

Focus of Attention Affects Performance of Motor Skills in Music

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Abstract

To test the extent to which learners performing a simple keyboard passage would be affected by directing their focus of attention to different aspects of their movements, 16 music majors performed a brief keyboard passage under each of four focus conditions arranged in a counterbalanced design—a total of 64 experimental sessions. As they performed the test passage, participants were directed to focus their attention on either their fingers, the piano keys, the piano hammers, or the sound produced. Complete MIDI data for all responses were digitally recorded by software written specifically for this experiment. Consistent with findings obtained in tests of other physical skills, the results show that performance was most accurate and generalizable when participants focused on the effects their movements produced rather than on the movements themselves, and that the more distal the focus of attention, the more accurate the motor control.

Keywords

motor learning, focus of attention, music skills

The skillful execution of complex motor behavior requires efficient processing of sensory feedback, which facilitates moment-to-moment adjustments in the parameters of movements that skilled behaviors comprise. Of course, the nature of skillful movement changes over time, as learners become more familiar with movement structures and more accurate in their performance. In tasks as varied as riding a bicycle, hitting a baseball, and playing the piano, there are numerous sources of sensory feedback,

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including proprioception. The development of skill is a process by which learners come to notice and respond to external variables that matter and ignore variables that are superfluous, shifting their focus of attention from proximal, near-term goals to more distal, long-term goals (Beilock, Bertenthal, McCoy, & Carr, 2004; Ford, Hodges, & Williams, 2005; Wulf, Shea, & Matschiner, 1998).

Learning where to devote limited attentional resources is an obvious challenge for novices. Depending on the extent to which movements in a novel skill resemble those commonly practiced in everyday motor behavior, focusing attention on movement goals (i.e., the effects that movements produce) may be more advantageous than focusing on the movements themselves (i.e., the movements of limbs and fingers; for a review, see Wulf, 2007). This topic has been of interest to researchers studying motor behavior and procedural memory for several decades. Their findings seem particularly germane to applications in music performance, but as yet no one has researched the topic of attentional focus in terms of its effects on the motor behavior of musicians, whose physical movements produce auditory feedback.

Investigations of musicians' practice have begun to reveal aspects of practice structure and learner cognition that contribute to the effectiveness of practice by experts (Chaffin & Imreh, 1997, 2001, 2002; Chaffin, Imreh, Lemieux, & Chen, 2003; Duke, Simmons, & Cash, 2009; Gruson, 1988; Maynard, 2006; Williamon, Valentine, & Valentine, 2002) and novices (McPherson, 2005; Miksza, 2007; Rohwer & Polk, 2006). Other research in music education has begun to connect work performed in related disciplines to the learning and teaching of music skills, adopting experimental procedures that have proven effective in illuminating fundamental principles of human learning and procedural memory formation (Cash, 2009; Duke, Allen, Cash, & Simmons, 2009; Duke & Davis, 2006; Simmons & Duke, 2006). The study of attentional focus in the performance of music skills likewise may contribute to a deeper understanding of music learning.

The learning of a given movement structure, especially one that is highly complex like many of the skills involved in music performance, seems to benefit from different attentional foci at different stages of skill acquisition and refinement. Thus, teachers may facilitate learning by optimally directing learners' attention to strategically selected points of focus, a notion that is not unfamiliar to teachers of music, who often direct learners' attention to various components of sound production.

As one might imagine, the execution of novel motor skills necessarily involves the recruitment of long-practiced movement structures that have become highly automatized by the time the new skills are introduced. Learning to dance, for example, recruits procedural memories related to balance in movements like walking and running; learning to sing recruits procedural memories related to speaking; and learning to play baseball recruits procedural memories related to grasping, reaching, and aiming at targets.

Attending to body movements that have become highly automatized over a lifetime of experience can disrupt the performance of well-practiced skills. It has been demonstrated repeatedly that increased attention to the movement of limbs (e.g., focusing on a leg movement in a soccer kick, as opposed to focusing on the intended

trajectory of the ball), whether self-initiated or in response to instructions or feedback, interferes with the automatic control processes usually engaged during execution. Attending to movement goals (external focus) rather than on movements themselves (internal focus) has been shown to result in more rapid skill acquisition and more accurate performance (Beilock, Carr, MacMahon, & Starkes, 2002; Shea & Wulf, 1999; Wulf, Höß, & Prinz, 1998; Wulf & Prinz, 2001; Wulf, Weigelt, Poulter, & McNevin, 2003).

