trial to subjectively measure the participants' levels of cognitive engagement. A 2 x 2 repeated measures ANOVA for the mean stress rating (Figure 3) revealed a significant main effect for Key, $F(1, 21) = 14.89$, $p = .001$, $\eta_p^2 = .42$, and for Task, $F(1, 21) = 11.66$, $p = .003$, $\eta_p^2 = .36$, revealing that participants

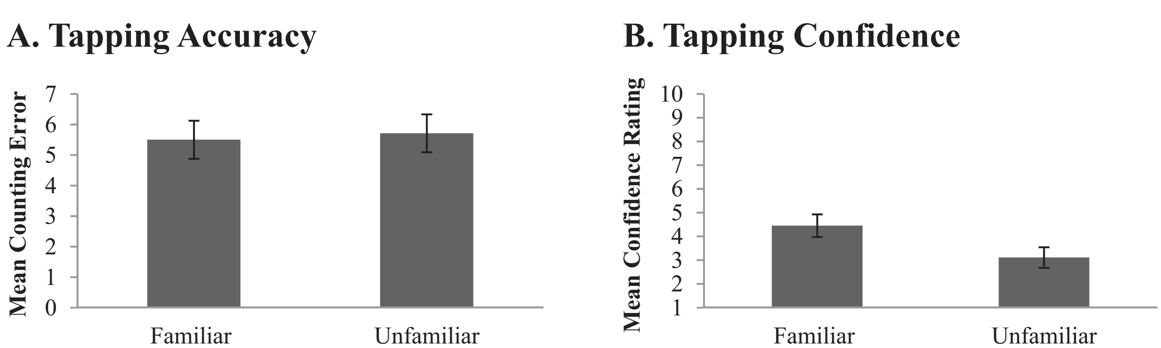

FIGURE 2. Results of Tapping Task while playing in the Familiar and Unfamiliar Keys for (A) the mean of the absolute value of the counting error and (B) the mean confidence rating on a scale of 1 (*totally guessing*) to 10 (*100% sure*) for accuracy.

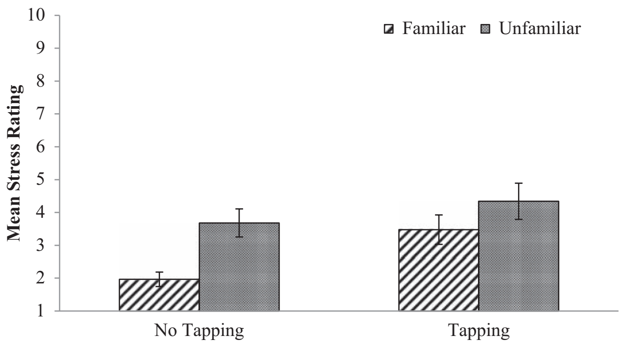

FIGURE 3. The mean stress rating on a scale of 1 (*no stress*) to 10 (*highly stressful*) for both levels of Key (i.e., Familiar, Unfamiliar) and Task (No Tapping, Tapping).

found it more stressful to play in an Unfamiliar ($M =$ 4.01, $SD = 2.31$) than Familiar Key ($M = 2.72$, $SD =$ 1.81) and in the Tapping Task ($M = 3.91$, $SD = 2.37$) than in the No Tapping Task ($M = 2.82$, $SD = 1.80$), respectively. The interaction between Key and Task was also significant, $F(1, 21) = 10.22$, $p = .004$, $\eta^2_p = .33$. Probing of the simple main effects revealed that participants found it more stressful to perform while simultaneously completing the Tapping Task (Familiar: $M = 3.47$, $SD = 2.10$; Unfamiliar: $M = 4.34$, $SD = 2.58$) than performing in the No Tapping Task (Familiar: $M =$ 1.97, $SD = 1.03$; Unfamiliar: $M = 3.68$, $SD = 2.00$) while playing in both the Familiar, $F(1, 21) = 16.10$, $p = .001$, $\eta^2_p = .43$, and Unfamiliar, $F(1, 21) = 4.54$, $p = .05$, $\eta^2_p =$ .18, Keys. The analysis of the collected effort ratings revealed similar effects. These results demonstrate that participants viewed performing in the Tapping Task and Unfamiliar Key as successfully increasing the level of difficulty.

MAIN ANALYSIS

Interval and pitch data were analyzed separately using 2 × 2 repeated measures ANOVAs with Key (Familiar vs. Unfamiliar) and Task (Tapping vs. No Tapping) as factors. Furthermore, these analyses were conducted for interval and pitch when a pattern was defined less stringently (i.e., two or more iterations) or more stringently (i.e., four or more iterations). The analyses of interval data are displayed in Figure 4 and pitch data in Figure 5.

