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Score One for Jazz: Working Memory in Jazz and Classical Musicians

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Jazz musicians rely on different skills than do classical musicians for successful performances. We investigated the working memory span of classical and jazz student musicians on musical and nonmusical working memory tasks. College-aged musicians completed the Bucknell Auditory Imagery Scale, followed by verbal working memory tests and musical working memory tests that included visual and auditory presentation modes and written or played recall. Participants were asked to recall the last word (or pitch) from each task after a distraction task, by writing, speaking, or playing the pitch on the piano. Jazz musicians recalled more pitches that were presented in auditory versions and recalled on the piano compared with classical musicians. Scores were positively correlated to years of jazz-playing experience. We conclude that type of training should be considered in studies of musical expertise, and that tests of musicians' cognitive skills should include domain-specific components.

Keywords: working memory, auditory imagery, jazz improvisation, multimodal

Auditory information processing of all kinds requires considerable executive resources, given that the incoming information is only available for a short time and is constantly replaced by new information. Comprehending language, environmental sounds, and music all require this quick and accurate processing. Understanding music makes particularly intense demands on both attention and working memory. Music is not constructed with the redundancy of at least some environmental sounds (like the repetitive pattern of waves lapping against a shoreline); nor does it benefit from some of the prediction engines we have when parsing novel speech, such as semantic and (strict) grammaticality constraints.

Music seems to have evolved in every known human culture, and most people seem to understand and enjoy music, even without special training. Babies have been shown to comprehend many aspects of music (Trehub, 2011), suggesting a biological capacity to integrate pitch and rhythm. Adult informal musicians are defined as nonprofessionals or "amateur" musicians; the term nonmusicians is used in the training literature to refer to individuals with no musical training. People of varying degrees of music training, including none at all, show their abilities to comprehend music in many everyday situations, such as clapping along or dancing to a new song, knowing when the hymn is about to end in church, or joining in on a chorus of *Happy Birthday*, no matter what the starting pitch.

Our focus in this article is working memory (WM), the ability to maintain information for a short time in the face of competition for resources and to update it constantly as new information arises. In music, all listeners, regardless of training, need WM to relate incoming notes to the ongoing tonal schema, to parse meter, and to understand phrases, among other things. But for professional musicians, having a good WM would seem to be even more important, given that the profession places high demands on many aspects of auditory processing. Even setting aside the memorization of pieces from a score or by ear, musicians learning new pieces or playing in an ensemble need to keep track of motives, anticipate repetitions, and integrate across modalities, such as the visual-motor loop so important to pianists. String, wind, and brass players need to constantly monitor auditory feedback to adjust their tone and attack, and singers have the added memory burden of integrating language with all these other musical demands (often in a nonnative language). Further, error detection relies on the ability to process heard versus expected pitches in WM (Stambaugh, 2016). Musical performance also places demands on attention, and we know that good WM is related to good selective and divided attention (Colflesh & Conway, 2007; Conway, Cowan, & Bunting, 2001).

It has been well established that experts show superiority to novices in long-term memory (LTM)—knowledge stored indefinitely—for information in their domain (Charness & Tuffiash, 2008), but evidence has been mixed about whether musicians show enhanced cognitive abilities generally, or only in domains relevant to music (George & Coch, 2011; Radvansky, Fleming, & Simmons, 1995; Schellenberg & Moreno, 2010). We know that WM—the capacity to temporarily retain information for

