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Cognition and Motor Execution in Piano Sight-Reading: A Review of Literature

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Sight-reading is an integral part of the musical experience for all musicians. Pianists, in particular, often find themselves confronted with situations that necessitate adequate sight-reading skills. The widespread need for sight-reading at the piano may be due to pianists' widespread participation in collaborative music making. The size of the piano literature also contributes to this need, in that the repertoire is so voluminous that no one player can be familiar with all of the solo and collaborative pieces written for piano, nor do recordings of every piece in the literature exist. This is particularly the case with the pedagogical literature. Professional pianists often sight-read in the course of collaborating with other musicians or accompanying choral ensembles. Teachers frequently sight-read through a large volume of literature to determine which pieces are appropriate for their students and further call on their reading skills to demonstrate these pieces to their students. Also, student pianists sight-read in diverse situations (e.g., sight-reading pieces), including competitive situations such as festivals or contests. Sight-reading can be considered a procedural component of learning repertoire as well.

The nature of the sight-reading task varies according to the situation in which it is undertaken. Perhaps pianists are given a few minutes to engage in examination and preparation of material, or they may be called upon to sight-read music with little or no preparation. In any case, performance of sight-reading material precludes total refinement of physical movements in the motor execution phase of the task. The sight-reading task may be viewed in direct contrast to a repertoire task in which the pianist has engaged in weeks and often months of cognitive and motor training and thus gained a high level of physical familiarity with the music.

A review of the pertinent literature regarding the cognitive and execution demands of sight-reading offers some insights for educators striving to find pedagogical strategies that help their students surmount difficulties of sight-reading. While the literature reviewed and teaching applications derived from this literature relate primarily to piano sight-reading, observations are readily adaptable to other instrumentalists. Studies conducted regarding sight-reading ability to date have fallen into three broad categories:

1. Cognitive/perceptual, including eye movements, perception of notation and other aspects of the score, and the influence of visual and auditory feedback.
2. Factors affecting success in sight-reading achievement, including differences pertaining

to specialization among pianists.

3. Educational/pedagogical approaches, which focus on sight-reading acquisition or improvement through specific instruction or pacing devices. These approaches have not typically been verified through research. Moreover, there are a large number of publications of this latter type, far too many to explore here.

Specialized Demands of Sight-Reading

In general, there is a relation between overall level of musical skill and ability to sight-read (Lehmann & Ericsson, 1993). However, in his study of various instrumentalists other than pianists, McPherson (1994) found that this generalization is not true in the earliest stages of learning an instrument, when the most basic motor sequences necessary to play the instrument are still being established. A certain amount of technical mastery of an instrument must be attained in order for instrumentalists to sight-read. Basic motor programming demands are high for pianists, since both hands are actively engaged and must be coordinated during playing. In the first few years of study, sight-reading may consist only of tapping rhythmic patterns or playing single-line melodies with either the right hand or the left hand. Establishing basic motor patterns, such as finger control, and gaining familiarity with the geography of the keyboard are thus prerequisites to sight-reading. Cognitive studies on sight-reading to date have primarily focused on determining the internal processes successful sight-readers use in comparison with those musicians who are less skilled or less experienced at the sight-reading task. Cognitive/perceptual studies have addressed the processing work done by the brain during sight-reading rather than examining physical outcomes (i.e., task *execution*). In other words, physical motion is typically a factor in these studies only insofar as it makes manifest the internal work done by the brain.

The sight-reading task may itself be divided into two large phases: preparation and performance. Preparation time and activities vary widely from one situation and one player to the next. In his study involving clarinetists and trumpeters, McPherson (1994) noted that instrumentalists develop preparation strategies that uniquely serve the demands of their instrument and suit their individual learning styles. Some examples of these preparation strategies might include determining and mapping out the overall form of the piece; paying attention to aspects such as key, meter, and other features; tapping rhythms; and planning and writing in fingering. The preparation phase involves not only briefly scanning the musical score for relevant details and identifying potential difficulties but also employing strategies to rehearse problematic aspects of the music.

