

The Relationship Between Musicians' Internal Pulse and Rhythmic Sight-Reading

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**Abstract**

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Playing music at first sight involves coordination of auditory, visual, spatial and kinesthetic systems to produce an accurate and musical performance (Hayward, 2009). Accurately performing pitch and rhythm in tandem has been observed to be difficult in a sight-reading task.

Musicians' rhythm reading ability has been found to be the best predictor of sight-reading performance (Elliott, 1982). It may be conjectured that stable and consistent internal pulse is necessary to perform accurate rhythms. The purpose of this study was to assess the relationship between an individual's timekeeping ability and performance on rhythmic sight-reading tasks.

Fifty-three wind, string or percussion instrumentalists participated in one rhythmic sight-reading and three timekeeping evaluations in two separate sessions. The sight-reading evaluation included rhythmic excerpts that increased in difficulty as participants performed the exercises out loud with a neutral spoken syllable. The timekeeping evaluations involved silently reading rhythms and keeping steady beat with and without visual notation while tapping at specified points. Absolute deviations from

the target performance were analyzed in relation to performance on the sight-reading evaluation. Participants were also asked to report any specific strategies used in performing the rhythm reading or timekeeping tasks.

There was no significant correlation between the sight-reading evaluation and tests of internal timekeeping. A significant correlation was found between tasks involving rhythm reading and tasks focusing on timekeeping. Analysis of strategies indicated no difference in accuracy between participants who employed strategies and those who did not. Supplementary analyses were completed to determine possible reasons for the dichotomy of rhythm reading and timekeeping. Results suggested that participants had difficulty maintaining tempo rather than misreading rhythms or placing taps at incorrect points.

These data suggest that timekeeping and rhythm reading are two separate tasks. This contradicts the initial assumption that participants who perform well on rhythmic sight-reading examples would have strong time keeping ability.

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**Dedication**

For Grandpapa



## Chapter 1: Introduction

*A student sits behind a screen having just played through several prepared excerpts for an audition. The final step of the student's audition is to sight-read a novel piece of music to evaluate his music reading skills. My colleague asks the student to turn over a sheet of paper, look over the provided music and perform the tune when he is ready. The student takes a few nervous breaths and utters a few indistinct sounds while tapping his foot loudly. Finally a deep breath followed by an apprehensive sound from the instrument. The tone is shaky and under-supported, but the student manages to navigate through the first measure. As the student progresses, confidence wanes and mistakes begin to appear. As I follow along on my copy of the music, trying to match what the student is playing to what I see on the page, eighth-note values begin to compress and whole note values only receive brief valuations. I attempt to extract a beat pulse from the performance but am unable to do so. The student's performance has become unrecognizable as compared to the notation on the sheet. Finally the student concludes the excerpt and I grow increasingly curious as to what happened in that student's mind to abandon the basic element of music reading, the thing upon which all rhythmic values are based: the beat pulse.*

Sight-reading is the ability to read and play music without prior rehearsal involving coordination of auditory, visual, spatial and kinesthetic systems to produce an accurate and musical performance (Hayward, 2009). Sight-reading is also an evaluation of one's fluency in music reading, a skill that demonstrates a musician's comprehension of the system of musical symbols (Gromko, 2004). As a highly valued skill in music education, sight-reading is demonstrated frequently in the audition process, in rehearsals of new pieces and evaluations of musical ability. Although musicians are asked to regularly perform this task, it remains a highly variable skill among performers creating an ongoing obstacle for educators.

## **Statement of the Problem**

As described in the opening anecdote, personal observations of poor sight-readers have led to the current research. As a teacher and performer, I have observed an inability to simultaneously perform pitch and rhythm in sight-reading and am interested in exploring possible reasons for this deficiency.

Musicians frequently participate in the task of sight-reading in a variety of different environments. Sight-reading is used as a tool for assessing fluency in music reading, which can be translated into an individual's ability on an instrument. Sight-reading is more often conducted in a casual setting when reading a piece of music for the first time with an ensemble or in personal practice. Although the ramifications for mistakes in this situation are less consequential, they can still develop into learned mistakes or result in ensemble performance issues.

A musician processes multiple layers of visual information when reading notation, which include pitch, rhythm and extra-notational elements (e.g. tempo, dynamic and stylistic markings). Each of these layers needs to be processed simultaneously while manipulating an instrument to result in an accurate performance. Presentation and performance of these layers occur simultaneously but research in cognitive psychology and attention has demonstrated perceptual independence and distinct processing between melodic and rhythmic information (Besson, 1995). Waters and Underwood (1999) found that processing of temporal information can occur independently from pitch processing, but processing of temporal information may constrain the processing of pitch. Their study uncovered independence in processing both pitch and temporal structures when performing recall tasks. The only instance of perceptual dependence was found with

pitch recall in metrically manipulated conditions that resulted in decreased performance. Waters and Underwood (1999) found this difference to be small, suggesting a likely independence of processing pitch and temporal information.

Elliott (1982) found similar results among undergraduate wind instrumentalists who demonstrated more rhythmic errors than any other error type in a sight-reading exercise, suggesting independence between the processing and performance of pitch and rhythm. Accurately performing both pitch and rhythm in tandem appears to be difficult in a sight-reading task, but a clear understanding of how one processes the interaction between these two musical elements is not concrete.

### **Rationale**

Many levels of processing are required to perform the task of sight-reading in addition to pitch and temporal aspects. When reading a new piece of music, the performer's initial task is to decode written notation, transform the information to psychomotor processes and evaluate auditory information from performance. Research in the performance of rhythmic material focused on the kinesthetic aspects of performance and characterizes the traits of proficient and poor sight-readers. An individual's motor responses, or reaction time, have been shown to affect sight-reading ability. This component, known as psychomotor speed, serves as a connection between basic and higher cognitive functions, helping to relieve workload and allow the performer to take in new information at a faster rate (Hayward, 2009; Kopiez, 2008; Kopiez, Weihs, & Ligges, 2006). Psychomotor speed has also been found to have an effect on one's fluency of reading highly complex music notation in addition to sight-reading expertise

(Gromko, 2004; Kopiez, 2008). Fluency demonstrates a mastery of notation reading and performance ability on an instrument, a desired skill from musicians and educators (Gromko, 2004).

After the performer actualizes appropriate execution of motor behavior, a feedback loop of auditory information is created which the musician uses to evaluate his or her performance. This feedback loop is comprised of the auditory elements of the performance that are continuously processed while simultaneously evaluating his or her performance, providing an added level of complexity. This form of self-monitoring requires great skill to match visual information and auditory information to accurately evaluate one's own performance (Besson, 1995; McPherson, 1994).

Cognition research in rhythm frequently addressed aural perception of rhythmic stimuli with very little transfer to the visual perception of written notation. Levy (2001) suggests sight-reading errors may arise due to mismatches between expected and actual information. One of the few discussions of notation reading suggested listeners' cognitive structuring may affect their reading as a result of an expectancy violation (Levy, 2001). Throughout the music reading process, a musician gathers visual information from written notation and generates an abstract internal representation (Schön, Anton, & Roth, 2002). An expectancy violation is created when the music reader's preconception does not match the actual representation of the written notation. A mismatch can result from inappropriate structuring by the performer related to grouping of rhythmic information within the metrical structure. This occurs when a listener, the performer in this case, segments musical information into smaller units according to the metrical structure. For example, a performer may see a series of three

eighth notes and compress them into eighth-note triplets, compressing the rhythms according to group rather than the underlying meter. Musicians are also better able to perform rhythm recognition tasks when written representations of rhythmic patterns were grouped to reflect accent patterns of aural presentations (Wiltshire, 2006). The likelihood of a mismatch increases when the written notation does not reflect the performer's inner representations. An alternative form of interference is created when the performer attempts to place attentional demands on different metrical hierarchies, also termed encoding (Grahn, 2009a; Levy, 2001). In a 2009 review by Grahn, she determined that the process of encoding metrical hierarchies requires more attention than encoding surface rhythms (i.e. recognizing changes in individual note patterns was easier to detect than overall metric grouping). This was concluded from reviewing studies that explored event related potentials (ERP) demonstrating negative component responses only when attending to metrical conditions. There are also limited attentional resources available. When presented with stimuli containing temporal and nontemporal information, participants attend to nontemporal events, rather than temporal events, removing attentional resources from the "central pool" (Grondin, 2010). Attention directed to different levels of metrical hierarchy can also affect tempo production with lower level – faster tempo – attending resulting in a faster performance (London, 2004). If an individual is attending at a lower level, he or she is focusing on the individual rhythmic elements produced, rather than larger metric beats. More experienced musicians are known to synchronize at higher (slower) levels, meaning a reduced likelihood of compressing rhythmic figures. Less experienced musicians who attend to smaller metric

divisions would be more likely to compress rhythms into smaller durations (London, 2004).

### **Need for this Study**

Sight-reading is a complex activity, often perceived as a skill that reflects ability level. While previous literature has explored the perception and production of music notation, little research has explored the fundamental unit of rhythmic measurement: pulse. Pulse and beat are terms used interchangeably to refer to individual units of time that establish a tempo, or speed, for the performance of a musical excerpt. In an ensemble setting, the conductor or leader typically generates the pulse, but maintenance of individual pulse is also expected of the performer so the ensemble can play in synchrony. Steady pulse is essential for accurately subdividing rhythms into equal parts, as dictated by the notation. Elliott (1982) found rhythmic reading ability to be the best predictor of overall instrumental sight-reading scores. I am interested in exploring the cognitive basis of good rhythm reading to better understand the relationship between rhythm reading and sight-reading ability.

I have observed a deficiency in the sight-reading abilities of college level musicians. Inquiry into school band (music) programs has revealed that an orientation toward ensemble performance goals often outweighs long-term individual musical goals, such as the development of music reading skills (Bostain, 1970). Boyle (1970) also recognized sight-reading ability as one of the most deficient skills in school bands. My observations of sight-reading performances in an audition setting support this assertion with accurate rhythmic performance being the most regular and obvious deficiency.

Inaccurate performances tend to be characterized by the lengthening of longer note values, improper subdivision, loss of overall pulse, and stopping and re-starting (McPherson, 1994). Previous research has outlined traits of poor and strong sight-readers, influenced by various cognitive processes and multiple notational elements, but a gap remains in the literature exploring the relationship of internal time keeping on rhythmic sight-reading.

### **Purpose of this study**

If accurate rhythmic performance was a significant predictor of instrumental sight-reading performance, it would be assumed that strong internal pulse would result in performance of accurate rhythms resulting in stronger rhythmic sight-reading (RSR) ability. Maintaining a given tempo would allow the participant to more accurately divide rhythms into correct ratios. The purpose of this study was to assess an individual's internal timekeeping ability in relation to performance on RSR examples.

This study focused on the following questions:

1. Do participants with more accurate internal pulse perform better on rhythmic sight-reading examples?
2. What strategies, if any, did the participants use to perform the tasks measuring internal pulse?

The results of this study expanded on existing sight-reading literature while exploring a possible relationship between internal timekeeping ability and RSR. In breaking down the complex task of sight-reading, it is the hope of the researcher to pinpoint a possible link between an internally maintained tempo and RSR ability.

Previous research on synchronization to auditory and visual stimuli has been modified for the current study to evaluate internal pulse and was used to evaluate relationships between internal pulse and RSR (Patel, 2006).

## **Chapter 2: Literature Review**

Existing literature on instrumental sight-reading has covered topics ranging from factors influencing accuracy to cognitive processes involved in sight-reading tasks. This chapter focuses on connecting literature on sight-reading to research concerned with temporal perception. This review is divided into two major sections, the first considers sight-reading from the perspectives of processes involved with performing written notation, traits of skilled and unskilled sight-readers, interactions between pitch and rhythm in music reading and cognitive processes used in reading written notation. The second section explores the concept of internal timekeeping in relation to various cognitive processes, theoretical internal timers and factors that influence these timers.

### **Role of Rhythm in Sight-reading**

Multiple definitions of sight-reading exist within the current literature, generally describing this skill as reading and performing novel music notation with little or no previous practice (Elliott, 1982; Kopiez, 2008; Orman, Yarbrough, Neill, & Whitaker, 2007; Penttinen & Huovinen, 2011; Earney, 2008; Wurtz & Mueri, 2009). Elliott (1982) stipulated that a more accomplished sight-reader is able to read and perform a passage at first sight, whereas a less accomplished sight-reader may need two or three attempts to read the passage correctly. Accurately performing music without prior rehearsal demonstrates a musician's ability to simultaneously translate discrete pitches and rhythmic figures (Henry, 2011). This complex skill involves multiple perceptual, cognitive and motoric systems such as spatio-temporal processing, psychomotor speed

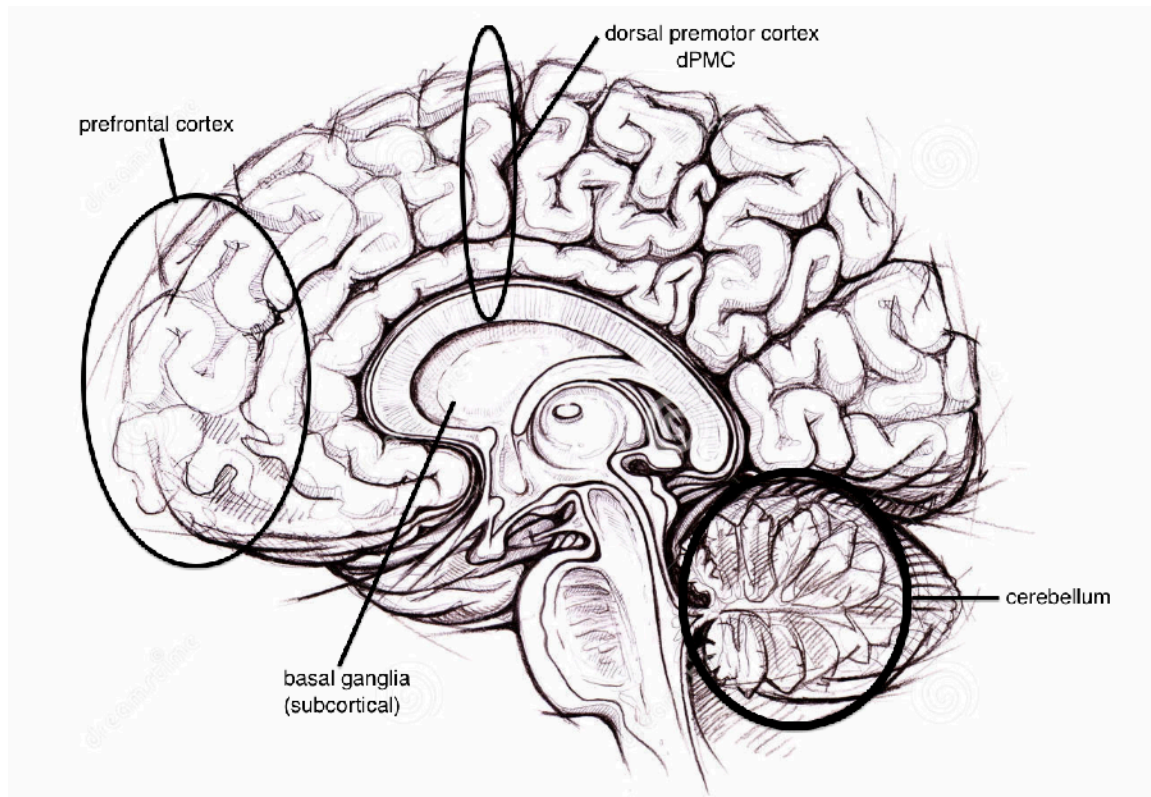
and pattern recognition (Penttinen & Huovinen, 2011). Spatio-temporal ability is the process by which an individual recognizes the relationship between objects and is able to transfer the objects through space and time without any physical representation (Gallagher, 2001). For the purposes of this study, these “objects” refer to initial performance of rhythmic notation without prior practice. Psychomotor speed represents the time in which mental processes are transferred to movement or muscular activity. Any deficit in this process would delay and alter the temporal performance by a musician. Sight-reading is considered a demonstration of one’s music notation literacy and is often included in auditions, during ensemble rehearsals and as part of individual practice. McPherson (1997) theorized that sight-reading skills might be reflected in the performance of prepared music, as both skills are demonstrations of music literacy.

This study is concerned with accurate rhythmic performance as compared to an individual’s internal timekeeping ability. Ben Falle (2011) described accurate rhythmic performance as respectful of absolute and relative durations with adequate sequencing. The nature of rhythm performance is not required to be exact, but maintenance of temporal ratios is necessary for rhythmic accuracy to be perceived by the listener. The term “expressive timing” usually identifies this concept. Repp (1998) clarified this idea of accurate performance of temporal ratios and noted that expressive timing is “far from arbitrary.” (p. 791) Expressive timing is bound by factors related to melody, harmony and musical structure, which is why Repp (1998) suggested that this notion is not generally random. While this study is not concerned with expressive timing, it is important to mention, as mechanical timing is not typically preferred in musical performance. Internal timekeeping data from this study were compared to a target

performance for the purpose of analysis. Assessment of the rhythmic sight-reading (RSR) task was not compared to a target performance to accommodate real time scoring. Instead, this assessment used a standard of accurate ratio performance, rather than mechanical rhythm production validated by an outside scorer.