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processing—contributes to domain-specific LTM superiority (Hambrick & Engle, 2002), again leading to the question of whether musician superiority in WM generally has been documented. Brandler and Rammsayer (2003) showed superiority of musicians to nonmusicians on verbal WM (Cohen, Evans, Horowitz, & Wolfe, 2011 and Jakobson, Lewycky, Kilgour, & Stoesz, 2008). Talamini, Carretti, and Grassi (2016) recently studied differences between musicians and nonmusicians on a variety of short-term and WM tasks for digits. They found WM superiority among musicians in all conditions, whether the digits were presented by ear or by eye and whether the task was presented with concurrent interference or not. The groups did not differ on cognitive tasks not as dependent on WM, such as a vocabulary test. Performance on a test of musical cognitive skills correlated with superiority on auditory and auditory-visual modes of presentation, but not purely visual tasks. Thus we have evidence supporting the relationship between musicianship and general WM abilities, and possibly a scaling of musical skill with WM tasks involving the auditory modality (see also a recent meta-analysis by these authors, Talamini, Altoè, Carretti, and Grassi [2017]).

This superiority could be due to predisposition, training, or both. It would be eminently reasonable to assume that individuals with better WM would self-expose to music, or to more complex music, gravitate to music lessons, and continue with music lessons throughout their education. It is equally reasonable to assume that musical training per se, including learning notation-auditory-motor mappings, ear training, and deliberate memorization, would enhance WM skills. And indeed, some evidence from training studies points to that enhancement in children (Moreno et al., 2011; Roden, Grube, Bongard, & Kreutz, 2014) and older adults (Bugos, Perlstein, McCrae, Brophy, & Bedenbaugh, 2007).

Of course, both influences likely co-occur. The fact that various cognitive abilities and neural substrates of those abilities often correlate positively with years of musical training (Kraus & Chandrasekaran, 2010) could indicate a propensity to begin and continue lessons, combined with the benefits of accruing from the training. In practice, these influences are hard to separate, but some studies have done so. For instance, Herholz, Coffey, Pantev, and Zatorre (2016) randomly assigned nonmusicians to a 6-week piano training regimen or a control condition. Data from a functional MRI study both pre and post training showed that some preexisting neural differences in networks supporting memory encoding and motor control predicted learning rates on the training. Other brain areas involved in sensorimotor integration, and perception and imagery of melodies, were more sensitive to amount of training.

Our specific interest in WM here was not the differences between musicians and nonmusicians but rather the differences in different types of musicians. Most musicians have a similar curriculum core in terms of theory and aural skills training, so it is reasonable that most research studying cognitive correlates of musical skill groups all musicians together. On the other hand, private lessons, motor and sensory demands, and memory requirements differ according to instrument, style, and type and amount of training. A pianist, for instance, must integrate many notes played simultaneously but does not have to monitor tuning, and the complementary demands would be true of a clarinetist (one note at a time, but must monitor tuning). Our previous study (Wöllner & Halpern, 2016) examined the differences between two groups of musicians we thought would differ in interesting ways in their cognitive abilities: pianists and conductors. We noted that the executive demands on conductors were considerable, having to monitor, predict, and error-correct while listening to many lines of music at once, and thus it was possible they would show cognitive superiority across executive functions. We studied students and professionals in both groups, which allowed us to at least informally account for both training (professionals having more years of training) and predisposition (even student conductors have made that choice of career). Importantly, conductors and pianists did not differ in years of training. We examined selective and divided attention in processing simultaneous musical streams, LTM for tempo (tapping the beat to both a familiar and two unfamiliar scores, tested both at the beginning and end of the session), and WM spans for words, notes presented in the auditory domain, and notes presented in written form. For the WM task, we asked for recall either by reproduction on a keyboard, or by writing notation.

Conductors in both experience ranges were superior to pianists in the stability of their tempo memory and also in their divided attention: Conductors were able to detect randomly shortened notes while monitoring two unrelated musical lines at a higher rate than pianists. This finding provides evidence for the conductors' superior attentional skills that are necessary when monitoring an orchestra with multiple musical streams (cf. Nager, Kohlmetz, Altenmüller, Rodriguez-Fornells, & Münte, 2003). Although conductors did not significantly differ from pianists in the WM span, however, there were a number of correlations between divided and selective attention and WM subtests, supporting previous research (Colflesh & Conway, 2007; Conway et al., 2001). Furthermore, we saw some support for pre-existing cognitive differences in the groups given that student conductors were superior to student pianists. But we also saw evidence of experience effects in that the professionals were overall superior to the students in the tasks, even though the professionals were considerably older.