Sight-reading performance entails a number of cognitive demands that can be distinguished from those inherent in the performance of practiced repertoire. Each of these cognitive aspects is

addressed in separate sections of this review, and some pedagogical strategies for addressing the challenges inherent in sight-reading are delineated. To decipher a score at sight, the reader must recognize musical patterns, generate a large-scale performance plan to govern performance of the piece as a whole, and learn to anticipate how the music continues (Lehmann & Ericsson, 1996). Basic elements that must be attended to during sight-reading performance include (a) rhythm (meter, duration, patterns, accentuation), (b) melody (pitch, direction, movement [e.g., skips vs. leaps], patterns), (c) harmony (chord structure, chord progressions), and (d) context (articulation, expressive markings, musical structure and form).

The way in which these basic elements are combined and interact within a musical score contributes to the complexity of the sight-reading task. There are also more subtle cues embedded in the music that, according to the experience and musical sophistication of the player, may or may not be rendered in a sight-reading performance. Some examples of these more embedded cues include (but certainly are not limited to) maintaining good balance between the melody and harmony, using the pedal, and playing according to the principles of performance practice that govern the piece. In addition to perceiving and decoding aspects of the score, successful readers actually anticipate problems while simultaneously observing musical markings and evaluating their sight-reading to correct the performance as necessary (McPherson, 1994).

Finally, successful sight-readers employ certain patterns of eye movements to efficiently decode scores. Pianists, in particular, are challenged by the visual aspect of music reading. The need to look at the musical score must be balanced with the need to look at one's hands and fingers to accurately place them on various parts of the keyboard so that correct pitches can be played. This involves the potential danger of losing one's place in the score as one's eye moves and refocuses. In contrast, rehearsed performance is based on free recall of musical materials, often by memory, and physical mastery of requisite motor-skill patterns. Each time a repertoire piece is practiced, the pianist makes more inferences about correct pitches and other musical details (Lehmann & Ericsson, 1996).

All of these cognitive and physical demands are governed by perhaps the most stringent constraint of the sight-reading task: continuity, or the ability to perform in "real time" without stopping to decipher the written score or correct mistakes. Maintaining a continuous rhythmic pulse is paramount. The musician must keep playing during sight-reading, even if she or he executes notations incorrectly.

Motor Execution. While motor execution has not been the primary focus of the aforementioned types of studies, several studies focusing on cognition during the sight-reading task have considered motor patterning as a *procedural* consideration of sight-reading. Apparently, there is some merit to the traditional and intuitive pedagogical notion that the best

way to improve sight-reading ability is to engage in sight-reading activity. Both performance accuracy and consistency of fingering correlate positively with expertise at the piano (Sloboda, Parncutt, Clarke, & Raekallio, 1998). Expert piano sight-readers develop rule-governed patterns of motor response in their fingers that are called forth upon recognition of familiar visual notational patterns. As their expertise increases, musicians are able to combine movements into variable patterns that successfully execute musical notation. Skilled motor performance in any human endeavor rarely consists of rigidly programmed motor sequences in which each individual movement arises invariably and inflexibly from the prior movement. Shaffer (1981) noted that expert pianists were able to develop a mental plan that specifically addressed the intended sight-reading outcome and employ a flexible motor programming system that efficiently enacted the required muscular contractions. It is thus apparent that, when sight-reading at their instrument, skilled sight-readers have better developed and more flexible motor programming systems than do novice sight-readers.

Even so, it is likely that sight-reading is more physically awkward than performing practiced repertoire regardless of the experience level of the player. In their examination of pianists learning new repertoire, Halsband, Binkofski, and Camp (1994) found that motor skills were not optimized during the early learning phases of a piece. As participants in their study moved from the beginning stages of working with a piece to more advanced interpretive and expressive phases, the perception of the task changed. Motor patterns changed in direct response to the change in perception, becoming more and more efficient as the pianists thought in terms of progressively larger metrical groupings.

Just how these motor sequences become ingrained in pianists or other instrumentalists remains a question for further research. One might presume that these patterns are absorbed over time through direct playing experience. Applying these observations regarding motor execution to the teaching of sight-reading raises additional concerns. For example, how can teachers cultivate student flexibility in motor response to notational stimuli? Also at issue is whether reading activities must be domain specific or whether, and through what mechanism, repeated reading as it is encountered during repertoire practice contributes to motor programming. Addressing the quality of motions enacted by instrumentalists as they undertake various musical tasks is an emerging research interest, and much more work remains to be done in this area. At the very least, given what is known about the inefficiency of motor execution in an unknown task, it would seem prudent to exercise caution during sight-reading activities. Perhaps using a slow tempo when sight-reading is warranted, especially if the task is complex. This approach would allow students more time both for cognitive processing and to enact the appropriate motor sequences without unduly taxing the body. In addition, given the cumulative physical demands of

sight-reading, musicians might consider avoiding sight-reading for extended periods of time and taking breaks when appropriate.