**Cognitive processes involved in performing written notation.** Studies that have utilized neuroimaging have been conducted to investigate neural regions associated with the perception and production of rhythms. Several areas of the brain have been identified as important to the perception and production of rhythm, but it is still unclear as to why some of these tasks are abandoned or absent when performing pitch-based notation. When reading notation, a musician experiences three stages of perception: auditory processing, structural perception and structural cognition while simultaneously employing three basic motor functions: timing, sequencing and spatial organization of movement (Repp, 1998; Zatorre et al., 2007). A study by Zatorre et al. (2007) outlined areas of the brain that contribute to music perception and performance. The cerebellum may contribute to precise motor control and accurate timing of rhythmic sequences, while the dorsal pre-motor cortex (dPMC) aids both in performance and perception of these rhythmic exercises. Other areas that aid in perception of complex rhythms include the lateral cerebellar hemispheres and the prefrontal cortex (PFC), while the basal ganglia (BG) has shown activation for learned sequences. Figure 2.1 displays the locations of the above-mentioned structures, keeping in mind the BG are a subcortical structure and are deeper within the brain. Zatorre et al. (2007) outlined the lateralization of rhythmic

perception functions within the cerebellum, but it is unclear how this transfers to rhythmic performance.



*Figure 2.1.* Anatomical Locations of Structures Utilized in Sight-reading.

Other studies using neuroimaging techniques have identified various areas of activation during the music reading process. Results demonstrated that musicians generally show more efficient recruitment of motor neural regions than non-musicians in a non-musical task and a greater competency in neural regions when tested on music-specific material (Chen, Penhune, & Zatorre, 2008). Repp (1998) also suggested that musical structure is reflected in motor behaviors and affects listener's timekeeping abilities. When analyzing rhythm, a musician may depend on interactions between

auditory and motor systems. The process of linking these two systems may be the foundation upon which mental representations of music exist (Zatorre, et al., 2007). Mental representations of music are important to sight-reading as musicians who frequently engage in mental performance tend to produce performances with comparable timing profiles (Clark & Williamon, 2012). Musicians who have more experience with forming these mental representations, also known as mental practice, produced similarly timed performances suggesting mental practice may aid in linking perceptual and motor systems.

Zatorre et al. (2007) also discussed an individual's propensity to tap his or her foot to the beat of the musical example, rather than to individual visual events or rhythms. In this case, participants would synchronize foot tapping to the pulse, or underlying beat of the stimuli, not the actual rhythmic patterns in the example. These researchers suggested that this demonstrates a loose connection of feed-forward and feedback. Feed-forward utilizes auditory systems which are predictive in influencing motor output, while feedback aids in real-time error correction during sight-reading. These processes are important for musicians to employ appropriate motor control systems to execute accurate rhythmic performance over an implied pulse (feed-forward) while evaluating their performance in real time (feedback).

These studies described specific neural regions responsible for the perception and performance of rhythm, but it is still unclear as to why certain tasks like timekeeping and rhythm reading are abandoned in favor of other aspects related to performance.

**Skilled and un-skilled sight-readers.** As sight-reading is explored throughout this study, it is important to note what good sight-readers actually do while performing this task. Skilled sight-readers are thought to be more regulatory in their preparation of unknown material and reflect upon information previously taught by their instructors (McPherson, 1994). Good sight-readers have also been found to demonstrate common processes when preparing novel music. Strong readers spend their preparation time scanning the excerpt and making note of any unusual rhythmic elements, which may include “triplets, fast and slow notes and ties and rests.” (Zhukov, 2006) They also consider the time signature of the example and make an informed choice of tempo based on their observations of the excerpt. After making judgments about appropriate tempo, proficient readers demonstrate more deliberate timing when encountering a difficult rhythmic passage to preserve the accent structure determined by the meter (Levy, 2001). The attention to deliberate timing not only preserves the accent structure, but also demonstrates a proficient reader’s attempt to preserve the proportional relationships of correctly subdivided rhythms. Skilled sight-readers are able to read in larger units and actively compare stimuli while also demonstrating fewer fixations of the eye on any single point in the musical example (Goolsby, 1994; Waters, Townsend, & Underwood, 1998). When comparing stimuli, a capable reader demonstrates an ability to recognize patterns and move ahead in the notation from the actual performance. Skilled sight-readers demonstrate planned preparation with attention to all musical details of the excerpt.

Alternatively, several common mistakes are observed among unskilled sight-readers when performing a new piece of music. Most often, musicians have a tendency

to compress small rhythmic intervals and increase longer intervals (Doumas & Wing, 2007). McPherson (1994) concluded that unskilled sight-readers are deficient in areas such as coordination of motoric responses and consolidation of different levels of information provided in the stimuli. Skilled sight-readers are able to merge multiple components in music notation (e.g. notes, expression markings, articulations) resulting in a decreased load on motor processes. Unskilled sight-readers are also more likely to divide phrases into smaller units by changing the duration of the rhythmic values or pausing to ensure accurate performance (Levy, 2001). When mistakes are made, several coping mechanisms have been observed. Unskilled readers will repeat notes until the correct pitch has been performed and will re-start or reset in close proximity to the original mistake (Fitch & Rosenfeld, 2007; McPherson, 1994). Syncopated rhythms have also been found to induce the reset behavior and trigger rhythmic adjustment resulting in a less syncopated performance in an attempt to perform the excerpt more accurately (Fitch & Rosenfeld, 2007).

It was also noted that poor sight-readers were unable to take in multiple elements of music notation at once, resulting in abandonment of notational elements (i.e. dynamics or articulations), or a demonstration of local judgments (McPherson, 1994; Prince, Thompson & Schmuckler, 2009). When a sight-reader makes “local” judgments, they are only able to focus on one dimension of the notation, rather than integrating all aspects over time (Prince et al., 2009). These studies establish a notion that poor sight-readers attend more to elements of pitch than to any other element, as if performing correct pitches was the only important feature of music.

Both behavioral traits and cognitive elements of the individual reader have been shown to have a significant effect on sight-reading performance. Behavioral traits such as an individual's ability to read rhythms accurately and play by ear have been shown to have a significant effect on improving sight-reading (Elliott, 1982; McPherson, Bailey, & Sinclair, 1997). Many cognitive elements have also been found to affect sight-reading ability. Kopiez et al. (2006) suggested that one's speed of information processing, or reaction time, plays a crucial role. In the same study, reaction time was hypothesized to improve as a result of the transfer of psychomotor control to subcortical systems, which reduced cognitive load. As a result of the load reduction, other processing systems are allowed to work more efficiently. The integration of information in the spinal cord and resulting transfer of psychomotor control occurs much faster in individuals with faster psychomotor speed (Kopiez, 2008; Kopiez et al., 2006). The combination of mental speed and psychomotor speed are strong predictors of sight-reading ability.

Several studies have discussed ways in which individuals have demonstrated improvement in sight-reading ability. Bostain (1970) developed several exercises to improve sight-reading by utilizing vocal counting and physical tapping to establish accurate timing in drum set players. These exercises were not evaluated empirically, but rather meant to provide a method for skill building through emphasis on individual timing. Prescribed physical movement has also been shown to improve individual timing and rhythm reading (Boyle, 1970). This study evaluated participants on pitch-based stimuli but lent itself to supporting the importance of pulse and rhythm and physical movement in sight-reading (Boyle, 1970). Transfer of skills is also thought to help individuals with problem-solving aspects of sight-reading (Olijnek, 2006). Her study

suggested that educators should focus on improving student ability to transfer skills from other musical tasks to sight-reading.

Previous literature has explored traits and practices of both skilled and un-skilled sight-readers, while other notational factors influence the process of reading music. The following section will explore pitch and rhythm reading both in isolation and in tandem.

**Pitch and rhythm.** Much of the research in sight-reading evaluated performances that included both pitch and rhythm presented simultaneously. It is still unclear how temporal and pitch information affect one another as they are represented differently in music notation. Pitch is discriminated by the positioning within the staff while stem, note head, dots or a combination of the three relays temporal information (Waters & Underwood, 1999). Although the interaction between the two concepts is still unclear, it has been identified that the reader is making two different judgments. A musician who is able to focus on just one element of pitch or rhythm is said to make local judgments, while a musician who is able to integrate information of all material is identified as making global judgments (Prince et al., 2009). A musician who is able to make global judgments is considered more fluent in music reading as they are able to comprehend more notational elements at one time.

Perceptual interaction between rhythm and pitch has been explored through identification of perceived accents. Intervals such as the perfect fifth and leading tone can imply a stronger accent because those intervals typically occur from a weak to strong beat. Direction changes within a melody along with pauses in the music, usually created by rests, have also been perceived as points of accent by listeners (Pfordresher, 2003b).

Another perceptual study relating pitch and rhythm completed by Kopiez and Lee (2008) found that pitch and contour are better cues for music memory than rhythmic elements. Rhythm, especially syncopated rhythm, has been shown to be more difficult to retrieve from memory in performance, a finding which supports notions of pitch having more impact and salience on individual sight-reading when explored through memory tasks (Fitch & Rosenfeld, 2007). Waters and Underwood (1999) also suggested that processing of temporal information can happen independently of pitch information but pitch processing can be altered by temporal factors.

When dealing with rhythmic notation alone, there are three beat types considered in the literature: metrically strong, metrically weak and syncopated. Meter defines weak and strong beats; for example, in 4/4 time the four pulses of the measure are perceived as strong-weak-strong-weak. Syncopated beats occur when an accent is placed off of a strong or weak beat by means of a notated accent or rest placed on the beat itself. Fitch and Rosenfeld (2007) found reproduction of syncopated rhythms to be less accurate than non-syncopated rhythms. The same study also found that listeners felt as if syncopated rhythms produced a certain amount of ambiguity, causing poor readers to reinterpret syncopated notation by shifting the rhythms closer to the metric pulses of the measure. The shift results in weaker performances of syncopated rhythms while also inferring a preference for performing rhythms that occur in time with the pulse, which is necessary for the individual to maintain when performing alone.

Research in eye-hand span has been used to determine how much information a performer has gathered ahead of the point of performance. It has been found that readers are typically looking between two and four notes ahead of actual performance, or to the

end of the bar, suggesting a structural strategy. A structural strategy has also been demonstrated when removal of stimuli at different relational points to the structural boundary (bar line) affects the participant's eye-hand span (Sloboda, 1974; Goolsby, 1994). A participant's ability to gather information ahead of the point of performance could affect a musician's ability to appropriately divide complex rhythms according to the underlying beat structure (Repp, 1998).

Krumhansl (2000) found that musical meter is perceived as having a hierarchy with embedded time spans. Encoding of these metrical hierarchies is more complex and requires more attention than encoding of surface rhythm patterns (Waters & Underwood, 1997). While encoding may be more difficult, research also suggested that the role of meter allows a listener to measure time and perform temporal patterns more accurately (Palmer & Krumhansl, 1990). The same study mentioned that listeners could grasp a metrical structure from an unknown set of pitches, which may later aid in comprehension of both pitch and rhythmic structures. These studies suggested that meter may serve as a foundation in music reading.

Meter also influences the way seemingly similar rhythmic figures are interpreted. For example, a group of three eighth notes are interpreted differently depending on if they appear in 6/8 meter or 4/4 meter. Longuet-Higgins and Lee (1984) provided another explanation of the relationship between rhythm and meter and how one may influence the other:

The relationship between the rhythm and the meter may be simply stated: The former is one of the structures that is generated by the grammar associated with the latter. On this view, a rhythm is much more than just a sequence of note

values; it is a syntactic structure in which the note values are implicit in the terminal symbols, but do not by themselves define the rhythm; if they did, then no sequence of note values could be rhythmically “ambiguous” – open to alternative rhythmic interpretations – as such sequences undoubtedly are. (p. 429)

In support of this statement, Povel and Essens (1985) also described rhythmic patterns in relation to language. They posit that rhythmic patterns are not transposed when seen in repetition because the pattern is not recognized in the same way as other sensory information. “[Temporal] Intervals are not alphabets,” state Povel and Essens (1985, p. 412) meaning that musicians are unable to recognize these patterns as unique, making it more difficult to transfer and recognize. Temporal patterns do not follow a set of rules that are recognizable and transferrable as those found in language, for instance. These patterns appear to be determined by structural elements making the process of recognition more difficult (Povel & Essens, 1985).

The studies discussed in this section explored the perceptual effects of pitch on rhythm revealed a performer’s inclination to attend to pitch, rather than rhythm when sight-reading. While joint effects of pitch and rhythm in the perception of music have been explored, these effects have yet to be discussed directly as related to sight-reading.

### **Cognitive Bases of Music Timekeeping**

The term “internal time-keeping” has been used in previous research as a substitute for internal pulse, a term more frequently used by educators. For the purpose of this study, internal timekeeping (pulse) was defined as a task requiring an individual to maintain a generated tempo throughout an exercise while performing rhythmic exercises

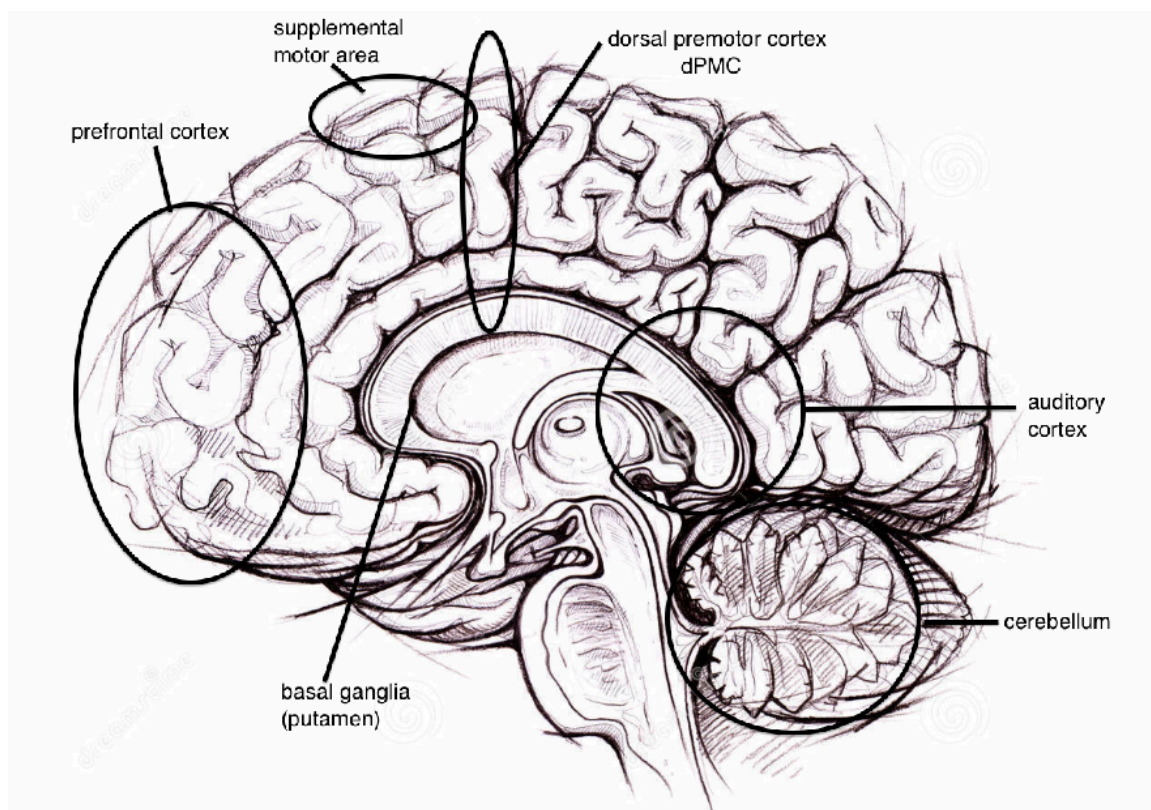
at sight. The given pulse represented the underlying beat of the exercise upon which the participant was to divide the notated rhythms. Krumhansl (2000) found that listeners are sensitive to small differences in durations of performed rhythms. Perceptual characteristics of rhythm are shown to be cognitively controlled and demonstrate automatic timing from the performer. It is important for the individual musician to maintain consistent pulse to perform correctly subdivided rhythms.

A great deal of extant literature described the process of temporal generation and processing. The following section outlines the cognitive and theoretical basis for internal timing from the standpoints of perception and production.

**Cognitive factors associated with internal timing.** Several cortical and sub-cortical regions link to form a network involved in temporal perception and production. Cortical regions involved are: dorsal pre-motor cortex (dPMC), pre-frontal cortex (PFC), dorsal auditory cortical pathway, parietal cortices, and supplemental motor area (SMA). The parietal cortices, PFC and SMA are regions known to play a role in differing timing tasks with the PFC and dPMC (Fig. 2.2) being involved with the perception and production of complex rhythms. The dorsal auditory cortical pathway is relevant for spatial processing and tracking events that vary in time (Grondin, 2010; Zatorre et al., 2007).

The network of temporal processing continues into subcortical regions of the brain and includes the basal ganglia (BG) and cerebellum. The BG are widely accepted as responsible for processing temporal information (Grahn, 2009b; Grondin, 2010). The putamen, a component of the BG, have been found to utilize temporal sequences and

perhaps produce “putative beats.” (Grahn, 2009b) The putamen works in conjunction with the SMA and PFC to engage in this analysis. The cerebellum contributes precise control of movement related to accurate timing while computing differing timing tasks (Grondin, 2010; Zatorre et al., 2007). More specifically, the lateral cerebral hemispheres combine with the PFC and dPMC (Fig. 2.2) to aid in the perception and production of complex rhythms (Zatorre et al., 2007).



*Figure 2.2.* Regions of the brain associated with internal timekeeping

The sub-cortical to cortical network is understood in the process of temporal processing and production but it is still unknown how the lateralization of the perceptual process affects the motor process as these two functions have only been studied

independently (Zatorre et al., 2007). While this point is not the focus of the current study, it is interesting to note the ambiguity of the research connecting the processes of perception and motor skills.