Interval analysis. Interval data were first analyzed under the less stringent criterion in which a four-interval sequence only needed to occur twice to qualify as a pattern. In order to be counted, one iteration of the pattern had to occur within the 100-note moving window within the trial. The second iteration could be anywhere within the trials of the participant. This analysis revealed a significant main effect of Task, $F(1, 21) =$ 13.31, $p = .002$, $\eta^2_p = .39$, showing that participants produced more interval patterns in the Tapping Task ($M = 37.50$, $SD = 8.18$) than in the No Tapping Task ($M = 35.09$, $SD = 7.50$). The main effect of Key was not significant, $F(1, 21) = 0.63$, $p = .44$, $\eta^2_p = .03$, nor was the interaction between Task and Key, $F(1, 21) = 0.64$, $p = .432$, $\eta^2_p = .03$.

Similar results were obtained under the more stringent criterion in which four or more instances of a four-interval sequence were required to qualify as a pattern. A marginally significant main effect of Task was found, $F(1, 21) = 3.71$, $p = .07$, $\eta^2_p = .15$, revealing that the number of interval patterns that participants produced in the Tapping Task ($M = 18.19$, $SD = 6.72$) was marginally greater than in the No Tapping Task ($M = 17.19$, $SD = 3.17$). Neither the main effect of Key, $F(1, 21) =$ 1.34, $p = .26$, $\eta^2_p = .060$, nor the interaction between

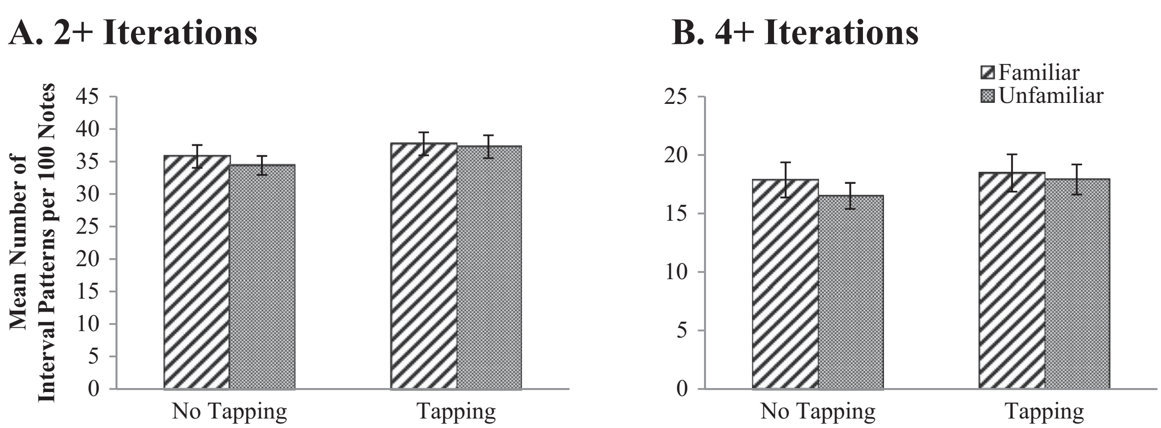

FIGURE 4. Mean number of interval patterns per 100 notes for Familiar Key (striped) versus Unfamiliar Key (solid) and No Tapping Task (left) versus Tapping Task (right) when a pattern is defined as being repeated two or more times (A) or four or more times (B).

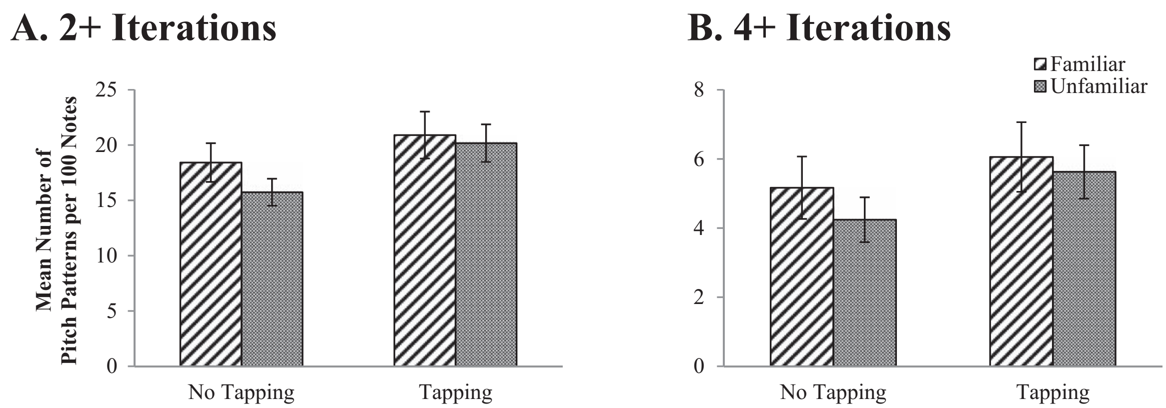

FIGURE 5. Mean number of pitch patterns per 100 notes for Familiar Key (striped) versus Unfamiliar Key (solid) and No Tapping Task (left) versus Tapping Task (right) when a pattern is defined as being repeated two or more times (A) or four or more times (B).