Regarding WM performance, one of the most striking results for both groups of musicians was that visual presentation led to higher recall as compared with auditory presentation. This finding could be interpreted as being in contrast to the research summarized earlier on domain-specific enhancements. The advantages for visual WM led us to consider potential differences in performing musicians that have training experiences in different domains. In other words, we were interested in studying groups of musicians who rely to different degrees on auditory and visual information in learning, memorization, and information processing during performance. All of the participants in the prior study were classically trained, which generally means relying on scores to learn their music and little emphasis on improvisatory skills. And of course all the musicians had piano training: The conductors had studied piano on average for 12 years. Only a few studies have looked at cognitive skills as a function of type of instrument training, mostly looking at online tasks such as monitoring different kinds of deviations during music listening. For instance, Carey et al. (2015) compared classically trained violinists and pianists and found very few differences across a wide variety of tasks such as sequence reproduction. The violinists were more sensitive to tuning differences, as might be expected (Nager et al., 2003).

Although many jazz musicians have classical training, those who pursue jazz get experience that differs from advanced classical musicians in a number of ways. Compared with classical performance style, jazz students are additionally involved in jazz ensembles and jazz lessons involving improvisation and related ear-training activities. Further, they may participate in formal or informal jazz combos, practicing skills appropriate for small ensembles in addition to large jazz bands. In these formations, it is quite common that standards and patterns are not notated but rather conveyed in an auditory way, by playing and listening. In addition, one could assume that jazz musicians often incorporate patterns in their improvisation that they have heard somewhere else, also supporting auditory types of learning (Berliner, 1994; cf. Norgaard, 2014).

Given these differences, one might expect that jazz musicians might excel in tasks that require auditory memory skills. In one of the few studies comparing jazz to classical musicians, Tervaniemi, Janhunen, Kruck, Putkinen, and Huotilainen (2016) and Vuust, Brattico, Seppänen, Näätänen, and Tervaniemi (2012) looked at preattentive processing in jazz, classical, and rock musicians (and also nonmusicians). They examined electroencephalography (EEG) signatures for detecting various kinds of deviants in a series of target melodies. Although the musician groups showed some similarities, one of the interesting findings from our perspective is that the jazz musicians were superior to the classical in detection of two kinds of auditory deviants: single pitches and melodic phrases.

Although this difference is consistent with the proposal that jazz musicians might have some superior auditory skills, we pursued this question in the context not of preattentive detection, but of the more conscious process of WM. We presented the WM battery from our prior student two groups of young adult musicians, music majors concentrating in jazz and classical styles, respectively. We controlled other factors such as age as far as possible, which is here correlated with experience. It should be noted that jazz majors commonly also participate in the classical ensembles of a traditional music major. Although we expected that the musicians would all do well on the tasks, we predicted that the jazz musicians would be superior to the equally trained classical musicians, particularly in the WM versions that tasked auditory–kinesthetic linkages, namely, hearing a set of pitches and recalling them on a keyboard. We predicted that differences would be small to nonexistent in verbal WM, and in presentation/recall conditions that were less dependent on purely auditory memory. However, we were open to the possibility that classical musicians who are more score-dependent might show some superiority in memory of notated pitches.