**Internal timers.** While the neural network necessary to process and produce internal pulse is understood, previous research has yet to agree upon the action of maintaining and transferring pulse accurately to performance. Two theoretical internal timers have been discussed in the literature. The first, known as Dynamic Attending Theory (DAT), was pioneered by Jones and Boltz (1989) and outlined a process comprised of two components. These components are nonlinear oscillators that combine to adapt and entrain to environmental stimuli. These oscillators are internal rhythmic representations that align with external temporal examples occurring in the environment. This process resulted in listeners aligning internal oscillators to the provided pulse resulting in a matching expected internal beat with actual onset of stimuli. The other theoretical timer discussed in the research involved a single internal clock where the listener is required to switch between multiple hierarchical levels and operate in a serial manner (Doumas & Wing, 2007; Grondin, 2010; Povel & Essens, 1985; Falle, 2011). These levels of the internal clock operate at different rates and the listener is required to match the external tempo with the appropriate internal level.

Research that explored these timers explained how internal representations aligned with external examples while listening, not the process of temporal generation and maintenance for performance purposes. Research involving these timers gave insight into the complex process of listening and entraining to external temporal information.

While these studies did not explore initiation and maintenance of internal pulse, it seems as if this process would be equally as complex.

**Factors affecting timers.** Syncopation has been shown to provide another level of difficulty for the performer while also causing the performer to lose internal pulse, even when the rhythms are only moderately syncopated (Fitch & Rosenfeld, 2007). The conflict between an individual's demonstration of automatic timing during a perceptual task and a loss of timing in a performance task revealed a breakdown of internal time keeping between tasks, a conflict that remains to be systematically examined and explained.

Structural elements have also been shown to affect central timers. Studies by Repp (1998) and Grahn (2009a) discussed the effect of accent and unaccented beat structure on influencing an individual's timekeeping abilities and internal clock induction. Repp (1998) explained that these implications are then transferred to motor behaviors and resulted in imprecise timekeeping. The same study found that providing an underlying clock – similar to a metronome – for participants led to an improvement of internal representation of a temporal pattern, but the improvement was smaller for less skilled musicians. These findings suggested that skilled musicians are experienced in matching internal representations of temporal information with an underlying clock (e.g. ensemble performance). Less skilled musicians may have difficulty with this task, resulting in less improvement when performing over an underlying clock. These implications are important to the current study in that musicians' reliance on performing

against provided clocks suggests that internal temporal production in a performance task is either difficult or perceived as unnecessary.

In a 2002 study by Repp, it was suggested that detecting deviations from temporal regularity is context sensitive for perceptual detection tasks, but not sensorimotor tasks. This could lead to an assumption that timekeeping involving sensorimotor tasks differ from the perceptual task of identifying temporal differences. Repp (2002) proposed two reasons for this outcome. First, perceptual and sensorimotor tasks evoked two different timers and one is more context sensitive than the other. Second, perceptual and judgment tasks required more attention and conscious awareness while sensorimotor tasks were more automatic and subconscious (Repp, 2002). Regardless of which explanation is correct, these results suggested an independence of the role of perception and performance of temporal tasks.

Another explanation for variations in timing production focused on sensitivity to cognitive demands. Even light cognitive demands can affect processing modes like working memory and time estimation (Falle, 2011). Falle (2011) proposed that the accurate intake of temporal information is necessary to decrease cognitive load while editing these demands and processing ongoing information. The same author suggested that practicing motor skills involved for use in later efficient recall can lessen cognitive load. Alternatively, Doumas and Wing (2007) suggested that adding the task of rhythmic production compels additional resources and is the main factor affecting the central timer.

An interesting exploration of beta oscillations by Fujioka, Trainor, Large and Ross (2012) provided an explanation for a concept that may aid in more accurate timing. Beta band oscillations are located in the central and peripheral sensorimotor systems and

have been found to link auditory and motor communication. When measured, beta bands have been shown to decrease in amplitude just before and during a movement with recovery after a task has been completed. The authors found that beta modulations occur at the rate of a provided metronome with the amplitude peaking just before the next stimulus. They propose this reflects a neural mechanism for predictive timing and is an additional display of possible processing origins of internalized timing (Fujioka, et al., 2012).

### **Summary**

Previous literature has provided important concepts for understanding the processes utilized during sight-reading and internal representations of time. The practice of sight-reading is understood to be a highly variable skill among musicians with several factors influencing overall performance. Sight-reading involves the translation of visual information into a motor activity while processing auditory information facilitating evaluation of one's own performance. Written music notation provides pitch, rhythmic and expressive information, which must be interpreted as a whole to demonstrate an accurate performance. Musicians who are not adept at making these global judgments tend to demonstrate a preference for accurate pitch performance, which has been explored through the influence of pitch on perceptual accents and memory (Pfordresher, 2003). Many studies discussed and described the behaviors demonstrated by skilled sight-readers and common mistakes made by poor sight-readers. Poor sight-readers have been shown to attend to pitch by sacrificing tempo, rather than demonstrating an ability to read all elements of notation (McPherson, 1994; Prince et al., 2009).

Cognitive research has revealed multiple levels of processes imperative for decoding notation, perceiving aural elements used for feedback and engaging motor skills to ensure an accurate performance of sight-read materials. The importance of an individual's ability to sight-read rhythms and the role of meter and timing in musical examples provide evidence that underscores the importance of rhythmic elements to the perception and performance of written notation. If this is the case, little attention has been paid to individual musicians who demonstrate the ability to attend to these areas during the sight-reading process and even further, the behavioral or cognitive processes that provide a foundation for these attributes. Previous literature has revealed a lack of consistency between the perception and performance of music notation in a sight-reading exercise. Evidence in both areas suggested that rhythm and rhythmic structure play an important role, but a clear understanding of the type and magnitude of these effects is still unclear. Musicians have demonstrated an ability to synchronize to musical pulse in perceptual research, but a breakdown occurs in performance-based research when the musician is required to generate and impose his or her own musical pulse while reading music notation. Research exploring the theories of central timers lacks practical application of the perception and performance of music notation. This study seeks to explore the concept of internal pulse and its potential relationship to RSR.

### **Purpose of this study**

Accurate rhythmic performance is a significant predictor of instrumental sight-reading performance but processes underlying successful rhythm reading are unknown. The purpose of this study was to assess the relationship between an individual's internal

pulse and his or her ability to accurately perform RSR examples. I hypothesized that if a participant is better able to maintain a consistent underlying beat, they would have a foundation upon which to correctly divide written rhythms resulting in more accurate RSR performance.

### Chapter 3: Method

This study explored a possible relationship between internal timekeeping and rhythmic sight-reading (RSR) ability. Timekeeping can be defined as an individual's ability to maintain the underlying beat upon which the written rhythms are divided. Previous research identified rhythmic reading ability to be the best predictor of overall sight-reading scores (Elliott, 1982). Elliott's findings led to an assumption that an individual's ability to maintain underlying beat would result in appropriate division of rhythmic ratios, resulting in a more accurate sight-reading of rhythms. This chapter describes the characteristics of participants and outline stimuli and data collection procedures used to test this relationship.

#### Participants

Participants ( $N = 53$ ) were recruited from a large university in the Northwestern United States via announcements made at regularly scheduled large ensemble rehearsals. Potential participants provided the researcher with an email address and were contacted to select two time slots for participation in the data collection, one slot to assess timekeeping and the other to assess RSR. Participants were college-age or adult musicians (26 female) with a mean age of 23.6 years who had been playing an instrument for an average of 14.4 years, ranging from 6 to 55 years. Current involvement in a music ensemble (auditioned or non-auditioned) and self-identified ability to read music notation were the only requirements for participation in this study.

## Design and Procedure

Before taking part in this study, participants completed an approved consent form and background questionnaire (Figure. 3.1).

Participant Number: _____
Age: _____ Gender: <b>Male</b> <b>Female</b> Primary Instrument: _____
Major: _____
What is your current primary performing ensemble? _____
Have you ever conducted an ensemble other than for a class requirement? <b>Y</b> <b>N</b>
If yes, what kind of ensemble? _____
Have you ever taken private lessons? <b>Y</b> <b>N</b> If yes, for how long? (in years) _____
At what age did you begin playing your instrument? _____
Do you play any other instruments? <b>Y</b> <b>N</b> Name of instrument(s) _____ (MUSED majors, this does not include instruments learned for your methods courses)
If yes, how long have you played this instrument(s)? (in years) _____

*Figure 3.1.* Participant Questionnaire

Participants completed two separate assessments of RSR and internal timekeeping. Each participant was randomly assigned to initially participate in either the RSR or internal-timekeeping evaluations and both sessions occurred within 48-hours of the other. Data collection commenced in a quiet office space with an available computer monitor (iMac IPS Display/Dell AS500) and an office chair placed at a comfortable distance from the monitor. Only RSR sessions were videotaped using a Canon FS200 camcorder for later reliability measurement.

The RSR evaluation consisted of rhythmic exercises that were created using recent research by Bergee (2009). In this study, Bergee used a Rasch model to determine the difficulty of one-measure rhythm patterns. Rasch modeling analyzes a single variable and set of participants who had similar musical experience to the participants in the current study. Variables and participants were placed on an ordered continuum to determine how much of this variable one participant possesses compared to another while also ordering the variable item by difficulty; results from the ordered variable portion of the analysis were used for this study. Measures were then ordered from least to most difficult, grouped by similar difficulty level, and randomized within levels to create eight-measure test items. Two excerpts from each level of difficulty were created for a total of eighteen examples. Each evaluation was divided into three parts: preparation, introduction and performance. During the preparation, one excerpt appeared on the monitor and participants had approximately 25 seconds – equivalent to eight measures – to silently review the excerpt. The introduction consisted of four clicks from a metronome at 80bpm. This tempo has been identified as having the strongest beat salience in spontaneous tapping studies (Parncutt, 1994). During the performance, participants were asked to perform the example on a neutral spoken syllable (e.g. “tah,” “bah,” “dah”).

The timekeeping assessment consisted of three internal pulse evaluations, one without visual notation and two with visual notation. Participants were asked to perform all three tests without physical or external representation of the beat such as foot-tapping, head-bobbing or any other type of motion. The following section describes the three tests of internal pulse in the order they were evaluated:

1. *Notated Rhythms with tap* –The format of this test was based on a test created by Patel et al. (2005) who examined temporal synchronization in visual and non-visual trials. The examples were derived from the same stimuli as the RSR, but measures were randomly re-assigned in a different order to create novel excerpts. Participants were shown an eight-measure rhythmic example (Fig. 3.2) and had preparation time equivalent to eight measures (approximately 25 seconds). After the preparation time, a four-count introduction from a metronome at 80bpm signaled the start of the test item. During the introduction, three arrows appeared over the example, one above the first note, one above the last note and one randomly placed somewhere within the example. The participant was asked to internally perform the rhythms and tap on the iPad device on each note located below an arrow. The second tap randomly appeared on strong, weak or syncopated beat (4 items for each metric placement) for each of the eighteen test items.

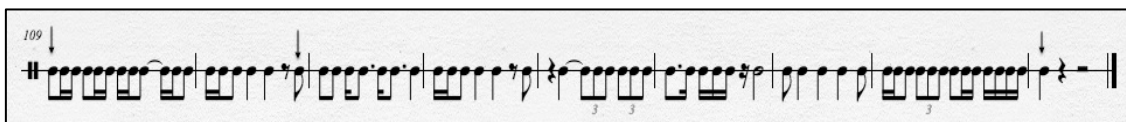
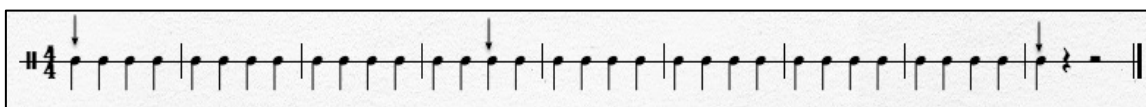


Figure 3.2. Notated Rhythms with tap

2. *Internal-pulse with tap* – This evaluation was completed without any visual stimuli and participants were given instructions from the researcher at the beginning of each test item (e.g. “Please tap at the beginning of measure one and beginning of measure two.”) After hearing a 4-count metronome introduction at 80pbm, participants were asked to tap on the first beat of the

first measure and the first beat of a subsequent measure specified in advance by the researcher (measures 2, 4, 6 or 8). This task included one practice example and four recorded measurements.

3. *Visual Internal Pulse with tap* – participants were shown an eight-measure example consisting of quarter notes and given a four-count introduction at 80bpm from a metronome. During the metronome introduction, three arrows appeared above the first quarter note, the last quarter note and a quarter note randomly selected within the example as seen in Figure 2. The participant was asked to keep time internally and tap on each note located below an arrow. A total of one practice trial and four recorded trials were given. No practice time was given in this assessment, as the stimuli never changed, only the placement of the second arrow.



*Figure 3.3.* Visual Internal Pulse with tap

At the conclusion of the second session, participants were asked to describe any strategies that were used to perform the tasks. Collection of the participant's strategies was completed in an interview format and transcribed by the researcher. The complete test is available in the Appendix section of this document.

## Data Collection

Participants performed the RSR evaluation as a live performance. Each participant had a brief period, equivalent to eight measures, to review the example before performing the rhythms aloud on a neutral spoken syllable (e.g., “dah,” “tah,” “bah”). A four-count click from the metronome at 80bpm signaled the initiation of the performance. Participants were not required to use any specific rhythmic counting system (e.g. 1-e-&-a, 1-la-li, ta-ka-di-mi, etc.), although a few participants elected to do so. Participants were allowed to make up to 2 errors on each test item before being asked to re-start the same excerpt again. These errors included re-starting or stopping, inaccurate subdivision of rhythms or elongation or truncation of rhythms, practices reported by McPherson in his 1994 study of sight-reading. If the participant made three mistakes on the second attempt of the same test item, the RSR portion of the data collection was concluded.

The tests of internal pulse were performed on an iPad2 using Garage Band application (Apple, Inc.). Participants were asked to tap with their dominant hand on the bass drum square on the hip-hop drum synthesizer. Figure 3.4 displays the visual application the participants saw while performing the examples on the iPad2. The bass drum square is located in the lower, right hand corner of the pad. Tap performance was recorded as a time stamp and time between taps, known as inter-onset-interval (IOI), was recorded. The IOIs were compared to a target MIDI performance and the deviations were used for analysis.



Figure 3.4. Garage Band hip-hop drum synthesizer used for data collection

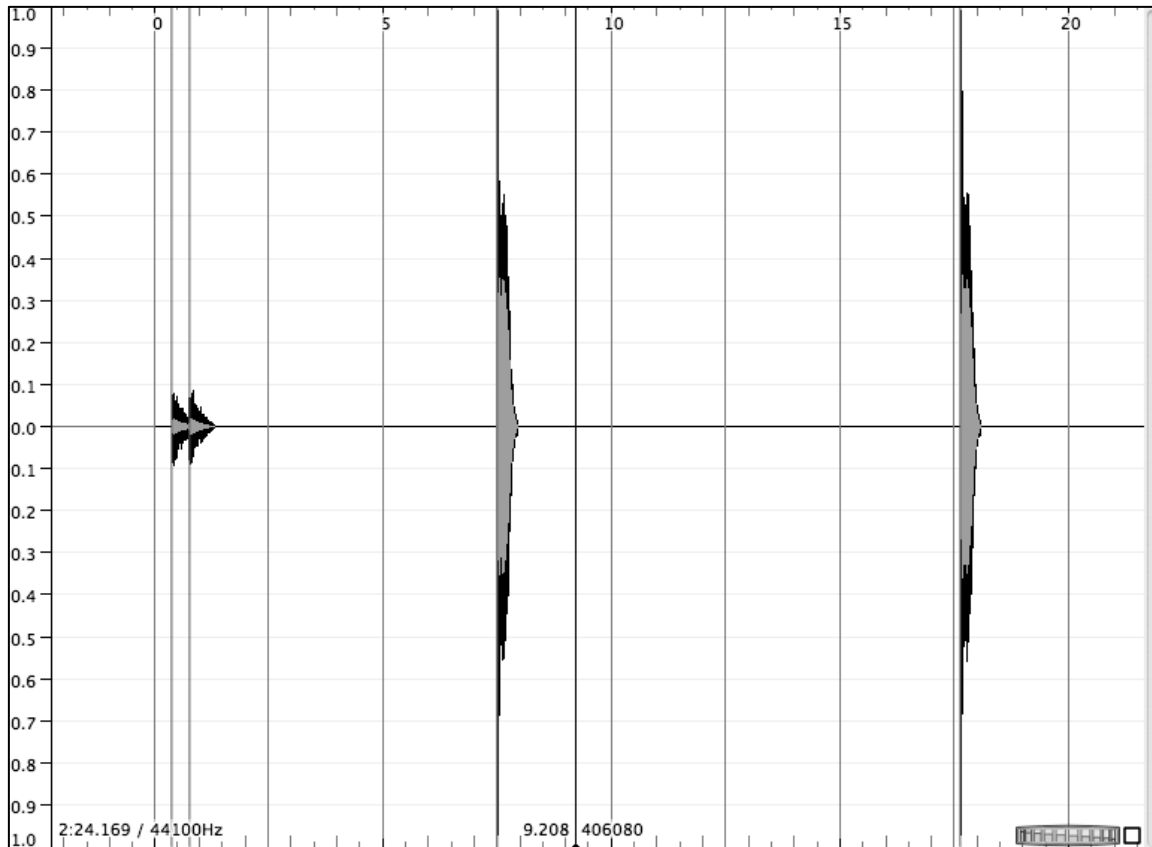
### Evaluation and Analysis

Evaluation of RSR performances was done in real-time by the researcher. One point was awarded for each correctly performed measure for a possible 144 points. Participants were not awarded double points during a second performance of an item. An outside evaluator was trained on scoring RSR and assessed fifteen participants (approximately 25% of the  $N$ ) via audio recording. Reliability between the two scorers was high at .91 and supported an accurate real-time assessment by the researcher. Figure 3.5 displays the formula used to determine scorer reliability.

$$\frac{agree}{agree + nonagree} = reliability$$

*Figure 3.5.* Formula Used to Determine Scorer Reliability

Data from the tests of internal pulse were analyzed through the Sonic Visualizer software program (Cannam, 2011). Garage Band files were uploaded as two-channel sound files, and then condensed to display a mean visual representation of the sound wave. The Aubio Onset plug-in for the Sonic Visualizer program was used to determine the onset of each tap as a time stamp in milliseconds and recorded for analysis, as displayed in Figure 3.6 (Brossier, 2013).