Eye Movements During Sight-Reading. A specialized area within the larger domain of cognitive research on sight-reading has focused on the patterns of eye movements discernible in experts. Goolsby (1994) compared eye movements among skilled and less skilled readers on various instruments. He found that while novice sight-readers tend to read in a note-by-note fashion, skilled sight-readers scan their eyes forward to take in details of the score ahead. He further noted that not only do skilled sight-readers "look ahead"—advice frequently prescribed by music teachers—they also use regressive eye movements to fill in details scanned previously. Sloboda (1974, 1977) determined that fluent sight-readers read up to seven notes ahead in the score and can continue playing up to this point after the score is removed. The number of pitches that the musician is able to retain in memory after the score is removed coincides with the distance the player scans ahead of where she or he is currently playing. This distance was designated by Sloboda as the "eye-hand span" and has been termed the "perceptual span" by other researchers. Expert readers are able to fit more detail into their perceptual spans than less experienced readers. As an interesting corollary to this generalization, Furneaux and Land (1999) found that highly skilled readers at the piano do not actually have a greater *time* capacity for storing information; rather, they can fit more information into this "information buffer" than can novices (Furneaux & Land, 1999).

As mentioned earlier, while expert sight-readers look ahead in the score, they also employ intermittent regressive eye movements (right to left) to clarify notational and musical details. Expert sight-readers at the piano tend to employ progressive and regressive "zigzag" eye movements and fixations (stopping points) that allow them to visually process both the bass and treble clefs (Furneaux & Land, 1999). The zigzag eye movement observed in pianists may be idiomatic to piano reading in light of the necessity for pianists to scan both vertically and horizontally across two staves to discern melodic and harmonic details.

Goolsby (1994) noticed that the expert reader in his study, in this case a trumpet player, appeared to use time allowed by long rhythmic durations to explore notation and look at expressive markings, sometimes even scanning other staves. Goolsby's findings in this regard were further elucidated by Waters and Underwood (1998), who confirmed that expert sight-readers who played various instruments associated with treble clef reading used a greater number of eye fixations (stopping points); in addition, they found that the initial fixation was shorter among experts than among less skilled readers. Also, expert sight-readers fixated their eyes on the score more frequently, sometimes even staring at "blank" areas in the notation. Although the reason for this is unknown, Goolsby has postulated that focusing on blank space allows the

reader to "bide time" while executing that which has already been cognitively processed. While eye movements are undoubtedly influenced by musical structure (Sloboda, 1993), there seems to be no difference in the duration of eye fixations made by expert instrumental readers when reading tonally simple versus more complex music, although speed and accuracy of execution decrease when experts perform tonally complex music (Waters & Underwood, 1998).

To summarize, research on eye movements in sight-reading demonstrates that expert sight-readers have a greater eye-hand span than novices, fixate their eyes on a specific location on the score for shorter durations, and use progressive and regressive fixations in a zigzag pattern to visually scan the musical score. Experts also appear to take maximal advantage of the time allowed by longer rhythmic durations to clarify details by either taking advantage of this time to cognitively process what they have visually scanned or using regressive eye movements to look back and clarify notational details. Effective patterns of eye movements might be encouraged by activities that encourage students to take in a short grouping of notational details and play from memory what they saw after the visual stimulus. However, since the specific brain mechanisms promoting eye movement patterning during music perception have yet to be explored, any pedagogical strategies to this end are speculative.

Grouping and Structural Perception. Expert sight-readers apparently use a method of "chunking" that allows them to perceive multiple details of the musical score as a single piece of information. As previously noted, while the perceptual spans of expert readers are not larger in their physical or temporal capacities, fluent sight-readers are able to fit more details into these spans. The ability to perceive musical notation as groups or "chunks" of related information is postulated as the reason for these more inclusive perceptual spans of expert sight-readers in comparison with novices, who tend to perceive individual bits of detail (Goolsby, 1994). This effect relates particularly to perceiving larger patterns in pitches and rhythm. If readers are perceiving "chunks" of information, it follows logically that they would move the eye over a block of notation (measures at a time) rather than sequentially looking at each bit of notation (note by note). Thus, perception of information "chunks" also offers an explanation for experts' greater number of eye fixations and use of both progressive and regressive eye movements to scan the score (Furneaux & Land, 1999). In a similar vein, Waters, Townsend, and Underwood (1998) found that skilled piano sight-readers made better use of contextual information than novices. In both chord-recall and melodic-pattern-recall tasks, experts were faster and more skilled than novices; skilled readers were more likely to perceive larger chunks of the music than less skilled sight-readers. Expert sight-readers exhibit better pattern recognition than novices, and they can better combine "chunks" of information into larger cognitive constructs.