The implications of these and similar results for instruction are clear: Optimally directing learners' focus of attention may enhance the acquisition and refinement of motor skills. In several experimental settings with simulated slalom skiing and balancing tasks, for example, participants who were directed to focus on the effects of their body movements (e.g., the force exerted on either side of a ski-simulator platform) generally performed better than did those who were directed to focus attention on the movements of their feet and better than those given no focus directions (Wulf, Höß, et al., 1998). It is important to note that the term *focus* in this research does not refer to visual focus but to focus of attention (i.e., what one is thinking about). In fact, in much of the laboratory research in this domain, participants look at a visual fixation point throughout all of the experimental conditions.

The effectiveness of an external focus of attention also has been observed in more naturalistic settings outside the laboratory. Wulf and colleagues demonstrated, for example, that golfers who were instructed to focus attention on the swing of their arms (internal focus) made less accurate shots than did those who focused on the motion of the club head (Wulf, Lauterbach, & Toole, 1999).

When learners focus on movement goals, the skills they develop tend to transfer more readily to similar tasks that have not been explicitly practiced (Maddox, Wulf, & Wright, 1999; McNevin, Shea, & Wulf, 2003; Totsika & Wulf, 2003). For example, Maddox and colleagues (1999) found that participants who first practiced a back-handed tennis swing while focusing on the trajectory of the ball were later more successful at forehanded swings than were participants who focused on the ball-racket contact point. Both groups executed similar movements, but learners who attended to the movement goal—the ball's trajectory—produced more accurate shots during practice and retention sessions.

The effects of attentional focus are not independent of the skill levels of learners. Learners who are first introduced to novel skills of moderate to high complexity produce more consistent and accurate performances when initial instructions focus attention on body movements (internal focus). In contrast, learners who are more skillful or who in the past have practiced skills similar to a new skill being learned tend to benefit more from instructions that focus attention on movement goals (Beilock et al., 2002; Castaneda & Gray, 2007; Perkins-Ceccato, Passmore, & Lee, 2003).

Of course, a given movement may result in more than one observable effect, which raises the question of which of several effects should be the focus of learners' attention. McNevin et al. (2003) speculated that focusing on effects of movements that are in close proximity to the body may not be distinguishable from focusing on body

movements themselves and that the advantages of external focus are enhanced as the distance increases between the external cue and the body. In many instances, as the focus of attention moves farther from the body, improvements are seen earlier in the learning process (Maddox et al., 1999; McNevin et al., 2003; Totsika & Wulf, 2003; Wulf, McNevin, Shea, & Wright, 1999). Yet, there seems to be an optimal distance at which external cues are most beneficial. Movement goals that are too far removed from movements themselves, such as the landing point of a golf ball, may be so distant from the actual movement structure as to provide no meaningful information to the learner (McNevin et al., 2003; Wulf, McConnel, Gartner, & Schwarz, 2002).

Wulf, McNevin, and Shea developed what they termed the *constrained action hypothesis* to explain comparative benefits of external over internal attentional focus (McNevin et al., 2003; Wulf, McNevin, & Shea, 2001). According to this view, learners who direct attention to their bodies begin to consciously control movements that have long ago become automatized and require little conscious effort. When the motor system is constrained by this contrived attentional focus, processes that would have occurred automatically may be inhibited. The constrained action hypothesis is supported by findings demonstrating the differing attentional demands of a balancing task. Wulf and colleagues (2001) observed that learners standing on a balance platform who were instructed to keep marks on either side of the platform level were significantly faster in reacting to an unrelated auditory cue than were learners who were instructed to keep their feet level. The shorter reaction times indicated reduced attentional demands in the external focus condition. Additionally, those in the external focus group showed more frequent balance adjustments and adjustments of smaller magnitude, indicating greater use of automatic processes that implement quicker and more refined movements (Wulf et al., 2001).

Differential effects of attentional focus have been demonstrated at the neuromuscular level as well (Vance, Wulf, Töllner, McNevin, & Mercer, 2004). Using electromyography (EMG) to measure electrical activity from muscle contractions, Vance and colleagues (2004) found higher levels of muscle activity when participants who lifted a curl bar focused on the movements of their arms than when the same participants focused on the movement of the bar, a result that demonstrates the increased physical efficiency obtained when automatized movement processes are engaged.