*Figure 3.6.* Soundwave Analysis in Sonic Visualizer with Aubio Onset Detector

The internal time-keeping portion of the data collection focused on the IOIs, examining if the participant was able to maintain the provided pulse internally. These IOIs were compared to the IOIs of a reference performance generated by a MIDI program (Finale 2012). The difference between the target performance and participant performance was summed and absolute deviations were calculated. Absolute deviation is the distance from zero (target performance) while disregarding the participant's performance as early or late (positive or negative). In an authentic music experience it is understood that "perfect performance" is not preferred to expressive timing, but as this study looked to assess participant's accuracy in timing, all performances were compared

to a temporally precise performance (Repp, 1998). These data were then compared with RSR scores to determine any possible relationship between tasks.

### **Summary of Methodology**

This study looked to explore a possible relationship between RSR ability and internal timekeeping. This was assessed in two independent sessions that focused separately on each task and performed in a random order. Participants were instrumentalists performing in a large ensemble on the campus and were self identified as able to read written notation.

The RSR assessment consisted of novel rhythmic excerpts constructed using results of Rasch modeling analysis of rhythmic difficulty from a study by Bergee (2009). Live performances of rhythmic examples were assessed in real-time by the researcher and checked for reliability by an outside evaluator. Three tests of internal timekeeping were assessed in a separate session, each occurring within 48 hours of the first. These evaluations recorded participant taps with deviations from a target performance being analyzed.

Scores earned in the RSR assessment and summed deviations from temporally correct taps were used to examine the potential relationship between an individual's internal timekeeping and RSR ability. The following chapter outlines this analysis.

## Chapter 4: Results

The purpose of this study was to explore the relationship between internal timekeeping ability and RSR accuracy. Rhythms are typically divided evenly over an underlying steady beat. An individual who is proficient at reading rhythms would maintain this beat while keeping the rhythmic ratios intact. In this study, I hypothesized that if a participant is better able to maintain a consistent underlying beat, he or she would have a foundation upon which to correctly divide written rhythms resulting in more accurate RSR performance. This chapter outlines the statistical analyses of performance on timekeeping and RSR performance and reports on performance strategies used by participants. An exploratory frequency and theoretical analysis will also be used to further investigate the initial results.

Participants were assessed during two sessions held within a 48-hour time period and randomly assigned to initially complete either the RSR or timekeeping tests. Rhythmic sight-reading examples were constructed using results from a Bergee study (2009) that employed Rasch modeling to identify the difficulty of one-measure rhythmic examples. Using the output of Bergee's analysis, each one-measure example was grouped by difficulty level then randomly assembled to create novel eight-measure test items. Participants were allowed 25 seconds to preview each exercise followed by four preparatory clicks at 80bpm to establish the desired performance tempo. Participants were asked to perform the rhythms on a neutral spoken syllable (e.g. "dah," "bah," or "tah") and were allowed two mistakes in each example. On the third mistake the participant was stopped and given an additional period of time to review the same

exercise before a second performance. The participant was allowed two additional mistakes on the second performance, but if a third error was committed on the second attempt of the same test item, the RSR portion of the test was concluded.

The internal timekeeping test consisted of three evaluations of pulse: (1) *Notated rhythms with tap* – participants were asked to silently perform rhythmic examples similar to the RSR evaluation and tap at three locations indicated by arrows above the note. (2) *Internal pulse with tap* – similar to counting measures of rest, participants were asked to tap on the first beat after the four-count preparation and another point specified by the researcher without the presence of visual stimuli. (3) *Visual internal pulse with tap* – participants were shown examples constructed of quarter notes and asked to tap at three indicated locations. Participants performed taps on an iPad2 recorded by the Garage Band application (Apple, Inc.).

## **Descriptive Statistics**

**Rhythmic Sight-reading.** The RSR evaluation consisted of test items comprised of eight-measure rhythmic examples that increased in difficulty throughout eighteen possible levels. A maximum of three mistakes were allowed for each test item. If the maximum was reached, a second attempt was permitted. Participants were given one point for each correctly performed measure but not awarded double points if a second attempt was required. Respondents could complete up to eighteen examples for a possible maximum score of 144. Final RSR scores were based on scores given by the researcher during the live performance.

Participants' RSR scores ( $n = 53$ ) were analyzed and ranged from 0 to 139 points out of a possible 144 points with a mean score of 70.15 ( $SD = 43.46$ ).

**Pulse Test 1 – Notated Rhythms.** In the first pulse test, participants were given approximately 25 seconds to study an eight-measure rhythmic figure in twelve examples using the same material as the RSR evaluation but re-randomized to create novel test items. After the preparatory period, a four-count click demonstrated the tempo (80bpm) at which participants were asked to silently read through the example at the provided tempo with no audible performance. As participants read through the exercise, they performed three taps on notes located under an arrow, one at the beginning, one at the end and one randomly placed within the test item. Arrows appeared above the example during the four-count click introduction to prohibit practicing of tap placement during the preparatory period. Taps were recorded using the Garage Band application on an iPad2 and imported into Sonic Visualizer, a sound wave analyzer. The Aubio Onset Detector plugin was used to mark the time of each tap and these data were calculated to identify the time between each tap, known as the inter-onset interval (IOI). The performed IOIs were then compared to a set of target IOIs. The absolute values of the deviations were summed and used in the analyses of the pulse tests.

Only valid IOIs from test 1 were analyzed. If a participant missed a tap at any point during the test, their IOIs were excluded from analysis, resulting in a different  $n$  from the other timekeeping analyses. Forty-seven participants ( $n = 47$ ) successfully completed twelve test items. Twenty-four IOIs – two for each test item – were summed for each participant, eliciting one total overall deviation for pulse test 1 (notated rhythm).

These totals ranged from 4.38 seconds to 121.42 seconds with a mean of 23.56 seconds ( $SD = 23.53$ ).

**Pulse Test 2 – Internal Pulse.** Data for pulse test 2 were collected in the same way as test 1. In this evaluation, participants were asked to tap on the first beat after a four-count click introduction and at the beginning of a later measure as specified by the researcher. This task was performed without visual stimuli and can be likened to the familiar activity of counting measures of rest. Each tap was evaluated for deviation from the target performance and summed deviations were used in this analysis.

Participants' ( $n = 51$ ) IOIs from four complete trials were analyzed from test 2. Four IOIs – one from each test item – were summed, to determine each participant's total deviation for pulse test 2 – internal pulse. Summed deviations ranged from .20 seconds to 12.25 seconds with a mean of 2.91 seconds ( $SD = 2.14$ ).

**Pulse Test 3 – Visual Internal Pulse.** The final test of internal pulse consisted of four items constructed exclusively of quarter notes, representing the underlying beat of the exercise. Participants were not given preparation time as the only difference between test items was the position of the three arrows upon which participants were asked to tap. The four-count metronome introduction began as each item appeared on the screen, signaling the beginning of assessment. Data were recorded and analyzed in the same way as tests 1 and 2 resulting in a total of 51 valid responses.

The summed deviations of the four test items for each participant resulted in a range of 10.94 seconds to 36.06 seconds with a mean of 15.16 seconds ( $SD = 3.94$ ).

Table 4.1 displays the average summed deviations from each of the timekeeping evaluations.

*Table. 4.1.* Descriptive Statistics from Internal Timekeeping Deviations

<b>Pulse Test</b>	No. of Items	Range (in seconds)	Mean (in seconds)	<i>SD</i>
Notated Rhythms	12	4.38 – 121.42	23.56	23.53
Internal Pulse	4	0.20 – 12.25	2.91	2.14
Visual Internal Pulse	4	10.94 – 36.06	15.16	3.94

The three tests of internal timekeeping and RSR have high reliability, Cronbach's  $\alpha = .93$ . Individually, tests of internal timekeeping elicited a Cronbach's  $\alpha = .98$  for test 1,  $\alpha = .63$  for test 2 and  $\alpha = .61$  for test 3. These results indicate that the tests of internal achieved a good level of internal consistency. Individually the IP1 (rhythm reading) had excellent internal consistency, while IP2 (non-visual) and IP3 (visual quarters) measured as being less consistent. This is most likely due to the low number of test items in these two tests, each only having four examples. This number was deemed appropriate after pilot testing.

### Correlation between internal timekeeping ability and RSR performance

A bivariate correlation was conducted to answer the primary research question: *Do participants with more accurate internal pulse perform better on rhythmic sight-reading examples?* Results are given in Table 4.2.

Table 4.2. Correlations between RSR Evaluation and Tests of Internal Pulse

	Pulse Test 1	Pulse Test 2	Pulse Test 3
SR Score	-.26	.08	.07
Pulse Test 1		.33*	.43**
Pulse Test 2			.80**

\* $p < .05$ , \*\*  $p < .01$

Although the correlation between pulse test 1 (rhythm reading) and RSR was not significant, the relationship is expected. Performance on pulse test 1 showed a negative correlation with RSR scores,  $r = -.26, p > .05$ . Although a negative correlation would suggest an inverse relationship, this outcome is consistent with the initial hypothesis as the summed deviations were closer to zero. In other words, a lower summed deviation on pulse test 1 generally resulted in a potential increase in score on the RSR evaluation, but this relationship was not strong enough to reach statistical significance.

Each of the three pulse tests had either a significant moderate or strong correlation to one another, suggesting that these tests were related and measured the same variable. Significant high correlation between tests 2 and 3 was expected as there was a presumed similarity between these assessments, differing only in visual and non-visual presentation.

### **Early-late analyses of IOIs**

Participants' IOIs were compared to the target performance and deviations were examined according to four possible early/late performance scenarios on tap 2 and tap 3: Late-Late (L/L), Early-Late (E/L), Late-Early (L/E), and Early-Early (E/E). A small number of participants were able to align either tap 2 or tap 3 with the target performance, resulting in a 0.00s deviation and labeled as on time (OT). These performances are denoted as on time-early (OT/E), on time-late (OT/L), early-on time (E/OT), late-on time (L/OT) and on-time-on time (OT/OT). If a participant missed any tap, it was recorded as a missed trial. As seen in table 4.3, performances of both taps in pulse test 1 (notated rhythms) occurred most frequently in the same direction: E/E (42.6%) or L/L (25.9%). If a participant performed tap 2 either ahead or after the target position of tap 2, tap 3 was likely performed in the same direction as related to the target tap 3. These data imply that participants generally slowed down or sped up the tempo while performing the exercise. Although this assumption may be inferred, this analysis fails to reveal if participants made any other errors such as placing the tap in the wrong location or performing the exercise at the wrong tempo.

Table 4.3. Internal Pulse Test 1 (notated rhythms) & 3 (visual internal pulse) Early-Late frequency – Strict IOI

Test Item*	12	11	4	3	7	1	9	8	2	6	10	5	%	1	2	3	4	%
E/E	22	25	16	24	16	29	29	25	26	21	23	15	42.6%	7	14	11	8	18.9%
L/L	8	9	9	11	16	12	14	16	15	16	18	21	25.9%	25	24	32	28	51.4%
E/L	15	16	9	7	14	9	4	6	9	2	5	16	17.6%	3	11	6	12	15.1%
L/E	8	3	4	7	6	2	1	5	2	5	6	1	7.9%	13	4	3	3	10.8%
OT/E	0	0	9	0	0	0	2	0	0	4	0	0	2.4%	1	0	0	0	0.4%
E/OT	0	0	4	1	0	0	2	0	0	2	0	0	1.4%	0	0	0	0	0.0%
Missed	0	0	0	3	1	1	0	0	1	0	1	0	1.1%	0	0	0	2	0.1%
OT/L	0	0	2	0	0	0	0	0	0	3	0	0	0.8%	4	0	1	0	2.4%
OT/OT	0	0	0	0	0	0	1	0	0	0	0	0	0.2%	0	0	0	0	0.0%
L/OT	0	0	0	0	0	0	0	1	0	0	0	0	0.2%	0	0	0	0	0.0%

\*Test Items have been listed from shortest to longest IOII (tap 1 – tap 2).

## Strategies

At the conclusion of the data collection, participants were asked if they had utilized any specific strategies to help with their performance on the exercises. Answers given by the participants were transcribed by the researcher and coded for emergent themes. A total of six themes emerged from the analysis of the responses:

1. Focused on preparation time – participants made comments about how they prepared themselves during the allotted time. “*[I] look for unique rhythms [and] notice repetitive measures.*”
2. Used a physical timekeeper – although participants were asked to avoid using a physical timekeeper, several participants admitted to using some sort of physical aid (i.e. foot tapping). Participants disclosed use of a timekeeper in a hidden fashion or were aware of using a timekeeper and made an attempt to stop the action. “*It wasn’t entirely possible to not keep physical time, I would click in my throat.*”
3. Employed subdivision – this response was mentioned most frequently of all responses. Participants discussed focusing attention on subdivision of the beat or more difficult rhythms found within the exercise. “*[I was] subdividing eighths and sixteenths.*”
4. Focused on the beat – this response was separated from the previous strategy in that participants made no mention of attempting to divide the beat into smaller divisions. It is assumed that participants simply attended to the beat provided during the metronome introduction. “*I would try to remember the beat from the woodblock [and] close eyes to remember tempo.*”

5. Did not read rhythms – this response came as a result of participants developing a strategy to attempt a more accurate performance. Participants would simply keep the provided beat and only subdivide the measures in which an arrow appeared. “*On the first test [IP] I counted measures and didn’t read rhythms, I was lazy.*”
6. Did not use a strategy – These participants mentioned not using any kind of strategy.

Frequency of participants providing a particular response can be seen in Table 4.4. A single participant may have responded in more than one category.

*Table 4.4.* Frequency of Strategy Responses

	No. of Participants
Used a physical timekeeper	12
Employed subdivision	19
Focused on the beat (without subdivision)	20
Focused on preparation time	13
Did not read rhythms	8
Did not use a strategy	3

Three strategies were selected for further statistical analyses: *Employed Subdivision, Focused on Beat (without subdivision) and Used a Physical Timekeeper*. These were selected because these strategies were used during performance on test items, rather than prior to performance. The remaining strategies may have some sort of impact,

but as this study was focused on timekeeping, only the three strategies reflecting direct engagement of timekeeping were selected for further analysis. If participants focused on subdivision or beat while performing, this may have had an impact on RSR scores. The timekeeping strategy was selected for analysis due to the specific request to avoid using a physical timekeeper, which could potentially aid in performance. Participants' results were grouped according to strategy and RSR scores were analyzed. Each strategy was analyzed separately using an independent samples *t-test* because participants were represented in more than one response category.

Participants using subdivision ( $n = 19$ ) were compared with participants who provided responses that did not fit into the three categories selected for further analysis ( $n = 16$ ). On average, those who utilized a strategy focusing on subdivision of the beat performed better on RSR scores ( $M = 78.68, SE = 8.39$ ) than those who did not mention using this strategy ( $M = 68.13, SE = 11.34$ ). While this change in score was greatest for this strategy, the difference was not significant  $t(33) = -.76, p > .05$ , with a small effect size of  $r = .13$ .

A similar result was found for participants who employed a strategy relying upon the underlying beat ( $n = 19$ ). Participants who focused on the main beat pattern performed better on average ( $M = 72.42, SE = 10.09$ ) than those who did not employ this strategy ( $M = 68.13, SE = 11.34$ ) but again, this difference was not significant  $t(33) = -.28, p > .05$ , with a small effect size of  $r = .05$ .

Participants who admitted to using a physical timekeeper ( $n = 12$ ) demonstrated a weaker performance than those who did not provide a strategy selected for further analysis. Those who reported using a physical timekeeper had poorer mean RSR scores

( $M = 60.83$ ,  $SE = 12.79$ ) than those who did not provide this response ( $M = 68.13$ ,  $SE = 11.34$ ). Although the performance differed from the results of the other two strategies, the difference remained insignificant  $t(26) = .43$ ,  $p > .05$  with a small effect size of  $r = .08$ . A summary of these results is displayed in Figure 4.1.