Pattern recognition applies not only to pitches but to rhythmic units as well. Perception of

rhythm may well be the most central aspect of music reading. In a study of clarinet and trumpet students conducted by McPherson (1994), rhythmic errors were by far the most common type of error made in sight-reading, constituting more than two thirds of all errors. As is the case with pitch patterns, expert piano sight-readers attend more to temporal, or rhythmic, structures than do less skilled sight-readers (Waters et al., 1998). Both Clarke (1985) and Longuet-Higgins and Lee (1982) have discussed the primacy of perceptions of larger groups of rhythmic patterns, termed "structural rhythm." When a player perceives structural rhythm, she or he is attending to larger hierarchical groupings of notated rhythmic patterns and meter that often subsume several phrases or parts of phrases. Perception of rhythms as larger units contributes to sight-reading efficiency and accuracy. In a study examining the role of grouping perception in reading, Halsband et al. (1994) documented that perceiving rhythm in progressively larger groupings contributes positively to pianists' ease of motor execution. This finding makes sense given that perception of larger rhythmic groups would allow the player to effect longer and more efficient physical gestures.

Subtler musical details that expert piano sight-readers tend to group cognitively during sight-reading include melodic contour, phrases (Peretz & Barbai, 1992), meters and barlines, and strong versus weak rhythmic pulse groupings (Halsband et al., 1994). As discussed earlier, expert sight-readers are far more attentive to structural markers, while novice readers tend to focus more on denotive aspects of the score, such as notated pitch (Goolsby, 1994; Sloboda, 1977). Attention to a larger musical context is a likely explanation for "proofreader's error," a commonly occurring phenomenon among expert music readers that entails unconsciously correcting a pitch or rhythmic misprint on the score to match the melodic, rhythmic, or harmonic context of a piece (Sloboda, 1993). The ability of expert readers to automatically effect this change without conscious processing is evidence of larger, more inclusive perceptions of musical groups and patterns.

Several pedagogical strategies might be employed in aiding students in pattern recognition. Students might be asked to complete a musical pattern in terms of either pitch or rhythm. In addition, musicians need to be familiar with the deep background knowledge that governs musical context, including an understanding of harmonic and tonal function (e.g., scales, arpeggios, nonharmonic tones), melodic patterns, texture and form, and performance practice. Systematic study of music theory and history in combination with opportunities to apply knowledge is a likely vehicle for achieving this goal. Providing students with ample opportunities to hear and play music of various styles also contributes to background knowledge. Students can apply theoretical principles through improvising a melody over a provided chord progression or providing chords or adding melodic fills for a lead sheet. They might be asked to

identify and label formal, melodic, rhythmic, harmonic features in music that they have heard or are preparing for performance. An even higher-level application of these concepts might involve students composing a piece given certain formal parameters. Guided improvisation drill has also been postulated as a means of increasing pattern recognition. Montano (1985–1986) conducted a study in which beginning collegiate piano students practiced drills that emphasized improvising pitches within a given rhythmic duration and were coached on identifying relevant structural details of sight-reading excerpts. Prior to playing the sight-reading excerpt, participants also prepared by clapping or tapping rhythms. Participants in the experimental group demonstrated greater rhythmic accuracy than participants in a control group who were given no such guidance. If students missed pitches, they were able to maintain continuous rhythmic flow by "faking" their way through until they could get back on track with the musical score. Unfortunately, Montano's results cannot be generalized since no attempt was made to compare the effects of improvisation drills on sight-reading and the effects of simply practicing a greater quantity of sight-reading exercises. It may be that students in the experimental group improved purely on the basis of increased sight-reading experience.