The development and refinement of skills in music undoubtedly involve many of the processes described in the extant research reported above. But as yet there has been no systematic research conducted with experienced musicians in music contexts. In this experiment, we tested the extent to which learners' focus of attention affects the evenness of motor movements on a piano keyboard. Unlike many of the motor skills investigated to date, music performance includes an auditory component that provides immediate feedback to the player. We wanted to learn whether directing performers to focus on their body movements, the movements of the piano keys and hammers, or the sound of the keyboard would affect motor control.



Figure 1. Test sequence as presented to participants

Method

Participants were 16 music majors (8 males) enrolled in various programs in the Sarah and Ernest Butler School of Music at The University of Texas at Austin. All were between the ages of 25 and 57 and volunteered to participate. Twelve (7 males) were non-pianists who had extensive training in orchestral instruments; 4 (1 male) were advanced pianists.

Participants played a 13-note sequence composed of alternating sixteenth notes (see Figure 1) using the index and ring fingers of the right hand on a Roland KR-4700 digital piano. To compare the effects of different attentional foci, participants were directed to focus on either their fingers, the keys, the piano hammers, or the sound produced. All participants performed in all four conditions. The orders of conditions were arranged in a counterbalanced design, and order was randomly assigned to participants.

Testing took place in a small room, free of distractions. Throughout the procedure, participants wore Bose QuietComfort 2[®] noise canceling headphones through which we transmitted all demonstrations, metronome start signals, and the sounds of the digital piano as they played. Customized software written specifically for this experiment using Max/MSP (Puckette & Zicarelli, 2004) controlled all aspects of the experiment and data collection.¹

Each participant performed the test skill at a speed that was 75% of his or her maximum speed. To determine their maximum speeds, participants alternately played the notes A and F “as quickly and evenly as possible” until they were instructed to stop. We used 75% of this speed as the performance tempo for all subsequent trials in that session. Participants established a maximum tempo at each session of the experiment. Sessions comprised (1) a test of maximum tempo, (2) four training blocks, (3) a retest of performance on the trained task, and (4) a transfer test as described below.

Two computerized demonstrations of the sequence at the participant’s target tempo were played prior to the start of the training session. Each trial began with a visual (written text) and auditory (spoken) prompt reminding participants of the intended focus of attention (e.g., “Think about the keys”), followed by a metronome sound clicking at the target tempo. The metronome continued until the participant played the first note of the sequence, after which the metronome stopped. Each trial ended with the participant’s 13th key press. Participants’ instruction during the training session was to perform the sequence “as evenly as possible” in the tempo set by the metronome. There was a 2-sec delay before the beginning of the subsequent trial. Throughout the entire

experiment, participants directed their visual gaze to the computer screen in front of them, on which was displayed the attention cue in text prior to the start of the metronome (e.g., “Think about the keys”), which was replaced by a large letter X in the center of the screen during the trial.

Training sessions for each of the four focus conditions consisted of four blocks of 10 trials each. Training blocks were separated by 30-sec rest periods. The fourth block of training was followed by a 5-min delay, after which participants performed a retest, which comprised an additional block of 10 trials under the same conditions. A transfer test consisting of one 10-trial block of the sequence in inversion (starting and ending on F4) was administered 2 min following the retest. All 16 participants completed each of the four focus conditions after rest periods of a minimum of 5 min to avoid fatigue.

We assessed evenness in terms of both the evenness in timing and evenness in volume among tones in the sequence. To assess temporal evenness, we calculated the standard deviation of the interonset intervals, in milliseconds, between consecutive tones in each sequence (IOI SD). We assessed evenness in loudness by calculating the standard deviation of the difference scores between the key velocities (the downward rates of travel of individual keystrokes) of consecutive tones in each sequence (KV SD). To obtain an accurate measure of participants’ sustained motor control, we used only the inner 10 tones of each sequence in our data analyses, excluding the 1st, 2nd, and 13th tones.