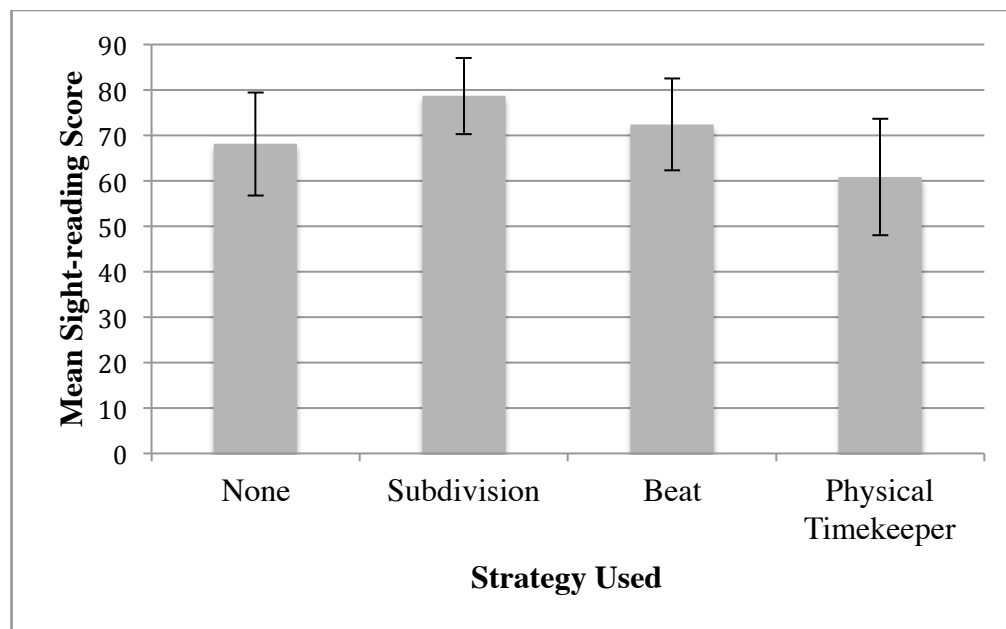


Figure 4.1. Comparison of Participant Strategy Use

While this study sought to examine a relationship between timekeeping and RSR ability, participants who specifically mentioned strategies related to the maintenance and production of pulse aids did not demonstrate any significant difference in performance scores than those who did not employ these strategies. It is also worthwhile to point out that while participants mentioned these strategies when prompted, it does not mean they effectively employed these strategies in their performance.

## Exploratory Analyses

The purpose of this study was to examine a possible relationship between an individual's internal timekeeping and RSR ability. The previous analyses revealed no significant relationship between the two tasks, an interesting finding considering they are often thought of as similar and complementary tasks in the performance realm. This led to the consideration of what participants could be doing during the timekeeping exercises to warrant these results. Did participants have problems maintaining tempo? Did participants place a tap at an incorrect point? A series of exploratory analyses were run to determine the effect these potential scenarios would have on timekeeping task performance and RSR scores. In the following analyses, I re-examined the data as a result of the following possible performance scenarios in the timekeeping tasks:

1. Tap 1 – for the purpose of these analyses, tap 1 is assumed to be performed at the correct point for each test item.
2. Tap 2 – (a) the participant incorrectly read the provided rhythms resulting in tap 2 being placed on a note that was not located below an arrow; (b) the participant was unable to maintain the provided tempo and placed tap 2 on the correct note but sped up or slowed down during the performance.
3. Tap 3 – (a) the participant incorrectly read the provided rhythms resulting in a tap that placed tap 3 on the wrong note – on a note that was not located below an arrow; (b) the participant placed tap 3 on the correctly indicated note, but an incorrect assessment of tap 2 performance resulted in imprecise estimation of tap 3; (c) tap 3 was placed on the correct note, but was influenced by the new

trajectory established with tap 2 – a slower or faster tempo that reflected an inability to maintain tempo

The following section outlines a frequency analysis of early and late taps examined in two ways – Adjusted IOI and Long IOI – that take into account the possible explanatory scenarios introduced above. Early and late deviations are explored so absolute values will not be considered, contrary to the initial analyses. Strict IOI evaluates the frequency of early and late taps based on raw data.

### **Adjusted IOI**

Adjusted IOI was calculated under the assumption that participants placed tap 2 on the correct rhythmic location and deviation from the target IOI was due to an increase or decrease in tempo. Therefore the first performed IOI was considered correct and the second IOI was adjusted to reflect this change in tempo. This new ratio was then compared to participants' actual performance and deviations were analyzed. As depicted in Figure 4.2, if a participant's error was due to a change in tempo then the deviation for tap 3 would be expected to decrease.

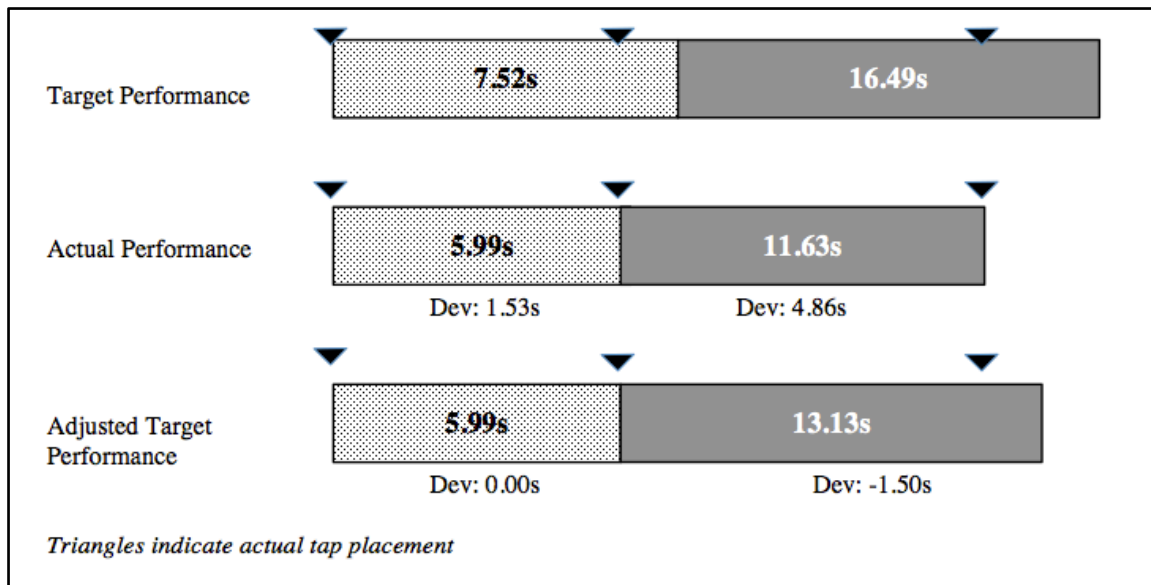


Figure 4.2. Example of Adjusted IOI Ratio Determination

The data from Figure 4.1 come from the first test item of IP1 (reading rhythms). This participant performed tap 2, 1.53 seconds before the target tap 1 (IOI1 = 5.99s) and tap 3, 4.85 seconds before target tap 2 (IOI2 = 11.63s). Assuming that tap 2 was performed on the correctly indicated note and the observed deviation was due to tempo compression, the adjusted time between tap 2 to tap 3 should have been 13.13 seconds if the same compression or elongation of tempo had been maintained. The difference between the adjusted deviation of IOI2 and performed IOI2 was 1.50 seconds compared to 4.86 seconds in the original analysis. This may indicate that the participant compressed time. This result could also indicate an incorrect placement of tap 2.

Early and late frequency analysis of Adjusted IOI deviations were examined according to the direction of error of the second IOI deviation under the assumption the participant had maintained a steady tempo throughout the exercise. The second Adjusted

IOI deviation was then compared to the second performed IOI deviation to investigate early and late performance. Table 4.5 displays the early and late deviations from original performance as well as the on-time and missed taps. The table reflects only deviations of the second performed IOI, as IOI1 was adjusted to zero.

Table 4.5. Internal Pulse Test 1 (notated rhythms) & 3 (visual internal pulse) Early-Late frequency – Adjusted IOI

<b>Test Item*</b>	<b>12</b>	<b>11</b>	<b>4</b>	<b>3</b>	<b>7</b>	<b>1</b>	<b>9</b>	<b>8</b>	<b>2</b>	<b>6</b>	<b>10</b>	<b>5</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>%</b>
Early	34	27	25	26	31	25	19	30	24	24	28	28	31	27	19	20	45.8%
Late	19	26	28	24	21	27	33	23	28	29	24	25	22	26	34	31	53.3%
Missed	0	0	0	3	1	1	0	0	1	0	1	0	0	0	0	2	0.9%
On-time	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0.0%

Table 4.6 outlines the frequency of IOI2 deviations (tap 2 – tap 3) that were greater than 750ms, equivalent to the duration of a quarter note at 80bpm. This threshold was selected as a point of maximal deviation. In an authentic ensemble performance scenario, if a performer was playing a whole quarter note apart from the rest of the group, this would result in an unsynchronized ensemble performance. A deviation of this magnitude suggests that the participant performed the exercise at the wrong tempo, sped up or slowed down or was reading far from the actual point of performance.

Table 4.6. Adjusted IOI - Frequency of IOI2 Deviations > 750ms

<b>Test Item*</b>	<b>12</b>	<b>11</b>	<b>4</b>	<b>3</b>	<b>7</b>	<b>1</b>	<b>9</b>	<b>8</b>	<b>2</b>	<b>6</b>	<b>10</b>	<b>5</b>
Pulse Test 1	43	37	36	28	21	24	16	16	20	13	9	5
<i>n valid trials</i>	53	53	53	50	52	52	53	53	52	53	52	53

<b>Test Item*</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
Pulse Test 3	20	14	4	0
<i>n valid trials</i>	53	53	53	50

\*Test Items have been listed from shortest to longest IOI (tap 1 – tap 2)

The frequency of IOI2 deviations (tap 2 – tap 3) greater than 750ms was observed in nearly one-third of the participants in 10 of the 12 test items in pulse test 1 (rhythmic notation). This meant that these participants had gained or lost at least one quarter-note of time by the time the exercise concluded. Participants did not have any tempo maintenance issues on the shortest IOI of IP test 3 (2.229s) suggesting an accumulation of error reflecting a tempo maintenance problem. A similar trend can be observed in pulse test 1, with the greatest amount of participants unable to maintain the tempo within the value of one quarter note on exercises with a longer IOI2. This suggests that performers were less accurate as the size of the IOI increased. These results of early/late frequency and deviations greater than 750ms imply an inability to preserve the provided tempo over longer periods of temporal maintenance, but the possibility of an egregious error cannot be eliminated.

### **Long IOI**

Calculating the Adjusted IOI explored the possibility of tempo inaccuracy by recalculating error deviation based on the assumption of a correctly placed, but incorrectly timed, tap 2. In contrast, Long IOI assumes that tap 2 was placed incorrectly. Error deviation for tap 3 was calculated in relation to tap 1, thus removing the impact of tap 2 inaccuracy. In other words, this calculation assumes correct tempo but inaccurate performance (Figure 4.3). This participant's tap 1 – tap 3 IOI – Long IOI – was 17.62 seconds which was 6.38 seconds faster than the target Long IOI. Only pulse tests 1 and 3

were analyzed, as there are only two taps in pulse test 2. Table 4.7 displays the frequency of Long IOI deviations greater than 750ms.

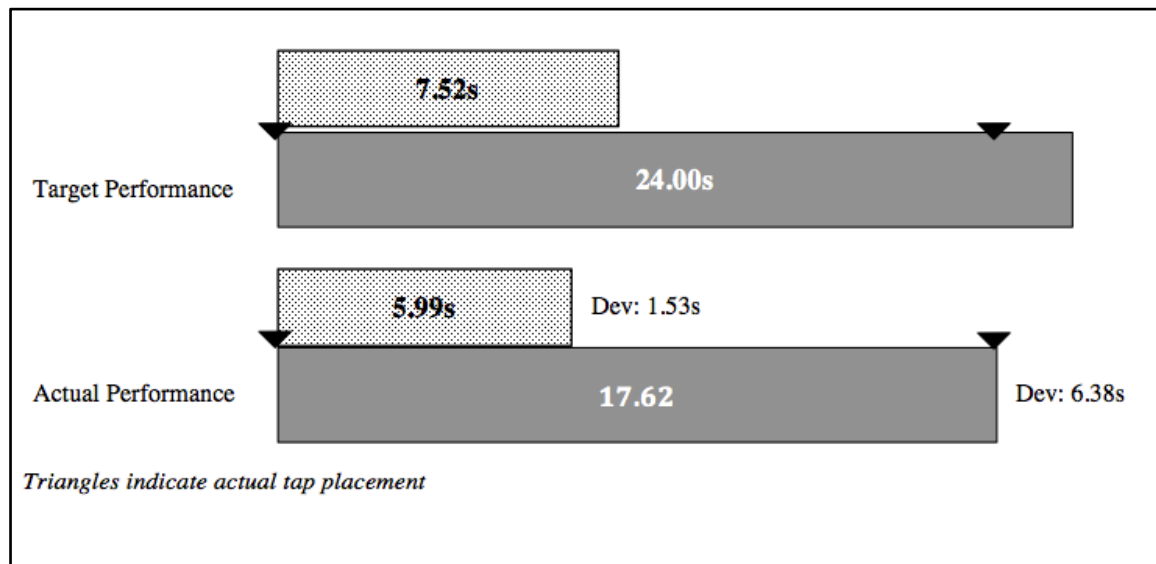


Figure 4.3. Visual Representation of Long IOI Determination

Table 4.7. Long IOI - Frequency of Deviations > 750ms

<b>Test Item*</b>	<b>12</b>	<b>11</b>	<b>4</b>	<b>3</b>	<b>7</b>	<b>1</b>	<b>9</b>	<b>8</b>	<b>2</b>	<b>6</b>	<b>10</b>	<b>5</b>
Pulse Test 1	40	33	36	37	29	17	42	31	35	36	41	31
<i>n valid trials</i>	53	53	53	53	52	52	53	53	53	53	53	53

<b>Test Item*</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
Pulse Test 3	33	28	34	35
<i>n valid trials</i>	53	53	53	51

\*Test Items have been listed from shortest to longest IOI.

Frequency of large deviation in the analysis of Long IOI is generally greater for many of the test items than in the Adjusted IOI analysis. This suggests that participants had greater issue with maintaining the given performance tempo by either speeding up or slowing down, rather than having a tap 2 placement issue.

### **Best Performance IOI**

In the original analysis, it was interesting to find a small and non-significant relationship between internal timekeeping ability and RSR performance. When examining the Adjusted IOI, it was observed that deviation of IOI2, improved (decreased) for many participants, as compared to the target performance. Best performance frequency of Original IOI, Adjusted IOI or Long IOI for each participant on IOI2 is displayed in Figures 4.4 and 4.5. In each of these examples, many participants' performances were most accurate when the Adjusted IOI was used for analysis, suggesting that participants most frequently suffered from issues of tempo maintenance rather than a major error or other mistake. It is also interesting to note that in Figure 4.5, participants had more trouble with tempo maintenance as the length of IOI2 (tap 2 – tap 3) increased as these test items are ordered from shortest to longest IOI2.

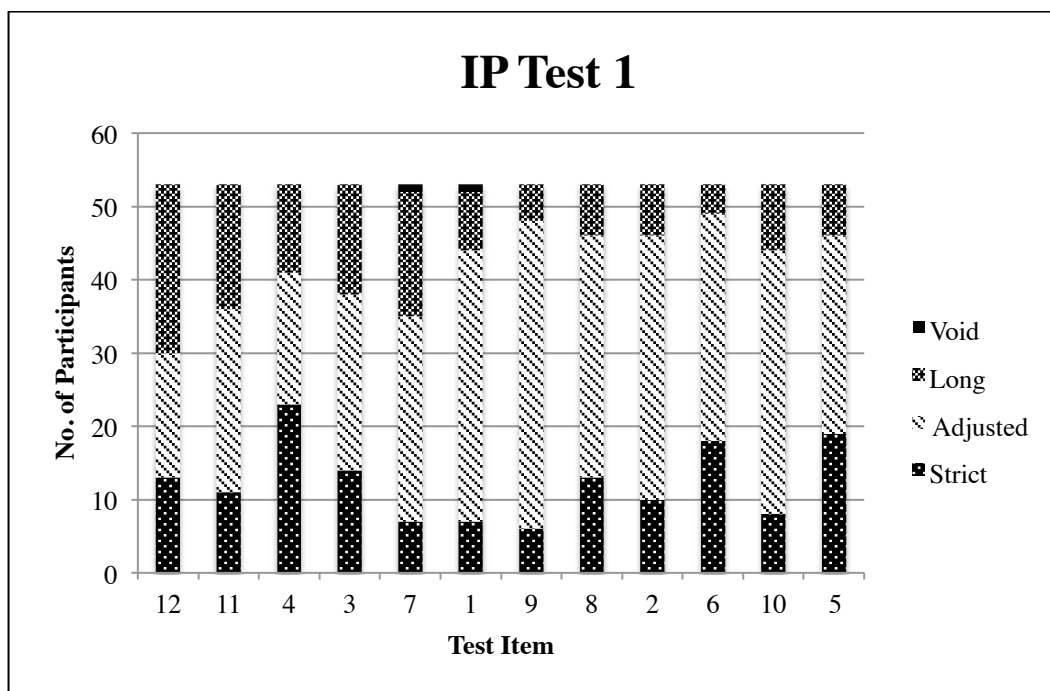


Figure 4.4. IP Test 1 – Participant Frequency of Best IOI used in Exploratory Analyses

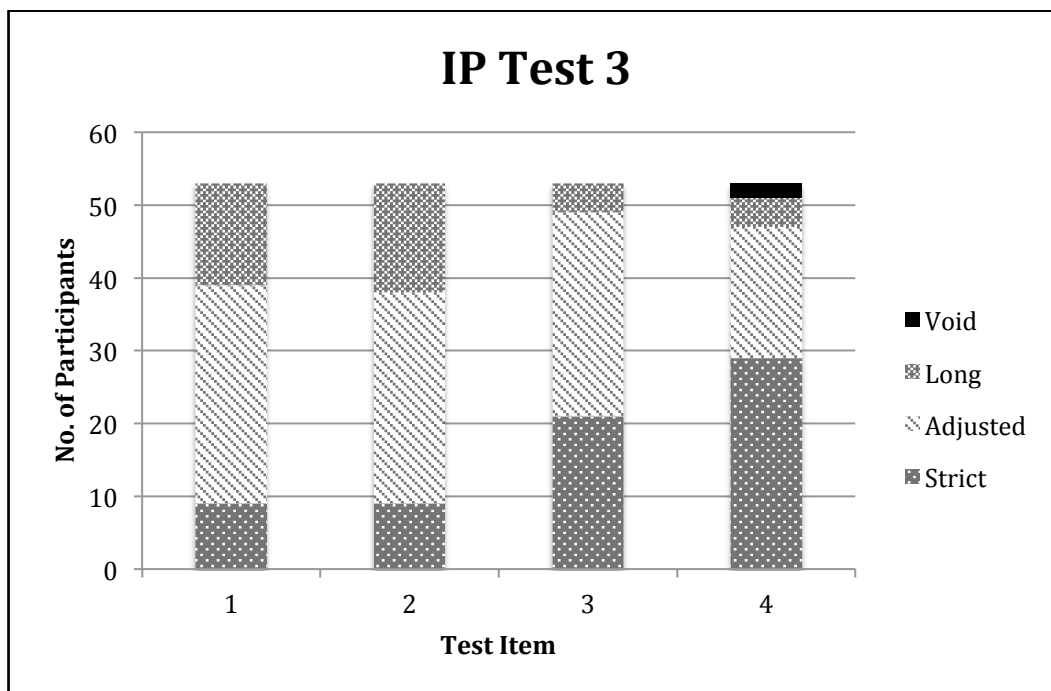


Figure 4.5. IP Test 3 – Participant Frequency of Best IOI used in Exploratory Analyses

Since many of the participants' best performance was revealed in the Adjusted IOI analysis, a bivariate correlation was run to determine if a relationship to RSR would emerge when accounting for participants' inability to maintain tempo. These data are presented in table 4.9 with corresponding original data IOI2 subset (in parentheses) included for comparison.