Visual and Auditory Monitoring During Sight-Reading. The role of feedback during the sight-reading task remains a question of interest. Visual feedback has clearly been demonstrated to be necessary for skilled sight-reading execution, specifically as it relates to positioning the hands and fingers on the keyboard. Banton (1995) studied the effects of both visual and auditory feedback during sight-reading on pianists. She found that when visual contact with the hands or fingers was completely prevented, the direct result was more note-accuracy errors in execution. Lack of auditory feedback did not have the same result. She hypothesized that the explanation for this effect might be that movement is largely based on visual feedback. Poor sight-readers tend to be overly dependent on visual feedback in judging the accuracy of their movements, suggesting that expert sight-readers have a stronger tactile command of keyboard geography. This finding is probably more pertinent to keyboard players than to other instrumentalists given that, in comparison with playing wind instruments, playing a keyboard instrument involves more complex and more frequent changes in hand positioning that require visual reference.

Strikingly, although withholding auditory feedback did not appear to directly affect accuracy of movement during sight-reading in Banton's study, it was implicated as a means of monitoring performance. In fact, more competent sight-readers in that study appeared to be able to use auditory and predictive skills to detect when the performance began to deviate from the musical notation, enabling them to make the appropriate adjustments to correct motor execution. The ability to self-monitor and adjust execution in this way involves accurately matching visual notation with aural feedback (McPherson, 1994). Thus, while lack of auditory feedback was not

linked to more sight-reading errors in Banton's study, the ability to form auditory *representations* of the notated score (hearing in the mind's "ear") is probably an important factor in skilled sight-reading. Researchers have repeatedly observed that competent sight-readers use self-regulatory processes, regardless of what instrument they play. Self-monitoring includes developing the ability to scan for relevant notational detail, engaging in brief mental rehearsals of problem areas, anticipating problems, observing musical markings, and evaluating the performance and making changes to get back "on track" when necessary. Waters et al. (1998) even asserted that the ability to form auditory representations and make predictions about how the music should sound may be more important than pattern recognition, although they acknowledged that sight-reading expertise probably depends on all three abilities.

Scripp (1995) noted that instrumentalists of all types are often unable to sight-read effectively without their instrument upon their entry as freshmen into college music conservatories. In effect, they do their thinking with their hands. They are unable to detect errors in simple melodies or demonstrate metacognition of their sight-reading process, even after years of training. Scripp postulated that sight-reading expertise involves development over time of specialized cognitive abilities evidenced when students are able to sight-read music *without* using their instrument. While Scripp did not describe how these cognitive skills develop, his findings indicate that successful internal audiation is a major factor in sight-reading execution. While the importance of auditory representation has been recognized and elaborated on by music educators, most notably Edwin Gordon, the exact role that internal audiation plays in sight-reading success has not clearly been defined from a perceptual perspective.

Since the ability to sight-read without one's instrument (i.e., using one's voice) necessitates the development of an internalized aural model of how a piece should sound, it follows that pedagogy should be directed toward this end. If sight-reading is dependent on development of the ability to form aural representations, then providing students with aural training and application opportunities may contribute to sight-reading expertise. This implies that students should be exposed to musically diverse styles and sounds, engaged in sight-singing, and taught to hear and identify various chord progressions so that their ability to internally predict how melodies and harmonies should sound is cultivated. These suppositions are supported by the findings of Yang (1994), who examined whether beginning piano students 6 to 9 years of age would attain higher levels of musical achievement if they were given training in solmization ("*do–re–mi*" solfège singing), rhythmic movement, or a combination of both. She concluded that students who received training in solmization or a combination of solmization and rhythmic movement were significantly more accomplished than control-group participants, who received no such instruction, in discriminating pitches and playing back melodies. She also found a correlation

between ability to play back melodies and vocal accuracy. This is yet another indication that sight-singing may contribute to the ability to form aural representations of music, which in turn influences sight-reading achievement.

Sight-Reading Related to Musical Specialization

In addition to the cognitive factors already discussed, piano sight-reading expertise is influenced by collaborative (accompanying) experience. Lehmann and Ericsson (1993) explored the role of specialized training in sight-reading, specifically the types of musical activities engaged in by accompanists. There is a notable difference in sight-reading ability between pianists who primarily practice repertoire and those who specialize in collaborative performance. Lehmann and Ericsson (1993) studied 16 pianists, both performance and accompanying majors, at Florida State University. They found that those students who had more accompanying experience exhibited consistently better sight-reading performances than those pianists who primarily practiced and performed solo repertoire, even though the latter students might have been slightly superior in their overall piano-playing ability. They noted that the accompanying majors consistently spent more time sight-reading than the performance majors and hypothesized that the reason for the demonstrated variance in sight-reading between the two groups was probably related to the real-time decoding and motor programming requirements of this task.