Method

Participants

A total of 20 jazz students and 20 classical music students were recruited from three universities in the Midwest United States, ranging in age from 18 to 27 years. In the jazz group, there were 16 males and four females (M_{age} = 19.84 years, SD = 2.34). In the classical group, there were eight males and 12 females (M_{age} = 19.40 years, SD = 1.05). The jazz group comprised undergraduate students who currently played in a jazz ensemble; all but one participant were music majors. Jazz students in general played in both a classical and a jazz ensemble (Table 1). Both groups had taken lessons in classical music (jazz group: M = 5.03 years, SD = 5.35; classical group: M = 5.63 years, SD = 4.28). Jazz students ranged in experience from 0 to 14 years of classical ensemble-playing experience (some participants had not yet completed a full year of experience) and 0 to 16 years of classical lessons. Jazz students ranged in experience from 1 to 13 years of jazz ensemble experience and 1 to 12 years of jazz lessons. Classical students ranged in experience from 1 to 14 years of classical ensemble experience and 1 to 16 years of classical lessons (a viola player had the longest history of lessons). All were native speakers of English.

Among the tasks described in the following text is a piano response mode where participants played back what they heard or saw while at the piano. In general, musicians at all universities are required to study a minimum number of semesters of class piano, sometimes substituted by piano lessons for piano majors. Thus it could be assumed that all participants in the classical and jazz groups had a degree of piano study and were able to identify or play back pitches on a piano. Participants were recruited from all instrument areas, however, including players of electric bass, flute, French horn, trumpet, percussion, saxophone, viola, and so forth

A prerequisite condition for classical musicians was that they had taken no Jazz lessons at all, whereas jazz musicians took an average of 4.08 years (SD = 3.23) of jazz lessons prior to the study. The classical group comprised undergraduate students in music performance or education in traditional classical ensembles. The jazz group comprised undergraduate students in performance, education, or general music studies. All participants were music majors at the time of data collection.

There were significant differences between groups in the number of years of ensemble performance, with classical musicians having played for a longer time in classical ensembles ($p < .05$) and jazz having played for a longer time in jazz ensembles ($p < .001$). Jazz musicians had also performed more often in public in the year prior to the study (M = 22.29 times, SD = 13.88) compared with classical musicians (M = 13.60 times, SD = 7.15).

Table 1
Characteristics of the Two Groups of Participants (Mand SD in Brackets)

Musician group	n	Age	Male, female	Years of classical lessons	Years of jazz lessons	Years of classical ensemble	Years of jazz ensemble
Classical	20	19.40 (1.05)	8, 12	5.63 (4.28)	—	8.55 (2.46)	1.98 (2.34)
Jazz	19*	19.84 (2.34)	16, 3	5.03 (5.35)	4.08 (3.23)	5.58 (4.89)	5.89 (3.36)

* One participant was excluded because of possessing absolute pitch.

Materials

Absolute pitch. The musical WM tests involved remembering musical pitches, and thus an absolute pitch test was used to screen participants. The test stimuli included 10 sine waves of different frequencies from F#^{3} to E^5, followed by silence and distraction sounds (cf. Schlemmer, Kulke, Kuchinke, & Van Der Meer, 2005). The task was to name the pitches of the sine waves. We considered a threshold of 80% correct to indicate good absolute pitch (Wöllner & Halpern, 2016). One participant had correctly identified all pitches and was thus excluded from further analyses. Jazz and classical musicians (without the one musician with absolute pitch [AP]) did not differ in AP.

BAIS. The Bucknell Auditory Imagery Scale (BAIS) was completed by every participant to measure individual differences in self-reported auditory imagery in terms of vividness and control (Halpern, 2015). Vividness refers to self-reported ability to generate an auditory image of music, language, or environmental sounds. Control refers to self-reported ability to change the characteristics of the auditory image. There were no significant differences on the BAIS mean score between jazz ($M = 5.02$, $SD = 0.71$ and classical ($M = 5.21$, $SD = 0.66$) musicians, nor on either of the subscales.