Results

We found that temporal evenness (IOI SD) was differentially affected by focus of attention, which is consistent with results obtained in the contexts of other motor behavior. This is the first instance in which focus on an auditory goal (in this experiment, the sound produced by the piano) has been shown to produce an effect on motor behavior similar to that produced by focusing on distal physical goals. We found no consistent differences in KV SD attributable to the experimental conditions, however. Although KV SD varied considerably among participants and among conditions, there were no consistent differences that seemed related to focus of attention. We present details of only the timing analysis below.

Recall that all 16 participants performed in all conditions in counterbalanced orders—a total of 64 experimental sessions. Upon initial examination of the performance data, we recognized that the responses of the 4 advanced pianists differed markedly from those observed among the 12 instrumental musicians who were less-skilled pianists. We therefore report the pianists’ and nonpianists’ performances separately.

Figure 2 presents the mean deviations in IOI (IOI SD) in the four blocks of training, the retest, and the transfer test for the 12 nonpianists. Evenness by condition was measured by calculating the standard deviation of the IOIs in each trial and averaging the SDs for each trial to obtain a mean IOI SD for each block.

During training, nonpianist participants showed the greatest improvement between Training Blocks 1 and 2 in every condition, with the sound focus resulting in the largest improvements and most even performances. There was little to no improvement between the second and third training blocks, and Block 4 performances tended to be

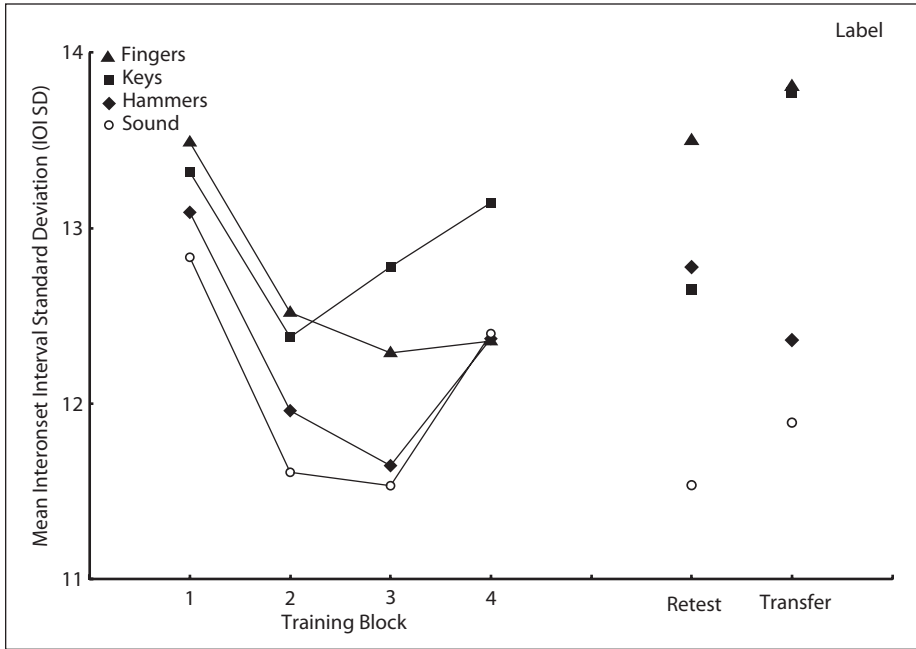


Figure 2. Mean interonset interval (IOI) standard deviation for each condition at four blocks of training, retest, and transfer

less even than performances in Block 3, perhaps as a result of fatigue. In general, focusing on the sound produced the most even timing across training blocks, although we did not test for differences among conditions at training.

At retest and in the transfer test, participants performed more evenly when focusing on the sound produced than when focusing on the movements of their fingers. The differences among the four conditions at retest, although consistent with other research, were not statistically significant, $F(3, 33) = 1.79, p > .16$; the differences among the conditions in the transfer task were significant, $F(3, 33) = 2.92, p < .05, h^2 = .21$. In the transfer performances in particular, attentional foci more distal to the performer (hammers, sound) produced more even movements than did more proximal foci (fingers, keys). Post hoc comparisons (LSD) indicate that the mean IOI SD for the fingers condition was not significantly different from the keys condition ($p > .97$) but was significantly higher (indicating greater unevenness) than the mean IOI SDs for the hammers ($p < .05$) and sound ($p < .05$) conditions, which were not significantly different from one another.

Analyses of the four expert pianists' performances indicated no differences among conditions, irrespective of the focus of attention to which they were directed. Their mean IOI SD throughout all sessions was approximately 40% lower than the mean IOI SD for the 12 nonpianists in the study.