*Table 4.8.* Adjusted IOI2 - Correlations between RSR Evaluation and Tests of Internal Pulse

	Pulse Test 1	Pulse Test 2	Pulse Test 3
SR Score	-.41** (-.25)	.08 (.08)	-.11 (.05)
Pulse Test 1		.10 (.35*)	.03 (.48**)
Pulse Test 2			.10 (.79**)

\*  $p < .05$  \*\*  $p < .01$

The Adjusted IOIs now exhibit a significant strong correlation between pulse test 1 and RSR scores, both tasks requiring visual intake of complex rhythmic material. No significant relationship between pulse tests 2 and 3 and RSR remains. Although this analysis does not reveal a stronger relationship between the tasks of RSR and maintaining a steady beat, it is interesting how the act of rhythm reading and timekeeping separate themselves.

### Descriptive statistics for skilled and un-skilled sight-readers

Descriptors of skilled and un-skilled sight-readers in previous literature were discussed in Chapter 2. In continuing to explore the data further to determine possible explanations for the lack of relationship between RSR and timekeeping ability, data from the most and least skilled sight-readers in this study were examined. Six participants were able to perform to the last possible level – level 18 – on the RSR assessment, while six participants were unable to perform beyond level 1. The descriptive statistics of these participants' performances are detailed in Table 4.10.

*Table 4.9. Descriptive Statistics for Skilled and Un-skilled Sight-readers*

	SR Score (SD)	Pulse Test 1 (SD)	Pulse Test 2 (SD)	Pulse Test 3 (SD)
Skilled	136.00 (3.58)	13.76 (6.39)	2.73 (1.74)	4.50 (2.62)
Un-skilled	3.83 (3.49)	38.41 (41.51)	1.52 (0.72)	4.63 (2.15)

*SR Score is mean score – Pulse Test scores are represented as mean deviations.*

A large difference in summed deviation score was revealed for Pulse Test 1, but this difference is not observed for Pulse Test 2 or 3. It appears as if the presence of complex rhythmic notation provides added difficulty for poor sight-readers and the disparity in performance is reduced when visual complexity is simplified.

## Summary

Results indicate that tests of internal pulse were highly related to one another but not related RSR performance. In completing supplementary analyses, data were analyzed further to explore potential errors made in performance on timekeeping tasks. It was revealed that participants had problems with maintaining overall tempo rather than incorrect tap placement. A large number of tap deviations greater than a quarter note in duration in the analysis of Long IOIs supported this supposition. Further analyses of performers best IOI2 resulted in similar, but not identical, findings to the original analyses. A strong relationship emerged between pulse test 1 and RSR scores suggesting similarity between the two. When participants' best performance was evaluated, tasks of rhythm reading and simple timekeeping appeared to be separate, unrelated tasks. Finally, the most skilled and un-skilled sight-readers' data were examined revealing a separation in timekeeping performance when complex visual rhythms were present, but not when an absence of visual stimuli or simple visual rhythms were assessed.

In the following chapter, a discussion of the data revealing an independence of timekeeping and rhythm reading examines this relationship in further detail.

## Chapter 5: Discussion

The purpose of this investigation was to determine if instrumental musicians who demonstrated better performance on rhythmic sight-reading (RSR) tasks have better timekeeping ability. Rhythm reading ability has been shown to be a strong predictor of sight-reading ability, but performing rhythmic figures over a self-sustained steady beat has not been examined (Elliott, 1982). Previous research in pitch-based sight-reading suggested that maintenance of consistent pulse was an important component of sight-reading (Boyle, 1970; Krumhansl, 2000). This study examined the relationship between an individual's timekeeping ability and RSR performance.

Fifty-three instrumental musicians ( $n = 53$ ) were evaluated in two sessions on RSR performance and timekeeping ability. Each session occurred within a 48-hour time period and participants were randomly assigned to initially perform either RSR or timekeeping tasks. The RSR test items were created using the results of an analysis by Bergee (2009) that examined the difficulty of one-measure rhythmic patterns using Rasch analysis. These individual measures were ordered from least to most difficult, grouped by difficulty level then randomly assembled within each level to create novel eight-measure test items. Participants were given approximately 25 seconds to examine the test item before hearing four metronome clicks at 80bpm signaling the start of the performance. Each participant was asked to perform the task on a neutral spoken syllable and assessed in real time by the researcher.

The timekeeping assessment consisted of three tasks: (1) notated rhythms with tap – participants were asked to internally perform rhythmic examples similar to the RSR

evaluation and tap at three locations indicated by arrows above the note (2) internal pulse with tap – this activity was performed without visual stimuli. Participants were provided a four-count metronome introduction and asked to tap on the first beat and another point specified by the researcher. This task is similar to counting measures of rest, which is a familiar action in music performance (3) visual internal pulse with tap –examples constructed of eight measures of quarter notes were displayed and participants were asked to tap at three indicated locations. Arrows appeared above the example during the metronome introduction to prevent practicing during the preparatory period.

Summed absolute deviations from the timekeeping assessment were compared to scores from the RSR test to determine if participants with more accurate timekeeping ability performed better on RSR tasks. A bivariate correlation analysis revealed no significant relationship between an individual's timekeeping ability and RSR scores. It was hypothesized that participants with better timekeeping ability would perform better on RSR tasks, but the findings from this study do not support this hypothesis.

This result is interesting as the relationship between an individual's need to keep consistent time has been emphasized for accurately performing written notation both anecdotally from a pedagogical standpoint and in previous research (Boyle, 1970; Krumhansl, 2000). In an effort to determine a possible reason for this outcome, the data were examined in more detail. The remainder of this chapter addresses the possible reasons for the lack of relationship between RSR and timekeeping.

### **Two separate tasks: rhythmic sight-reading or timekeeping**

Due to the outcomes of the initial analysis, it was important to investigate possible mistakes participants made while performing the timekeeping tasks. A series of additional analyses were conducted to examine possibilities and determine why the anticipated relationship does not exist. It is understood that this data collection did not seek to assess this information; it is simply an additional examination of the data to further understand the results. This examination was based on the possibility of several potential mistakes made by participants. First, a participant may have placed the tap on a note that did not appear beneath an arrow. Secondly, a participant may have placed a tap on a correctly indicated note, but did not maintain the provided tempo by speeding up, slowing down or varying the tempo. These potential errors were examined through additional data analysis. It is also possible that a participant placed the second tap on the correctly indicated note but assessed that tap as incorrect. This resulted in an adjustment to account for the perceived mistake, influencing the placement of the final tap. This idea was not explored through statistical analysis as this would be impossible to measure via the data, but the possibility of this error type is acknowledged.

Inter-onset intervals (IOIs) were re-examined in an attempt to determine which potential error was made. The first series of analysis produced a set of data that has been titled 'Adjusted IOI.' This adjustment was created after assuming the participant maintained the correct tempo for IOI1 (tap 1 – tap 2) and generating a new ratio for IOI2 (tap 2 – tap 3). This new ratio was then analyzed for deviation from actual performance with the resulting difference indicating a possible performance scenario. If the difference between the newly established ratio and actual performance were substantial (i.e.

deviation > 750ms – the duration of one beat), the participant was likely maintaining the incorrect tempo or varying tempo within the exercise. A threshold of 750ms was selected because it is equal to the length of a quarter note. If a participant were this far from the actual performance point in an authentic performance situation, it would result in an unsynchronized ensemble performance. If the difference between actual and adjusted performance IOIs were close to zero, the participant would likely have maintained the given tempo but may have incorrectly placed the second tap. The frequency of Adjusted IOIs greater than 750ms was observed in a majority of the timekeeping test items. Perhaps participants had trouble maintaining tempo during the timekeeping exercises, but the influence of the second tap could not be fully eliminated, requiring additional exploratory analysis.

This led to the analysis of participants' Long IOIs. Performance from tap 1 to tap 3 in internal pulse (IP) test 1 (notated rhythm) and IP3 (notated pulse) was examined – IP3 (non-notated pulse) was not included, as it only required two taps. Analysis of this longer interval eliminated the potential influence of a misplaced tap 2 in only looking at the longest performance of the participant. If a participant misplaced a second tap but maintained the given tempo, deviations from the target performance would be closer to zero. If this difference was large (>750ms), it was likely the participant did not maintain the given tempo or varied the tempo widely within the exercise.

The results of these supplemental analyses suggested that participants had more problems with tempo maintenance rather than misplaced taps. The number of Adjusted IOIs and Long IOIs that were greater than 750ms supported this. In the Adjusted IOI analysis, participants were more than one beat away from their newly adjusted (ratio)

IOI2 a majority of the time. The same result was seen when examining the Long IOI deviations removing the possibility of a tap 2 error. (Refer to Tables 4.5 and 4.6)

Finally, original performance (strict IOI), Adjusted IOI or Long IOI was selected to reflect participant's most accurate performance depending on which analysis was closest to zero. Most participants' best performance occurred with the Adjusted IOI analysis. Participants' Adjusted IOI was then used in a bivariate correlation to determine if the relationship between timekeeping and RSR would improve when removing the impact of poor temporal performance. The analysis revealed a strong significant correlation between RSR and IP1 (notated rhythm) and no relationship between IP2 (non-notated pulse), IP3 (notated pulse) and RSR. This result showed an even clearer distinction between tasks of rhythm reading and timekeeping in the presence of complex visual notation. This result also highlights participants' inability to maintain tempo while processing complex visual notation and seen in the strengthening of the relationship between RSR and IP1 (notated rhythm).

The addition of rhythmic material appears to provide a level of complexity to the tasks involving complex notation. A 2007 study by Doumas and Wing found greater variability when participants tapped rhythmic material as opposed to isochronous beats. Their study concluded that the addition of rhythm requires additional cognitive resources resulting in variability of the individual's central timer. They also suggested that these issues are not a result of motor processes, but rather a timer problem occurring before temporal information reaches the motor modality. The current study supported these results as many motoric elements were removed to avoid interfering with performance. The exploratory analysis of the current study did not reveal an appreciably stronger

relationship between RSR and timekeeping ability, but it does provide evidence suggesting that participants differentiate tasks related to rhythm material and isochronous beats.

### **Sensory modalities in performing music**

Music performance involves visual, auditory and motoric modalities. These modalities were considered when determining the possible factors that may have influenced performance on RSR or timekeeping. Performance on the second IP test (non-notated pulse) was most accurate in the original analysis and remained unchanged even after employing alternative methods of data analysis. In other words, participants' responses to unadjusted, in-tempo IOIs resulted in the highest level of accuracy. This is an interesting outcome as this test was the only component presented without visual stimuli suggesting some difference between performance with and without visual notation. This led to an exploration of the effect of visual notation on timekeeping ability.

Typically, research on synchronization to visual stimuli has been done with participants tapping in tandem with a flashing light (Doumas & Wing, 2007; Kolers & Brewster, 1985; Repp & Penel 2002). This is not the same task as reading written notation, but decreased accuracy while performing with visual notation implies an additional level of processing when dealing with visual components, regardless of visual presentation type. A strong significant correlation was found between IP1 (notated rhythm) and IP3 (notated pulse) with only a moderate significant correlation being found IP1 and IP2 (non-notated pulse). These results lend support to an influence of visual stimuli on timekeeping ability.

Previous research has demonstrated a compartmentalization of sensory modalities when processing temporal information. Visual and auditory events are thought to be imbedded in their respective modalities with auditory information taking superiority over the visual mode for temporal processing (Grondin, 2010). Timekeeping assessments were performed without any form of auditory feedback, which may have contributed to the lack of relationship between the two tasks due to the supremacy of the auditory mode. This feedback plays a role in real-time error correction and has been known to affect temporal performance (Clark & Williamon, 2012; Zatorre et al., 2007). This results in a variability of an individual's temporal consistency if he or she is unable to hear his or her own performance in real time. The superiority of the auditory modality explains why discrimination and categorization of time intervals proves to be difficult as the individual is required to integrate these modalities for accurate performance (Grondin, 2010).

The dominance of the auditory modality also affects motoric production of rhythms. These two systems appear to be utilized and highly linked when analyzing rhythmic material (Zatorre et al., 2007). The cerebellum is known to contribute to accurate perception and timing of rhythmic sequences while producing precise motor control to execute these rhythms. Musical structure has also been found to be represented not only in musicians' motor behaviors but also in listeners' timekeeping abilities (Repp, 1998). These findings were examined with stimuli presented through auditory means, demonstrating an association between auditory and motoric processes. While the present study sought to eliminate motoric interference, it is important to mention how the auditory and motor systems are linked and may affect performance. The absence of

auditory feedback during the timekeeping tasks provides a potential explanation for the lack of relationship between timekeeping and RSR.

Motoric, visual and auditory modalities are linked together in the perception and performance of music, but the supremacy of the auditory domain may help explain the lack of relationship between RSR and timekeeping. It may be interesting to explore these two assessments again to determine if a relationship would develop when participants are allowed to perform timekeeping tasks aloud.

### **Perception before production**

Several cognitive processes are implemented in the perception of music notation before the realization of performance is possible. Previous research has indicated that musicians process structural elements of notation while implementing motor processes related to timing, sequencing and spatial organization (Repp, 1998; Zatorre et al., 2007). The dorsal pre-motor cortex (dPMC), pre-frontal cortex (PFC), cerebellum and basal ganglia have been identified as aiding in the perception and production of complex rhythms (Zatorre et al., 2007). When perceiving rhythmic notation, an individual must retain the notational fragments in short-term memory as it transfers to motor processes. A Midorikawa, et al (2003) study likened the process of retaining rhythmic patterns to the process of verbal short-term memory. This case study examined a patient with Wernicke's aphasia, a type of brain damage in the left posterior area of the brain leading to poor auditory processing, fluent speech and repetition. This patient was asked to perform unfamiliar written notation on a piano. She was able to perform pitch-based elements, but no rhythmic elements, but when asked to perform from familiar notation,

she performed both pitch-based and rhythmic elements accurately. Their result led to a hypothesis that short-term retention of rhythm occurs in the left hemisphere – the location of brain damage – while performance related process occurs in the right hemisphere. When storing rhythmic material in short-term working memory, even light cognitive demands can affect time estimation and rhythmic perception (Falle, 2011). This seemingly vulnerable process supported the findings of the exploratory data analysis that revealed a relationship between exercises involving the perception of unfamiliar, complex rhythmic material and exercises requiring only basic timekeeping.

Following the initial perception of rhythmic material, performers are then tasked with transferring perceptual information to motoric responses. Repp (1998) found structural implications represented in motor behaviors resulting in an alteration of timekeeping ability. If written notation has such an influence on individual timekeeping, it would also affect one's ability to divide complex rhythm according to the beat structure (Repp, 1998).

### **Skilled and Unskilled Sight-readers – Current Study**

The traits of skilled and un-skilled sight-readers were outlined in chapter two. Skilled sight-readers maintain appropriate accent structure of the example and are able to take in larger amounts of information at one time while un-skilled sight-readers adjust syncopated rhythms closer to the beat or repeat or disrupt phrase continuity by altering rhythmic durations (Fitch & Rosenfeld, 2007; Levy, 2001; McPherson, 1994; Waters et al., 1998). This section describes sight-readers in the current study and how observed behavior was inconsistent with previous findings.