WM tasks. All participants completed the six WM tests used by Wöllner and Halpern (2016), preceded by practice trials to familiarize participants with each test (Table 2). To evaluate WM capacity, all tests used a standard operation span approach (Engle, 2002), where the to-be-remembered material is presented, and then the participant must make a judgment about the material, which serves as a cognitively engaging distractor. After all the items in a trial are presented, recall of the last part of each stimulus from the entire list was required. Tests 1 and 2 were verbal recall tasks where participants were asked to remember the last word in each sentence. The first item contained two sentences, and each subsequent item added a sentence; thus the sixth, final item contained seven sentences. Test 1 presented material visually: participants read sentences and said aloud whether each sentence made logical sense ("yes" or "no", the distractor task). Because WM was hypothesized to vary for jazz and classical musicians based on perceptual mode (visual vs. auditory), Test 2 was an auditory task where participants heard each sentence, and then said aloud again whether each sentence made sense. After the sentences in each item were presented, the participant was asked to recall the last word in each sentence out loud. Items were scored correct if the participant recalled the last words of the sentences in the accurate order.

Tests 3 and 4 were musical tasks in which participants heard melodic triads (arpeggiated) with the distraction task of noting whether the triad was major or minor. Each set was preceded by the aural presentation of an open 5th on G to provide a tonal context because participants were not expected to have AP. At the end of each set of triads, the participant was asked to recall the last pitches of each triad by playing them back on the piano within a limited range of five notes (Test 3) or writing them on staff paper with the range of pitches given to them before (Test 4). Tests 5 and 6 were similar to the previous musical tasks but were presented visually. Participants recorded the last pitches after presentation by playing them back on the piano (Test 5) or by writing them on staff paper (Test 6). Although a previous study of differences between musicians and nonmusicians reported superior verbal memory in musicians, we hypothesized no effect between musician types in the current study (Brandler & Rammsayer, 2003).

Table 2
Working Memory Tests

Test	Input material/modality	Output modality
1	Words/visual	Spoken
2	Words/auditory	Spoken
3	Triads/auditory	Played on piano
4	Triads/auditory	Notated
5	Triads/visual	Played on piano
6	Triads/visual	Notated

Procedure & Scoring

All jazz and classical participants completed all six tests, balanced for order effects (half the participants did the visual music tests (Tests 5 and 6) prior to the auditory music tests). The tests were administered one-on-one in the following order: BAIS, AP, and WM test for a total test time of approximately 50 min. Presentation of the stimuli was made using PowerPoint slides, and each stimulus (auditory and visual) was presented for 5 s, with 3 s in between.

Results

Differences between jazz and classical musicians were tested with a multivariate analysis of variance for the six WM tests (two verbal and four musical), with AP as a covariate. Jazz musicians ($M = 4.00$, $SD = 1.75$) outperformed classical musicians ($M = 2.20$, $SD = 2.00$) in the auditory-piano WM test, $F(1, 38) = 7.88$, $p < .01$, $\eta_p^2 = .18$. In other words, jazz musicians recalled more pitches that were presented in auditory versions and performed them more accurately on the piano as compared with classical musicians. AP as a covariate had no effect on results, $F(1, 38) = 1.05$, $p = .31$, $\eta_p^2 = .03$, so participants' auditory-piano test performance was independent from AP. Therefore our first hypothesis was confirmed (Figure 1).

There were no further significant main effects for groups of musicians for the other WM tests; that is, jazz musicians did not differ from classical musicians in WM in the auditory- notated, visual-piano, or visual-notated tasks. Across both groups of musicians, AP as a covariate influenced results in the auditory-notated test, $F(1, 38) = 19.46$, $p < .001$, $\eta_P^2 = .35$, indicating that those musicians with higher scores in the AP test also recalled more auditory pitches when reproducing them in notation. There were no differences between jazz and classical musicians in the two verbal WM or in the visual musical tests (visual-piano and visual-notated). Classical musicians thus did not show superior visual memory for notated pitches, despite their general score-based approach to music performance.