Task and Key, $F(1, 21) = 1.01$, $p = .33$, $\eta_p^2 = .05$, were significant.

Pitch analysis. Under the less stringent criterion for a pattern (i.e., two or more iterations of a five-note pitch sequence), the analysis of pitch data also revealed a significant main effect of Task, $F(1, 21) = 19.48$, $p < .000$, $\eta_p^2 = .48$, showing that participants produced more pitch patterns in the Tapping Task ($M = 20.54$, $SD = 8.91$) than in the No Tapping Task ($M = 17.08$, $SD = 7.13$). The main effect of Key, $F(1, 21) = 2.26$, $p = .15$, $\eta_p^2 = .10$, was not significant. However, the interaction between Task and Key, $F(1, 21) = 3.89$, $p = .06$, $\eta_p^2 = .16$, was marginally significant. Because this interaction approached significance, we decided to probe the simple main effects of the two levels of Task. While the two levels of Key (i.e., Familiar vs. Unfamiliar) did not differ within the Tapping Task, $F(1, 21) = 0.35$, $p = .56$, $\eta_p^2 = .02$, a significant difference was found within the No Tapping Task, $F(1, 21) = 4.68$, $p = .04$, $\eta_p^2 = .182$, such that participants produced more patterns in the Familiar Key ($M = 18.42$, $SD = 8.22$) than in the Unfamiliar Key ($M = 15.74$, $SD = 5.72$).

The analysis of pitch data under the more stringent definition of a pattern (i.e., four or more iterations of a five-note pitch sequence) also revealed a significant main effect for Task, $F(1, 21) = 10.67$, $p = .004$, $\eta_p^2 = .34$, showing that participants produced more patterns in the Tapping Task ($M = 5.84$, $SD = 3.95$) than in the No Tapping Task ($M = 4.70$, $SD = 3.67$). Neither the main effect for Key, $F(1, 21) = 1.31$, $p = .27$, $\eta_p^2 = .06$, nor the interaction between Key and Task, $F(1, 21) = 0.78$, $p = .39$, $\eta_p^2 = .04$, were significant.

Discussion

Here we investigated the presence of melodic patterns in improvisations by artist-level jazz pianists. Participants improvised in a familiar and unfamiliar key in both single and dual-task conditions. Confirming our hypothesis, we found that improvisers relied more heavily on recurring melodic patterns in the dual-task condition in which their attention was diverted away from the improvisation task. This finding held true for both pitch and interval patterns under both the less and more stringent definitions of a pattern (albeit with marginal significance in the case of the more stringently defined interval patterns); however, no such differences were found between the performances in the familiar and unfamiliar keys. These results thus suggest that in order to regulate the attentional demands of completing the counting and improvising tasks simultaneously, pianists indeed relied more heavily on a strategy of pattern use. As such, we conclude that the use of patterns stored in memory is likely commonplace in the production of all improvisations, and propose that the reliance on patterns increase when greater demands are placed on improvisers' attentional resources.

Our results suggest that the ability of experienced jazz improvisers to create coherent melodies—even when their attention is diverted—may hinge on their ability to reuse material learned previously (Norgaard, 2014; Pressing, 1988). This observation may not be surprising to skilled improvisers, who are often well aware of the presence of habitual figures in their own improvised performances (Berliner, 1994; Norgaard, 2011). An artist-level pianist in a previous study described the process of improvisation as connecting previously learned "Lego blocks" (Norgaard, 2008). Another participant from the same study outlined how a two-measure figure was inspired by a previously learned version yet adapted to the current context. Such reports align with our findings here and with a model of the psychological processes underlying improvisation by Jeff Pressing, in which learned auditory and motor patterns play a central role (Pressing, 1988). However, it is important to differentiate idiomatic phrases (i.e., licks) used deliberately (Berliner, 1994; Norgaard, 2011) from shorter patterns that may be inserted automatically in a fast subconscious process (Norgaard, 2014; Pressing 1988). We believe the latter process may account for the observed results.

The ability to selectively allocate attention may allow improvisers to focus on various aspects of performance. We speculate that jazz soloists' attention is often allocated to interactions with other ensemble members, a central feature of jazz performance (Berliner, 1994; Monson, 1996). Monson (1996) outlines how musicians in a trio setting communicate using musical ideas. She notes that this communication can include both overt musical exchanges and obscure references to a shared history. Our findings may help to demonstrate how such communications can be exchanged between musicians without affecting the integrity of the solo improvisation.