Experience level notwithstanding, there is often a wide difference between a pianist's rehearsed performance ability and her or his sight-reading ability. While a pianist may be an accomplished performer, his or her sight-reading level may be considerably lower than his or her repertoire level. Lehmann and Ericsson (1996) asserted that pianists with more collaborative experience are better sight-readers. These observations led them to the conclusion that sight-reading is a specialized skill that improves with direct experience. Collaborative pianists tend to be more successful sight-readers because they tend to play a large volume of literature and, out of necessity, tend to sight-read more than performance majors. Lehman and Ericsson thus postulated that expertise in sight-reading among accompanists is probably primarily a function of the *amount of time* spent actually engaged in sight-reading. However, it must be noted that the differences observed in sight-reading ability between piano performance majors and accompanying majors might simply demonstrate a "weeding out" effect in choice of subspecialization. Collaborative pianists are typically required to use their sight-reading abilities on a regular basis; thus, it is unlikely that a pianist who was not a good sight-reader to begin with would be attracted to a concentration in accompanying.

In addition to time spent engaged in domain-related activities, Lehman and Ericsson (1996) pointed to the aspect of challenge as a large factor in developing sight-reading ability. Engaging

in progressively more difficult sight-reading seems to contribute to a pianist's ability to sight-read well. This observation led Lehman and Ericsson to conclude that sight-reading ability does not correlate with overall musical talent, nor does it represent a specific type of innate talent. Rather, sight-reading expertise results from long-term, deliberate engagement in sight-reading activities that maintain a continued aspect of challenge. The findings described would seem to confirm the long-held notion of music teachers that the best way to improve sight-reading ability is to sight-read progressively more difficult music, although specific pedagogical strategies are not indicated by these studies.

Suggestions for Further Research

While research on the cognitive aspects of sight-reading has somewhat illuminated the mental processes used during this musical task, many questions remain with regard to the pedagogical implications of these findings. As discussed earlier, one means of increasing sight-reading ability might be to engage in long-term, progressive sight-reading. Yet another pedagogical dimension that deserves further consideration is use of solfège and other methods of sight-singing to promote students' ability to develop an internal aural representation of music notation to guide motor execution. It is evident in reviewing the studies described here that "chunking" information greatly facilitates sight-reading. Providing students with collaborative playing opportunities in which they routinely sight-read progressively more challenging music may also be a key for developing sight-reading ability. While some teaching tools can be extrapolated from extant research, cognitive studies on sight-reading have not yet given rise to specific pedagogical aims or methods. In fact, there is a lack of agreement even on what constitutes a true sight-reading experience (Some preparation? None at all?). Piano sight-reading is encountered in many different guises, including sight-reading at musical festivals or contests after little or no preparation, performing collaborative repertoire on short notice, and rapidly preparing solo repertoire pieces. In the latter case, while sight-reading serves as a component of the process of learning, it is not the objective but rather a means to an end

What is the relationship between cognitive processing and motor execution? Future directions for research on sight-reading might include continuing to elaborate on the cognitive processes used by successful sight-readers. Investigation of whether the processes used during sight-reading are the same or adaptations of those used in preparing solo repertoire might lead to pedagogical recommendations for both tasks. Rehearsal of repertoire seemingly involves more than repeated readings of the musical score. Commonly encountered rehearsal techniques include tapping/clapping, "blocking" chord structures, altering rhythm or fingering, and other reductive strategies. Are these practice strategies the most efficient, reliable means of achieving repertoire

mastery? Can they also be applied effectively in sight-reading? Further understanding of the cognition involved in music reading in general may point to pedagogical approaches more specifically applicable to sight-reading. For example, can we *teach* students to visually scan ahead during sight-reading, and, if so, how?

Finally, what are the characteristics of motions enacted during sight-reading performance? Researchers need to question whether there are quantitative or qualitative differences in the motions musicians employ when they are sight-reading versus when they are performing rehearsed repertoire. This type of exploration might lead to maximizing physical efficiency while successfully conquering the cognitive demands of sight-reading.

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