We further assessed relationships between WM recall and other characteristics of the participants by calculating Pearson correlations. To control for multiple correlations of the six WM tests, we set alpha to .0083 (i.e., $\alpha = .05$, divided by six). We found significant correlations between auditory-piano WM scores and years of ensemble experience in jazz ($r = .43$, $p < .008$), extend-

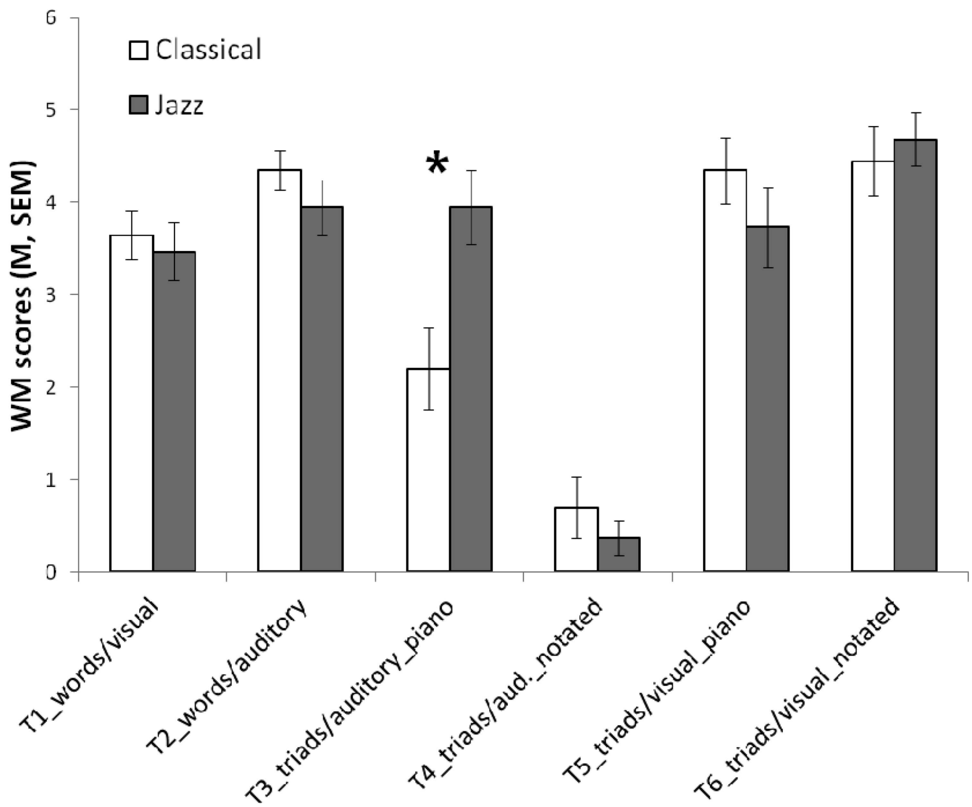

Figure 1. Mean scores (and *SEM*) for all six WM tests.

ing the group differences for the same WM test. Furthermore, AP correlated with auditory-notated recall ($r = .57$, $p < .001$) but did not correlate with any other WM test (all other $p > .24$). There was no correlation with BAIS, indicating that the jazz musicians' advantage in auditory pitch recall was not related to self-reported auditory imagery skills. Finally, the number of public performances in the year prior to the study did not correlate with any of the WM tests.

Discussion

We presented WM tasks that varied in domain and mode of input, as well as mode of output, to two groups of musicians: jazz and classical. The two groups were equated on a number of important aspects, including age, general educational environment, and average score on an AP test (no one in the final sample had good AP, and AP as a covariate did not influence the results). The groups did differ in a few ways: The jazz students had played in public more often recently, but this did not correlate with any measures of interest. Although jazz students had fewer years of performing experience in jazz ensembles than classical musicians in classical ensembles (likely because jazz studies were started later), this factor was considered in our analyses, as described in the following text. Thus we feel confident making several conclusions about WM similarities and differences in the groups.