Discussion

Our purpose in this study was to test whether the motor behavior of musicians would be affected by directing their attention to different aspects of their performance. We in fact found significant results that are consistent with those observed in the study of other motor skills that do not involve auditory feedback.

We did not observe significant differences among conditions in the retest, which was separated from training by a 5-min rest interval; only in the transfer test were participants' performances affected by their focus of attention during training. In discussing the results of their investigation of attentional focus in a balancing task, McNevin et al. (2003) explained that

even though increasing the distance of the effect from the action producing it did not produce immediate performance improvements (a trend for immediate performance benefits was only seen for the far inside condition), the present results were clear in showing that increasing the distance of the effect from the action producing it, through the attentional focus manipulation, enhanced *learning*. (p. 27)

Whereas the retest in the present investigation may have been too close to the training blocks to reveal effects of differential focus conditions on performance of the trained task, the transfer task, which required participants to perform a movement structure that was sufficiently different from the training task, may in fact have served as a measure of learning. Further investigations are needed to clarify these speculations.

The sizes of the effects observed are relatively small and may have no direct application to pedagogical prescriptions, but the results are informative with regard to the cognitive organizational structure of motor behavior in music. Our results support Wulf et al.'s (2001) constrained action hypothesis. It seems that in this limited example of a music performance skill, participants performed more effectively when they were able to recruit automatized components of long-practiced motor behavior by focusing on the effects that their movements produced, rather than focusing on the movements themselves. This seems to be the most important aspect of our findings and the basis for continued research. The fact that the advanced pianists were unaffected by the instructions is entirely consistent with this interpretation.

The finding that pianists performed consistently more evenly than nonpianists, yet failed to improve over time, suggests that perhaps pianists' motor movements are so practiced that pianists tend to play the same way, despite their attentional focus. Or, perhaps pianists are so accustomed to attending to different aspects of their body, the instrument, or the sound while playing that our instructing them specifically to do so made no difference in their performance. These pianists' results are unlike those obtained by Beilock et al. (2002), Perkins-Ceccato et al. (2003), and Castaneda and Gray (2007), who found that higher skilled learners benefited from externally focused instructions. Further research is clearly needed on the interaction between expertise and attentional focus in music.

Because all participants were able to hear the sound in every condition, irrespective of the instructions given, it is difficult to know how the presence of this feedback affected their performance. Several participants reported having difficulty *not* reacting to the sound feedback while they were playing, which is understandable since musicians who have been the beneficiaries of excellent training have learned to listen to the sounds they produce and make adjustments as they play. This may have made it difficult and perhaps unnatural for our participants to attend to something other than the sound.

Fatigue and boredom were undoubtedly a consideration in the four training session blocks. Although participants were aurally and visually reminded before each trial to focus their attention on the target, it is impossible to determine to what extent they were successful at maintaining this focus. Several participants reported having difficulty in maintaining concentration in the last few trials of each block. Future studies may benefit from arranging training blocks of fewer than 10 trials each.

It is now widely accepted, based on the results of a number of published investigations, that the recruitment of automated control processes in the learning of novel skills increases both the efficiency and transferability of learned skills. Our results demonstrate that the sound produced by a musical instrument, under the control of a performer, seems to function as a movement goal similar to physical movement goals that have been studied previously. This result is an important part of understanding motor control in the context of music performance. Of course, the admonition to “listen to your sound” is commonly heard in the lessons of musicians at all levels of experience and expertise, but the results of this and previous research deepen our understanding of why this functions as an effective strategy.

All teachers and students are interested in maximizing efficiency in learning. The evidence from this and other research indicates that focusing attention in ways that exploit the long-practiced aspects of motor control may optimize the acquisition and refinement of skills. Future investigations that look more specifically at aspects of motor control involved in tone production and the movements of fingers and limbs on wind and string instruments promise to provide further insight into the processes of music learning.

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Note

1. Max/MSP is an interactive programming environment that allows users to design software that controls various aspects of auditory and visual events. The software was designed origi-

nally for electronic composition. For this study, a programmer created the software that provided real-time recording of all MIDI data from the digital keyboard, as well as a graphic interface (screen that participants viewed), pre-taped audio instructions, and a timer that alerted participants to the start of each trial.

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