Introduction

What do musicians see while reading music? Available research into this topic covers sight-reading, eye-hand span, processing of information, visual fields (including foveal, parafoveal, and peripheral vision), and saccadic eye movements. Factors that affect processing of information include expected versus unexpected patterns of music and sight-reading. Research into vision while reading written words will also be considered due to the correlations between reading music and English.

Definitions

Eye-Hand span – The distance between where a musician's eyes are focused versus the note they are playing.

Foveal – The center two degrees of the visual field.

Parafoveal – The range of sight between approximately three to five degrees around the center of a visual field.

Saccadic eye movement – The movement the eye makes between foci.

Bibliography

Bevilacqua, A., Paas, F., & Krigbaum, G. (2016). Effects of motion in the far peripheral visual field on cognitive test performance and cognitive load. *Perceptual and Motor Skills, 122*(2), 452-469.

Summary: Non-biological motion was used to determine if movement in the periphery would affect the time it took participants to complete a test. The researchers determined motion did not create cognitive overload.

Bishop, L., & Goebl, W. (2015). When they listen and when they watch: Pianists' use of nonverbal audio and visual cues during duet performance. *Musicae Scientiae, 19*(1), 84-110.

Summary: Pianists were tested for musical alignment with another pianist. The results showed the best alignment happened when they could both see and hear the other person. The alignment was equally affected by loss of visual contact or audio contact.

Calvo, Beltrán, & Fernández-Martín. (2014). Processing of facial expressions in peripheral vision: Neurophysiological evidence. *Biological Psychology, 100*, 60-70.

Summary: The researchers determined that facial expressions could be determined in peripheral vision, with happy faces being identified first. This implies that a conductor could communicate with the ensemble even if they are not looking directly at her or him.

Clayton, A.M.H. (1986) *Coordination between players in musical performance.* Unpublished doctoral dissertation, Edinburgh University, UK.

Summary: This unpublished study compares timing discrepancies for musicians in various situations, including with and without a conductor and proximity to other musicians.

Cofer, R. (1998). Effects of Conducting-Gesture Instruction on Seventh-Grade Band Students' Performance Response to Conducting Emblems. *Journal of Research in Music Education, 46*(3), 360-373.

Summary: The author analyzes students' performances on instruments, demonstrating that students who received instruction in conducting emblems identified gestures at a significantly higher rater while playing as well as during a "pencil-and-paper test." The students received practice time with the music before participating in the data gathering phase of the study.

Drieghe, D., Brysbaert, M., and Desmet, T. (2005). Parafoveal-on-foveal effects on eye movements in text reading: Does an extra space make a difference? *Vision Research, 45*(13), 1693-1706.

Summary: The study found that an additional space between words reduced saccade time. This translates into people reading the same passage faster due to layout of the words.

Fredrickson, W. E. (1994). Band musicians' performance and eye contact as influenced by loss of a visual and/or aural stimulus. *Journal of Research in Music Education, 42*(4), 306-317.

Summary: Performers who could not hear the ensemble but could still see the conductor were almost as accurate as students who could both see and hear. This suggests that visual contact with the conductor is more important than being able to hear the ensemble.

Goolsby, T.W. (1994) Profiles of processing: Eye movements during sightreading. *Music Perception*, 12, 97-123.
Summary: This study found that piano players with more experience fixate on specific spots in the music for shorter periods of time with a greater number of saccades. Less experienced players fixated for longer periods of time on the notes they played at the same time. The additional jumps allowed the performer to incorporate more information from the written music.

Gudmundsdottir, H. R. (2010). Advances in music reading research. *Music Education Research*, 12, 331–338.
Summary: The purpose of this paper is to provide a review of the research literature concerning the skills needed to read western staff notation.

Kinsler, V., Carpenter, R. H. S. (1995). Saccadic eye movements while reading music. *Vision Research*, 35, 1447–1458.
Summary: As the tempo of the music increases, the time between fixations decreases. This means that everyone, regardless of experience, moves faster when the situation demands. What is not discussed is the accuracy or amount of information incorporated by each fixation.

Luck, G., & Nte, S. (2008). An investigation of conductors' temporal gestures and conductor-musician synchronization, and a first experiment. *Psychology of Music, 36*(1), 81-99.
Summary: People with more experience in synchronization more consistently responded to a single conducting gesture. All participants were able to respond to the gesture in some way.

Madell, J., Hebert, S. (2008). Eye movements and music reading: Where do we look next? *Music Perception: An Interdisciplinary Journal*, 26, 157–170.
Abstract: This review discusses recent developments in the field and uses relevant conclusions to build a conceptual springboard for future research.

Pelli, D., Tillman, K. (2008). The uncrowded window of object recognition. *Nature Neuroscience*, 11, 1129–1135.
Summary: This literature review discusses object recognition when objects appear in the fovea, parafovea, and peripheral vision. It suggests that the more crowded the area, the longer it takes to recognize objects. It also references what can be recognized in peripheral vision.

Penttinen, M., Huovinen, E., Ylitalo, A. (2015). Reading ahead: Adult music students' eye movements in temporally controlled performances of a children's song. *International Journal of Music Education, 33*(1), 36-50.