At the conclusion of the data collection, each participant was asked if he or she used any strategies on either the RSR or timekeeping assessments. This was a free response from the participants and a response was not required. Responses were coded for emergent themes and three responses were selected for further analysis due to their potential impact on performance. The first strategy selected for analysis involved an increased focus on subdivision of the beat to aid in performance. Participants who employed this strategy performed better on the RSR task as compared to those who did not mention its use. Although the participants who used a strategy focusing on subdivision scored on average ten points higher than those who did not, this difference was not significant.

A second strategy mentioned by participants focused on relying upon the beat, meaning they worked to maintain the introductory beat provided rather than on any smaller divisions of the beat. Participants who used this strategy scored, on average, four points higher on the RSR task than those who did not mention of this strategy. This difference also was not significant.

Finally, some participants disclosed utilizing some form of a physical timekeeper, even when asked not to do so. This was perhaps the most interesting result as participants who admitted to using a physical timekeeper scored, on average, eight points lower on the RSR than those who did not mention it. This result was not significant, but contradicted previous research that found an improved internal representation of the beat and corresponding influence on motor response with a provided clock and foot tapping (Repp, 1998; Zatorre et al., 2007). While this finding is interesting, it is understood that

self-report of these strategies may be widely variable and inconsistent in actual application.

Additional analysis of Adjusted and Long IOIs revealed a potential deficit in temporal maintenance in the current set of participants. Timekeeping results for most participants improved when the Adjusted IOI was considered, otherwise “improving” their timekeeping via this particular statistical analysis. When this adjustment was made, mean performances on IP1 (notated rhythm) and IP3 (notated pulse) improved by fifteen and fourteen seconds, respectively. Unfortunately this improvement did not affect RSR scores, which substantiates the evidence suggesting a disparity in RSR and timekeeping tasks.

To expand on this, timekeeping ability of participants who were very strong or very weak sight-readers was explored to determine if these groups displayed the same disparity in timekeeping ability. All participants were ordered by RSR performance score from lowest to highest. Rhythmic sight-reading scores of the six participants who were not able to perform past the first level and the six who achieved the last level of performance were examined. An interesting difference was observed between the two groups on timekeeping ability on IP1 (notated rhythm). Participants who performed to the final level were, on average, twenty-one seconds more accurate on the timekeeping task of IP1. Differences on IP2 (non-notated pulse) and IP3 (notated pulse) were not as disparate, implying that the stronger sight-readers were better able to maintain tempo while reading complex rhythms than the weaker RSR group. The strong sight-readers in this study were better able to perform when varied rhythmic notation was present, while both groups were equally accurate on tasks involving maintenance of isochronous beats.

This could be the result of an ability to cope with an added level of complexity, or poor sight-readers may consider rhythm reading to be a different task than timekeeping.

Test items were presented with varying IOI lengths and participants' performance on longer IOIs was less accurate than IOIs of shorter durations. Poor sight-readers have been known to alter the duration of rhythmic values by dividing phrases into smaller units in an attempt to improve performance while others may compress small intervals or increase larger intervals (Doumas & Wing, 2007; Levy, 2001). A potential observation of this rhythmic alteration was observed in the frequency analysis of Adjusted IOI deviations greater than 750ms. Participants were better able to maintain tempo on timekeeping tasks when the distance between taps was equal to or less than one-measure in length (3000ms). As the distance between taps increased, participants were less likely to maintain the provided tempo (see figure 4.5). This finding was observed in all three timekeeping tasks.

Additional evidence for poor temporal maintenance was revealed in an early/late frequency analysis completed using raw data from IP1 (notated rhythm). Nearly three-quarters of the participants performed taps two and three either early/early or late/late. This indicated that although most of the participants had problems maintaining the given tempo, they generally kept the tempo going in the same direction by slowing down or speeding up.

The concept of compression and elongation of time has been examined in relation to the perception of visual information. Saccadic eye movement is a term used to describe the rapid eye motion that occurs when taking in visual information (Goolsby, 1994). Research in this area has demonstrated time compression due to an anticipatory

shift of the receptive fields of neurons. These fields of neurons are located in the intraparietal areas which have been implicated in encoding temporal duration and spatial distance in reading (Morrone, Ross, & Burr, 2005). This implication may explain why nearly half of the participants performed early/early on the original performance of the timekeeping assessment. This possibility was not measured in this study, but will be interesting to explore in the future.

The idea of mental practice has also been used to evaluate temporal accuracy in musicians. Preparatory time was given to participants to reflect authentic sight-reading practices. This time was allotted to allow for a mental run-through of the example, but each participant was able to use this time in any manner they chose. The assessments of timekeeping ability required participants to audiate each exercise, meaning to perform the excerpt within one's head without physical sound. These scenarios of mental practice and audiation are forms of imagined music. In a 2012 study by Clark and Willamon, temporal structures of melodies were generated during a mental imagery task in a way that was identical to live performance. They labeled the similarity between mental and live performance "mental chronometry," a time course of information processed by the nervous system. Although this notion had been established by previous researchers, the results of the Clark and Willamon (2012) study found that not all musicians were able to produce a consistent profile between live and mental performance (Halpern, 1988; Halpern & Zatorre, 1999; Zatorre & Halpern, 1993 & 2005; Zatorre, et al, 1996). Their results demonstrated a considerable amount of individual variation among participants, Clark and Willamon (2012) also found that imagery skills can be enhanced with frequent engagement of this specific task. As imagined music can reflect live performance or

improve with practice, the participants evaluated for the current study either did not produce an accurate mental performance or were unskilled at musical imagery. This may indicate a need to re-examine this stimuli with an extended amount of time to practice the rhythmic material or after participants have completed a series of mental performances.

### **Limitations of this study**

Previous research in sight-reading often included several variables, which I attempted to eliminate in the current study. The tasks were designed to eliminate as many confounding motoric and performance issues allowing participants to focus solely on rhythm reading or timekeeping. It is possible that the construction of these test items interfered with participants' expectations. It is known that pitch can affect rhythmic expectation and evaluating rhythmic ability without pitch may have been a factor in the performance of this group of participants (Fitch & Rosenfeld, 2007; Kopiez, 2008; Pfordresher, 2003a).

The source material for the test items involving varied rhythmic material was derived from a 2009 Bergee study using Rasch analysis to determine the difficulty of one-measure rhythmic segments. Rasch modeling analyzes a single variable and set of participants, placing both on an ordered continuum to determine how much of this variable one participant possesses compared to another while ordering the variable item by difficulty. The current study used the ordered item difficulty of Bergee's analysis reflecting the performance of that particular set of undergraduate music education majors, which may not reflect the abilities of the present group of participants.

The evaluation of performance on the RSR and timekeeping tasks differed. RSR tasks were evaluated in real time, with each measure being evaluated independently for appropriate rhythmic ratios. The timekeeping tasks were measured and analyzed through a sound wave visualizer because the participants' were required to perform each example internally. Perhaps by making the performance and analysis more similar between these two tasks would have presented a different relational result.

The RSR tasks were ordered and presented by level of difficulty, with the easiest rhythmic tasks assessed initially. IP1 (notated rhythm) test items were constructed in the same way, but presentation of rhythmic difficulty was randomly ordered and difficulty did not increase as in the RSR tasks. If a poor sight-reader encountered a level of difficulty they had not seen in the RSR tasks due to performance elimination, this may have impacted performance on the RSR task because the rhythmic difficulty was beyond the abilities of the participant.

### **Future research**

Results from this study revealed an interesting and unexpected independence of timekeeping ability and RSR skills. A relationship between these two tasks is widely accepted and additional research is needed to better understand this outcome. Further analysis of specific strategies mentioned by participants uncovered rather interesting information. Participants who mentioned using a strategy focused on subdivision of the beat showed the strongest, albeit insignificant, performance in RSR scores, while participants who admitted to using a physical timekeeper demonstrated poorer performance on RSR. Using a physical timekeeper, such as foot tapping, is suggested to

young musicians as a way to aid in timekeeping. Additional exploration of these two concepts is needed to determine any possible effects on RSR scores. If participants are specifically asked to focus on beat subdivision or implement a physical timekeeper does this have an impact on either RSR or timekeeping?

Temporal maintenance was identified as the deficiency most likely displayed by participants. Any exploration in relation to improving this task would be useful to further examine the potential relationship between timekeeping and RSR. Can temporal maintenance be improved? If so, how does this relate to RSR ability?

Previous literature has also demonstrated participants' ability to improve mental imagery, another area that could be explored in relation to RSR. It would be interesting to examine various methods of mental practice and identify which may improve audiation skills and possibly RSR performance. It is unknown how participants used their preparation time during the RSR evaluation or if they were reading the rhythms at all during the timekeeping tasks involving notated rhythms. Would RSR or timekeeping performance improve after applying strategies identified as improving mental performance?

Finally, previous literature has also identified problems related to auditory feedback and the absence of this affecting participants' sight-reading. If participants were to perform the timekeeping tasks aloud, in turn providing auditory feedback, would this result in a more accurate performance and an improved ability to maintain the provided tempo?

## Summary and conclusion

Data from this study found no relationship between an individual's timekeeping ability and RSR. Further examination of the data revealed tempo maintenance to be the most likely source of error in timekeeping tasks. Exploratory analysis also revealed that tasks of rhythm reading and basic timekeeping were more separate than in the initial analysis, suggesting that rhythmic complexity provides additional difficulty for participants. The dichotomy of rhythm reading and timekeeping could be explained by previous literature exploring independence or cooperation of sensory modalities used in the perception and performance of rhythmic notation. Visual and audio modalities do not work as cooperatively, while audio and motor modalities are typically more influential. A lack of auditory feedback in the timekeeping tasks may also provide discord in temporal processing and performance. It was also found that participants who focused on subdividing the beat performed better on the RSR task while those who used a physical timekeeper performed below those who did not use a physical timekeeper. Finally, both strong and weak sight-readers were able to keep basic time, but strong sight-readers were able to keep consistent and accurate time while reading complex rhythmic notation, while weak sight-readers were unable to do so.

The results of this study are compelling and unanticipated. It is interesting that the tasks of RSR and timekeeping appear to be unrelated as performed for this study. In moving forward it will be interesting to explore what tasks would improve performance on RSR tasks. It was observed that participants were unable to maintain the provided tempo, especially in the presence of complex written notation. Further research is needed to determine if this relationship could be improved by strengthening the connection

between auditory and visual modalities. It would also be interesting to explore the concept of musical imagery and how that may or may not influence performance on timekeeping or RSR tasks.

Although the current data do not support the author's original hypothesis, the concept of tempo maintenance for accurate rhythmic subdivision – a seemingly obvious task – is actually a highly complex and variable skill. This study originated from observations of students who were unable to perform rhythmic and pitch-based notation simultaneously. Components of sight-reading were considered to identify which factors may improve overall sight-reading performance. Although the results from this study do not support an influential relationship between RSR and timekeeping, my future research will work to continue toward finding the abilities necessary to strengthen individuals' literacy of music notation.

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## Appendix A: Consent Form

### UNIVERSITY OF WASHINGTON CONSENT FORM

The Relationship of Musicians' Internal Pulse and Rhythmic Sight-reading

Researchers: Alison Farley      Graduate Student      (816) 590-8802  
 Dr. Steven Morrison      Professor, Faculty Advisor      (206) 543-8986

#### Researchers' statement

I am asking you to be in a research study. The purpose of this consent form is to give you the information you will need to help you decide whether to be in the study or not. Please read the form carefully. You may ask questions about the purpose of the research, what we would ask you to do, the possible risks and benefits, your rights as a volunteer, and anything else about the research or this form that is not clear. When we have answered all your questions, you can decide if you want to be in the study or not. This process is called "informed consent." We will give you a copy of this form for your records.

#### **PURPOSE OF THE STUDY**

The purpose of this study is to examine the affect of an individual's internal pulse on rhythmic sight-reading. Previous research has examined the effects of pitch on sight-reading but has not explored processes involving the application of an individual's self-generated internal pulse on the sight-reading process.

#### **STUDY PROCEDURES**

As a participant, you will be involved in two evaluations, one of rhythmic-sight reading and another of internal pulse. You will be asked to perform short, novel rhythmic examples on the syllable "dah."

Tests of internal pulse will involve the use of an iPad to record tapping data.

48 hours will separate the two tests and each test will last up to 15 minutes.

Each session will be video taped to later analyze physical movements you may have used during the evaluations.

You will also fill out a questionnaire inquiring about your musical background.

**APPROVED**

MAY 01 2013

UW Human Subjects  
Review Committee

#### **RISKS, STRESS, OR DISCOMFORT**

Performance evaluations may cause some anxiety, it will be explained that this feeling is normal and you will be given the option to discontinue, should your anxiety become too great. Your standing in your respective performing ensemble will not be affected by inclusion in this study.

### BENEFITS OF THE STUDY

You may not directly benefit from participation in the evaluation of either sight-reading or internal pulse. You may become more aware of a potential relationship between the two skills and apply these concepts to your own music performance. This study will extend the area of research on music sight-reading, which has not explored the application of internal pulse. This study will also further the investigation on perception and production of music notation.

### CONFIDENTIALITY OF RESEARCH INFORMATION

You will be asked to provide your email address for the purpose of scheduling data collection. All subsequent data will be coded with a participant number to maintain confidentiality. Links between your email address and participant number will not be shared outside the research team and will be destroyed after one year. Video recordings will be kept for one year for analysis of physical involvement in rhythmic sight-reading..

Government or university staff sometimes review studies such as this one to make sure they are being done safely and legally. If a review of this study takes place, your records may be examined. The reviewers will protect your privacy. The study records will not be used to put you at legal risk of harm.

### OTHER INFORMATION

You may refuse to participate and you are free to withdraw from this study at any time without penalty or loss of benefits to which you are otherwise entitled.

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Printed name of study staff obtaining consent	Signature	Date
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#### Subject's statement

This study has been explained to me. I volunteer to take part in this research. I have had a chance to ask questions. If I have questions later about the research, I can ask one of the researchers listed above. If I have questions about my rights as a research subject, I can call the Human Subjects Division at (206) 543-0098. I will receive a copy of this consent form.

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Printed name of subject	Signature of subject	Date
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Copies to:    Researcher  
                  Subject

04/29/2013  
Version 1.1  
UW Ensemble Members

**APPROVED**  
MAY 01 2013  
UW Human Subjects  
Review Committee

## Appendix B: Sight-reading and Timekeeping Protocol

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The Relationship of Musicians' Internal Pulse and Rhythmic Sight-reading Protocol Sheet

### Rhythmic Sight-reading Evaluation

Thank you for participating in this data collection. You will be participating in a series of rhythmic sight-reading and internal timekeeping evaluations. All results are confidential and will be included in my dissertation which will be subject to review by the internal review board at the University of Washington.

The first test will include 8 measure rhythmic examples. When an example appears on the screen you will have time to look through the excerpt equivalent to 8 measures, this time will be followed by 4 clicks from a woodblock. At this time please perform the example, to the best of your ability, in tempo using the syllable "dah." Do not use any sort of external forms of timekeeping, such as foot tapping, leg movement, etc.

If the excerpt disappears, you have made a mistake and will have an opportunity to repeat the exercise.

Remember your preparation time begins once the example appears on the screen and wait to begin performance after the woodblock preparation counts.

Any questions?

### Internal Pulse Evaluations

#### *Tap with notated rhythms*

This timekeeping test involves visual examples of rhythm. 3 arrows will appear after your preparation time, one on the first beat, one on the last beat and one placed randomly somewhere within the exercise.

Time to review the example begins when it appears and a 4 count woodblock will signal when to begin. Only tap on the notes below the arrows. Do not use any method of physical timekeeping or perform any part of the exercise out loud.

Please tap on the lower right-hand corner of the app, you may tap there now if you'd like.

Any questions?

*(\*) twitchy fingers*

Here is a practice example.

Please press the record button at the top of the screen.

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*Tap with notated steady beat*

This timekeeping test involves use of the iPad. Time to review the example begins when it appears and a 4 count woodblock will signal when to begin. Follow along with the rhythms in your head and only tap when the arrows appear above a note. You will see 3 arrows, one on the first beat, one on the last beat and one placed randomly somewhere within the exercise.

Do not use any method of physical timekeeping or perform any part of the exercise out loud.

Any questions?

Here is a practice example.

At time time please press the record button at the top center of the iPad screen.

*Tap with non-notated steady beat*

At this time you will be performing evaluations related to internal timekeeping.

This portion involves use of the iPad.

In timekeeping test 1, you will be asked to perform without visual examples. As an example, I will ask you to press the key on note 1 of the exercise and the first note of measure 3. Lets try this example.

Please press the record button at the top of the screen.

## Appendix C: Recruitment Speech

### Recruitment Speech

Hello, my name is Alison Farley and I am a doctoral student in music education beginning work on my dissertation. I am here to recruit you for my study looking at the relationship between internal pulse and rhythmic sight-reading. The data collection will occur in two sessions that will last approximately 15-20 minutes each. The data collections will happen when your schedule allows, but the two sessions need to occur within 48 hours of each other. The data collections will involve one evaluation of rhythmic sight-reading and an assessment of your internal pulse. No instruments will be needed for participation. I have a sign-up sheet that will be going around where you can provide me with your name and email and I will contact you to arrange a time for participation. Participation is strictly voluntary and in no way linked with your involvement in this ensemble. I thank you for considering being a part of this study and helping to further the understanding of perception and performance music notation.