First, we note memory in the two groups was equivalent on most of the tests. Spans on a standard verbal WM span for heard or read words did not differ, nor did memory span for most of the musical tests. AP scores were not related to group differences (even moderately good AP would allow some labeling of pitches, providing an extra memory code). Thus to the extent we can establish, jazz musicians did not have generally better working memories compared with the classical musicians. WM tasks included a distraction element; we did not test simple short-term memory span but rather the ability to manage memory resources while under a cognitive load.

The jazz players did however excel in the predicted test: hearing notes that they then reproduced on a piano. Although we cannot separate out genetic predisposition from training (and they are no doubt intimately linked), it is notable that memory span on this test among the jazz students was positively related to years of jazz ensemble experience. One or both of those influences seems to have conferred a superior ability to take in sound patterns, maintain them during competition, and translate the memory into kinesthetic patterns. This sort of skill is no doubt useful in jazz situations where improvisation as a soloist or ensemble member requires in-the-moment translation of sound to action, forming automatized auditory-motor patterns (Norgaard, 2014). Our results thus provide evidence for effects on domain-specific WM, comparable with findings on jazz musicians' superior perception skills in comparison with other groups of musicians (Tervaniemi et al., 2016). It is interesting that the two groups did not differ in self-reported auditory imagery scores (BAIS), the mean ratings were equivalent to those reported by a group of students unselected for musical background in the original sample during the scale development (Halpern, 2015), and BAIS did not predict performance in any task.

We had left open the possibility that classical musicians might exceed jazz musicians in remembering pitches in notated form, particularly if both input and output were in notation. However, even though the notation task (Test 6) yielded one of the higher span estimates for both groups, no superiority among classical musicians was observed for the visual, score-based tests. This result is not due to potential ceiling effects. The auditory dictation condition (hearing notes and recall in notation) yielded the lowest span for both groups (and considerably lower than in our first study, Wöllner & Halpern, 2016). AP score did influence performance in this task, again suggesting that note labels provided a useful verbal mediating strategy for those who could use it in this most difficult task. Of course jazz musicians had had equivalent years of classical training to the nominal classical group. It might be the case that the extra jazz training only upregulates the auditory–kinesthetic connection; jazz musicians might still use notation enough in their performing lives to keep that skill active. Further research could investigate the skills of professional jazz musicians without an additional classical, score-based background. Another aspect of comparing different types of musicians is in terms of tradeoffs. Bianco, Novembre, Keller, Villringer, and Sammler (2018) for instance found that in a piano fingering task, jazz musicians were more flexible in responding to unpredicted harmonies but at the expense of fingering accuracy; and the reverse was true for the classical musicians.

The results here remind us that studies that just compare musicians to nonmusicians, or consider years of training as a correlate of other cognitive skills, would do well to consider the type of training the musicians are receiving. We also note that of course there was some variability in performance and predictors of that variability other than the ones we considered could be informative. This would be especially useful in a study design that compared musicians at the beginning of university training and again as they graduate, to see the effects of training once baseline scores and other factors are taken into account. Another comparison of interest would be to compare professional to student musicians. In our prior study on pianists and conductors (Wöllner & Halpern, 2016), we found evidence for both predisposition (similar conductor/pianist differences were observed in both students and professionals) and training effects (professionals were overall superior to students). Comparing jazz and classical students to those in the profession for many years could similarly illuminate the effects of aural training involved in jazz performance.

Finally, we note that our results should be of interest to educators and cognitive scientists. The overall unimpressive performance in the auditory dictation condition might suggest that this skill should receive more attention (see, e.g., Gamso, 2011 for an aural "jazz" approach to classical music learning). Furthermore, a good WM is important for many musical skills, including error detection and overall musicality. Although evidence that training can expand WM in general is decidedly mixed (Bugos et al., 2007; George & Coch, 2011; Schellenberg & Moreno, 2010), evidence is stronger that training specific WM skills is quite feasible. We of course may be seeing an example here in the jazz training these students received. Thus, although their superiority was not, technically, score-based, this study does score one for jazz!

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