One major concern in the current study was whether participants would make a serious effort to keep count of the taps. To assess this, we collected both stress and effort ratings after each trial, and analyzed counting error and confidence. Both the stress and effort ratings clearly showed that participants found improvising in the tapping condition more difficult, indicating a higher cognitive load. Interestingly, though participants felt less confident in their tap counts in the unfamiliar key, there was no significant difference in tap count error between key conditions. This would indicate that participants did indeed count in both key conditions when required to do so.

In the current study, participants may have sought novelty when playing in the single-task conditions in which their full attention was allocated to the improvisation, as demonstrated by a lower use of patterns in the No Tapping as compared to the Tapping conditions. Though most jazz musicians acknowledge using patterns, there appears to be a common sentiment that too many patterns reflect a less creative performance (Berliner, 1994; Norgaard, 2008). Yet here, when counting taps diverted the musicians' attention, novelty could have become less of a priority. Interestingly, our analysis of the pitch patterns using a less stringent criterion for a pattern revealed a marginally significant interaction between Key and Task driven by the lower number of patterns in the Unfamiliar as compared to the Familiar key condition in the No Tapping task. While caution must be taken while interpreting marginally significant effects, this finding could reflect the possibility that participants simply have fewer patterns available to them in the unfamiliar key. In an experiment conducted by Goldman (2013), participants were unable to execute known auditory patterns in an unfamiliar key presumably because the corresponding motor movements were not available.

In order to avoid subjective judgments related to pattern boundaries and function, we used a computer algorithm that analyzed patterns starting on each note. In previous research, subjective judgments were used to classify patterns according to the underlying chord progression (e.g., a ii-V-I cadential pattern) or internal structure (e.g., a scalar pattern) (Finkelman, 1997; Owens, 1974). This presents a number of problems. For example, how should one classify a pattern that appears to imply only part of a chordal progression? Or, which scales should be included when categorizing "scalar" patterns? Here we used a computer algorithm that analyzes patterns starting on each note and that disregarded internal pattern structure and chordal implications. Accordingly, we did not draw any conclusions related to pattern function. Also, we did not analyze whether the various conditions included more stepwise patterns. Finally, we did not distinguish between patterns repeated in quick succession and appearing further apart. Future research could investigate whether patterns appearing closer together are simply repetitions of an initial pattern while patterns appearing further apart are retrieved from memory multiple times. Here our focus was the difference in pattern use between the various experimental conditions assuming that basic pattern functionality did not change between conditions.

In order to identify patterns, we compared each trial with all the solos played by the participant in this experiment. It is therefore possible that many of the observed patterns were individually created using tonal rules (Johnson-Laird, 2002). In reality, improvisers probably use both tonal rules and learned patterns to create their improvisations (Pressing, 1988; Norgaard 2014). The results seen with the less stringent pattern definition could simply reflect figures created from scratch using tonal rules. However, the observed differences in pattern use were similar for the more stringent definition of pitch patterns in which a melodic figure had to appear four times to be considered a pattern.

To date, little experimental research on creativity has focused on attention and working memory demands during creation under real time constraints. In one such rare study, two experts' subjective ratings of improvisations performed by 32 semi-professional cellists were found to increase over time for musicians with higher working memory capability but to decrease over time for those with low working memory (De Dreu, Nijstad, Baas, Wolsink, & Roskes, 2012). The authors suggest that the musicians with higher working memory capacities were more able to focus their attention on the task at hand as well as to inhibit tendencies to play repeated patterns.

While similar in several ways, the current study improves upon the De Dreu et al. (2012) study in two key ways: First, rather than correlating performance with working memory capability, the present study actively manipulates attention *within participants* by placing additional demands on the musicians during improvisations. This allows for a more causal comparison of the role of attention on creative output. Second, while De Dreu et al. (2012) relied on subjective ratings of creativity, the present study applies objective criteria (i.e., number of patterns) for evaluating the musicians' improvisations. Future research on creativity might benefit from the inclusion of within-participant manipulations as well as more objective criteria for defining creativity.

Summary

Here we showed that advanced jazz pianists used patterns more frequently in improvisations performed while their attention was diverted by a secondary task. In reality musicians often play in ensemble settings where interaction is essential and expected. The ability of experienced jazz musicians to direct attention to the actions of other ensemble members while improvising may correspond with an ability to attend to a secondary task, as used in this study. Therefore, it is possible that the use of memorized patterns is an essential mechanism that allows musicians to focus externally away from their own actions during improvised performances.

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