Summary: The eye-span of adults were measured while playing known nursery rhymes at a set tempo. More proficient players fixated for shorter periods of time and all players reduced their eye span at the occurrence of unexpected notes. Unexpected occurrences will cause a slow-down in the process of music reading.

Polanka, M. (1995). Research note: Factors affecting eye movements during the reading of short melodies. *Psychology of Music*, 23, 177–183.
Summary: This study suggests that level of experience affects eye movement, with more experienced readers taking in larger groups of notes. Patterns of triads were more readily recognized as a unit than stepwise motion.

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin*, 124, 372–422.
Summary: This is a comprehensive literature review that gives great details about eye movements while reading printed words through 1998. It is the best place to start to gain a background into the field.

Rayner, K. (1986) Eye movements and the perceptual span in beginning and skilled readers. *Journal of Experimental Child Psychology,* 41, 211-236.
Summary: This study suggests that the perceptual span does not differ from beginning to experienced readers, but rather the difficulty of text in relation to the level of reader causes difference in reading speed. This correlates to pattern recognition when reading music.

Ryu, D., et. al. (2015). The Contributions of central and peripheral vision to expertise in basketball: How blur helps to provide a clearer picture. *Journal of Experimental Psychology: Human Perception and Performance, 41*(1), 167-185.
Summary: Using basketball players, the researchers introduced increasingly greater fields of blur into the vision of participants. Those with higher skill and experience were able to complete tasks despite a blurring of peripheral vision. The evidence accumulated suggests answers to several key questions surrounding the role that different sectors of the visual field play in expertise in dynamic, time-constrained tasks.

Schwartz, S. J., et. al. (2005). Attentional load and sensory competition in human vision: Modulation of fMRI responses by load at fixation during task-irrelevant stimulation in the peripheral visual field. *Cerebral Cortex, 15*(6), 770-786.
Summary: The amount of task relevant information experienced in the peripheral vision affects processing time in the brain. This would affect having a conductor in the peripheral vision, indicating that the amount of information obtained at each focal point would be affected.

Sidoti, V., Forsythe, Jere L. (1990). *The Effects of Expressive and Nonexpressive Conducting on the Performance Accuracy of Selected Expression Markings by Individual High School Instrumentalists,* ProQuest Dissertations and Theses.
Summary: Students' playing was measured for expressive sounds while playing with a video of a conductor who either did or did not give gestures reflecting the expressive marking on the

music. Students played a higher percentage of musical marks when the conductor's gestures matched the musical markings.

Sloboda, J. A. (1985) *The musical mind: The cognitive psychology of music.* Oxford, UK: Oxford University Press.

Summary: In this experiment, pianists were asked to sight read a piece of music. At a random point, the music disappeared, but the pianists continued performing. Sloboda determined not only that experienced pianists had larger eye-hand spans, but that they could keep accurately playing longer if the music fit expectations and patterns familiar to the individual.

Thompson, J. (2012). *The Effects of Conducting-gesture Instruction on High School String Orchestra Students' Recognition of and Playing Response to Common Musical Conducting Emblems,* ProQuest Dissertations and Theses.

Summary: This study ties in instruction given to high school string players with their ability to play expressive elements in a piece of music. The students successfully played a larger number of written expressive elements if the conductor's gesture matched the markings on the page.

Traschütz, A., Zinke, W., & Wegener, D. (2012). Speed change detection in foveal and peripheral vision. *Vision Research, 72*, 1-13.

Summary: Foveally, average detection thresholds are lower for accelerations than for decelerations. Deceleration detection becomes superior to acceleration detection in peripheral vision.

Truitt, F., et. al. (1997). The perceptual span and the eye-hand span in sight reading music. *Visual Cognition, 4*(2), 143-161.

Summary: Eye-hand span and fixation duration differed as a function of skill, with the skilled readers having shorter playing times, larger eye-hand spans, and shorter fixation durations than the less-skilled readers. Window size did not interact with reading skill.

Waters, A., Underwood, G. (1998). Eye movements in a simple music reading task: A study of experts and novice musicians. *Psychology of Music*, 26, 46–60.

Summary: Expert musicians used shorter fixations and larger saccades when sight reading music.

Wong, Y., Gauthier, K. (2012). Music-reading expertise alters visual spatial resolution for musical notation. *Psychonomic Bulletin & Review, 19*(4), 594-600.

Summary: This study suggests that experienced music readers suffer less from a crowding affect created by the additional information around a fixation. This effect was not seen when presented with a control sample, meaning that specialization in music allowed for more information to be processed because of experience with music.

Wurtz, P., Mueri, R., Wiesendanger, M. (2009). Sight-reading of violinists: Eye movements anticipate the musical flow. *Experimental Brain Research, 194*(3), 445-450.

Summary: The authors concluded that the results for violinists comparatively matched previous results with piano players. They determined that experience is mitigated by the structure of the music; musicians reduced anticipation of upcoming music by reading fewer notes ahead when reading a more complex piece of music.