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Ensemble Director Initial Contact Email  
Recruitment Script  
Version 1  
04/29/2013

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## Appendix D: Initial Contact Email

### Initial Contact Email

Dear [ensemble director],

My name is Alison Farley and I am a doctoral student studying music education with Dr. Steven Morrison. I am beginning the process of collecting data for my dissertation, which will explore the relationship between internal pulse and rhythmic sight-reading. At this point, I am only examining this relationship in instrumental musicians and was hoping I may be able to come to your ensemble rehearsal to recruit potential participants.

I will have a short speech that I will read to the ensemble, recruiting participants for a data collection, which will occur outside of your rehearsal time. I will also have a volunteer sign-up sheet that will need to be passed around so I may contact the students via email to set up a time for participation.

I am willing to come to rehearsal at the beginning, end or whenever works best for you. I really appreciate your consideration in allowing me to come to your rehearsal. If you have any further questions about the study feel free to contact me and I will be happy to answer them.

Thank you!  
Alison Farley.

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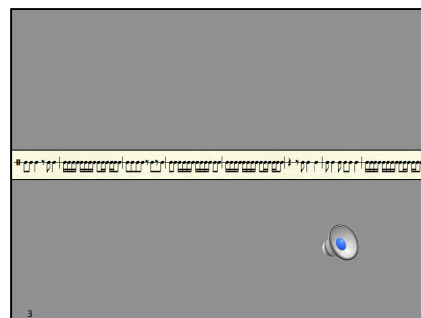
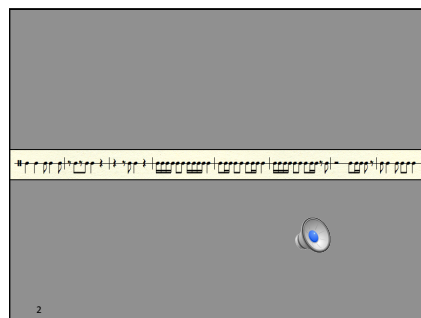
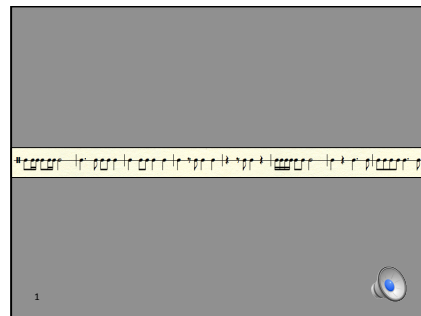
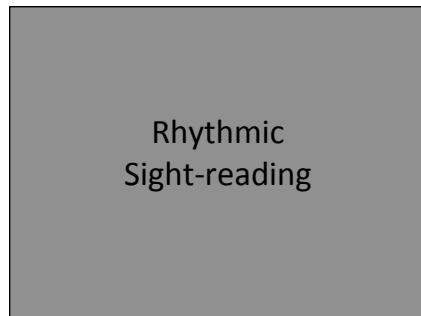
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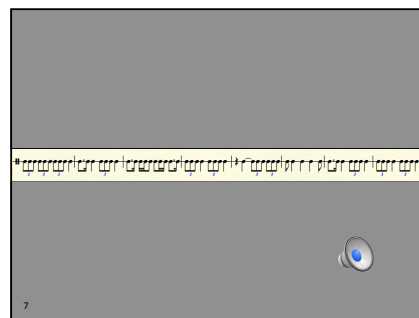
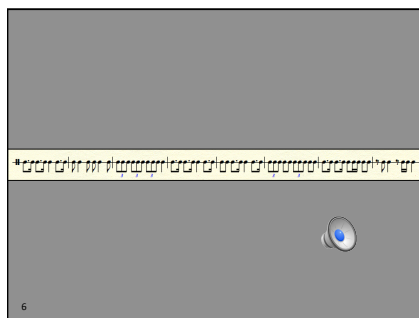
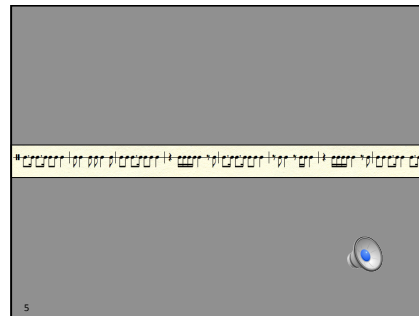
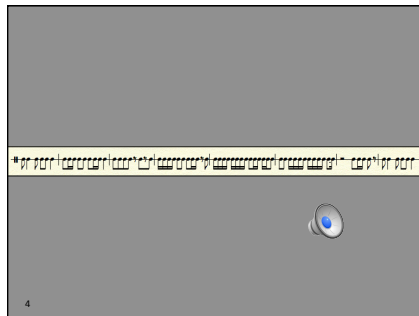
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# Appendix E: Sight-reading Assessment

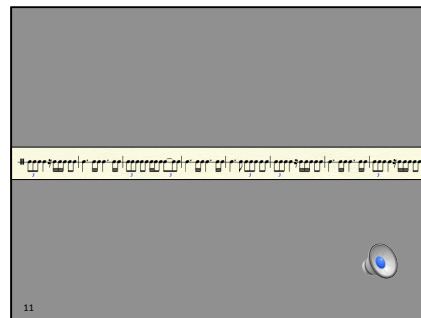
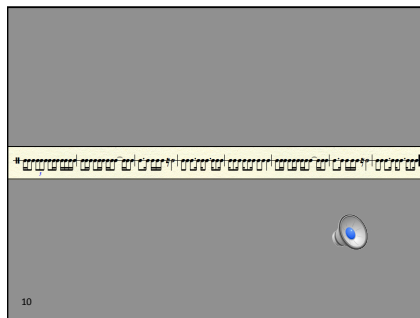
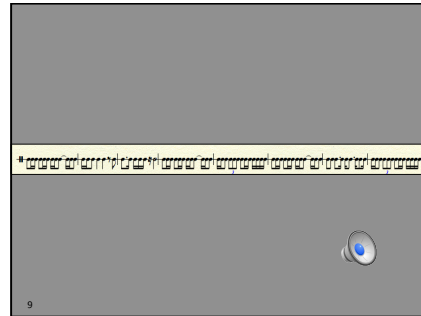
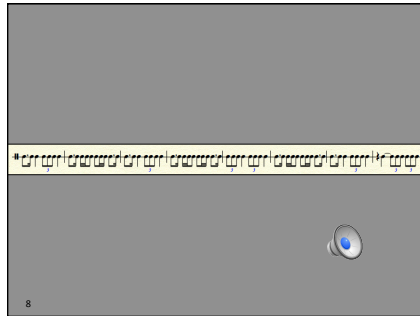
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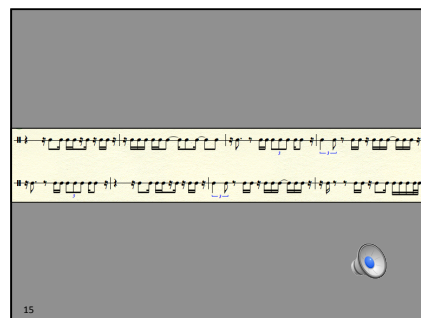
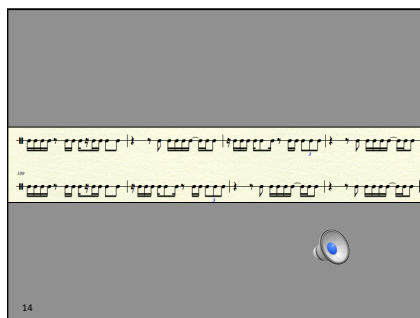
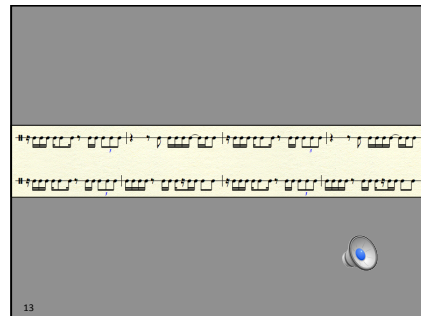
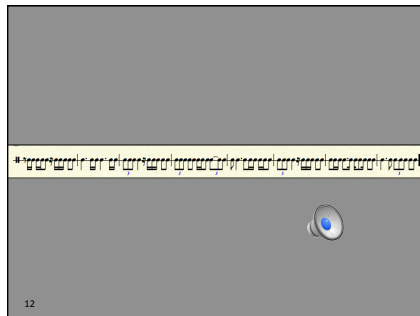
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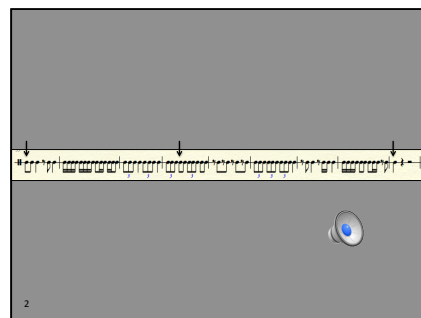
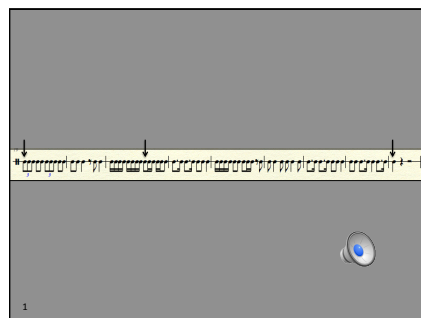
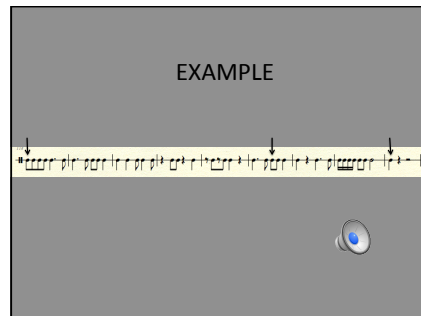
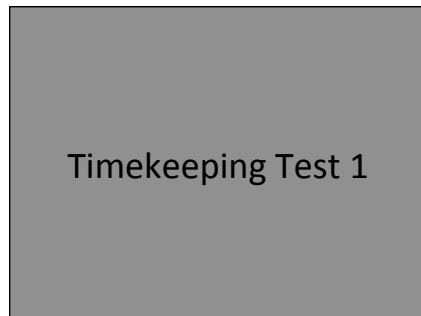
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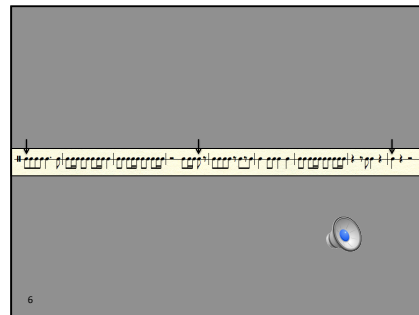
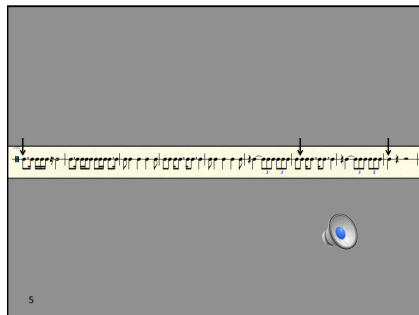
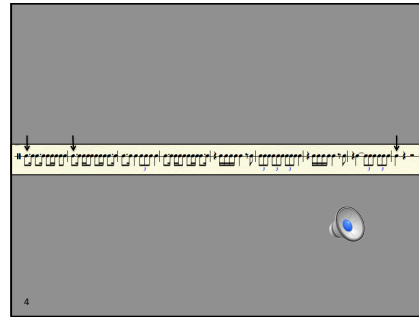
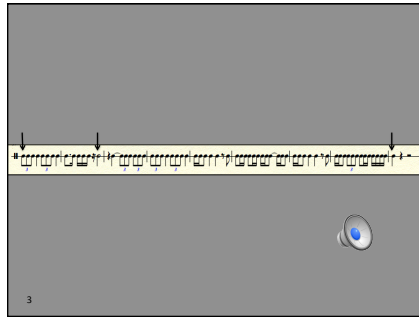
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# Appendix F: Timekeeping Assessment

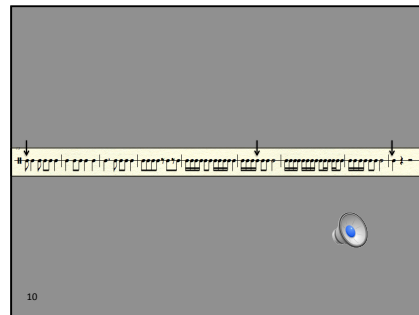
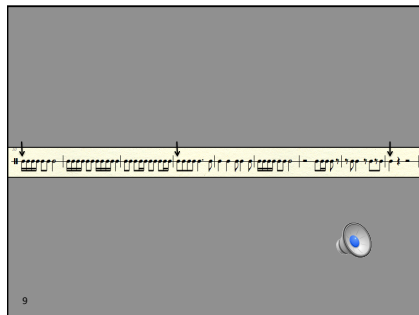
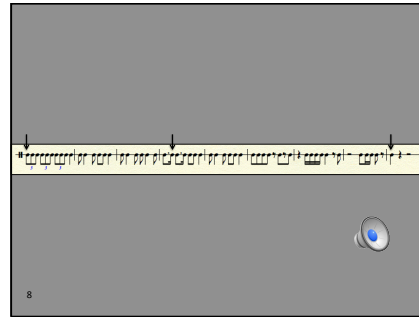
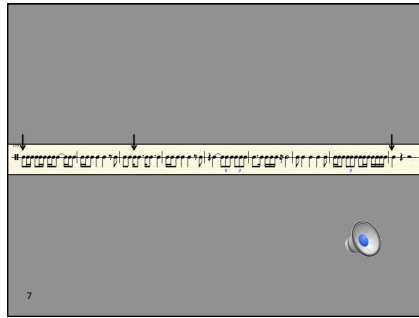
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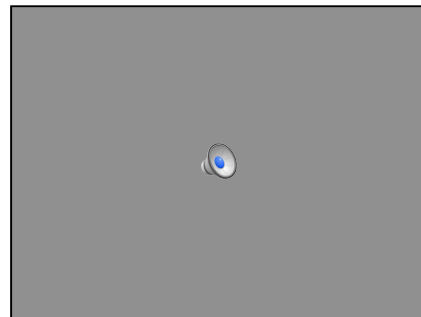
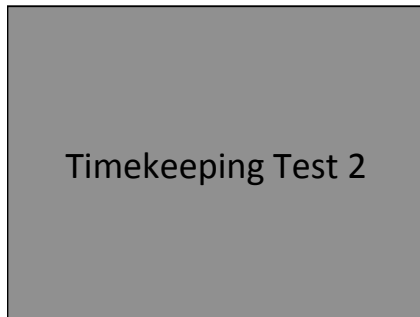
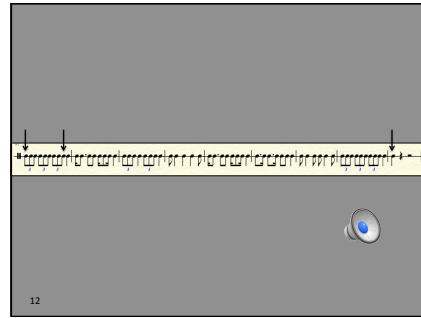
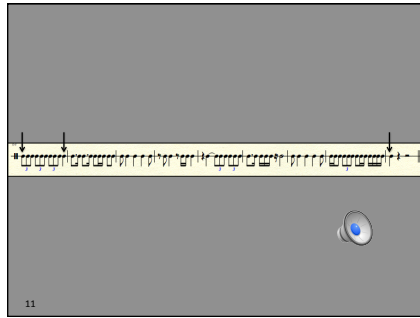
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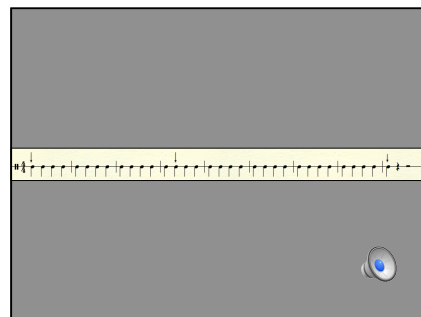
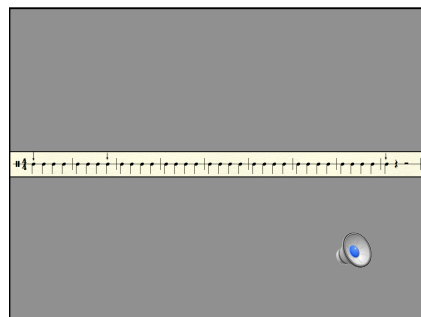
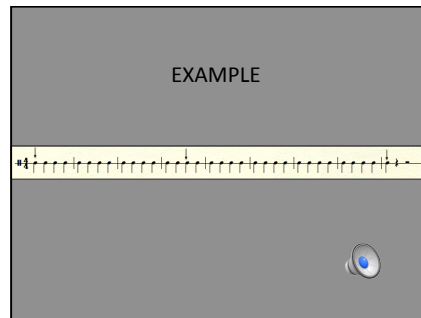
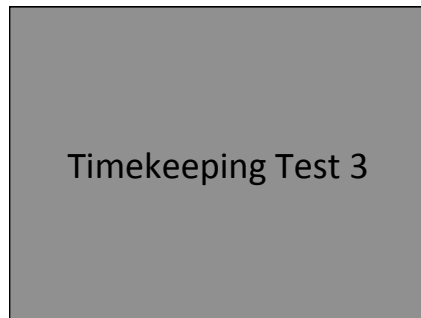
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