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Abstract

Many studies have been done on saccadic eye movements while reading text, but none have been done to see how reading music differs from reading text. The saccade is one of the major components of eye movements that has been observed in previous studies, and the EYE TRAC has been used to obtain a quantitative measurement of the number of saccades while reading. The intent of this study was to determine the difference in the number of saccadic eye movements between reading music and reading text, thereby indirectly measuring the difference in visual demand between these two tasks. We used the Eye Trac to measure the number of saccades made by keyboard musicians first while reading the standard Eye Trac text, and secondly by reading musical notes which have been reproduced to simulate the standard text as closely as possible. Both graphical and statistical analyses were performed on the data obtained during testing, and both dramatically show the difference in visual demand. The mean number of saccades per second was significantly higher for reading music (5.032) as compared to reading text (3.529), and the overall time required to complete each task also was very different (16.4 seconds for text, 120 seconds for music). Statistical analysis predicted that the probability that the data occurred by chance was .0001.

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A Comparison of Saccadic Eye Movements by Keyboard Musicians When Reading Music Versus Text

By

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BIOGRAPHY

Steven M. Larson was born in Austin, Texas, and graduated Cum Laude from Gustavus Adolphus College with majors in biology and classical area studies. He plays the cello and the guitar.

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ABSTRACT

Many studies have been done on saccadic eye movements while reading text, but none have been done to see how reading music differs from reading text. The saccade is one of the major components of eye movements that has been observed in previous studies, and the EYE TRAC has been used to obtain a quantitative measurement of the number of saccades while reading.

The intent of this study was to determine the difference in the number of saccadic eye movements between reading music and reading text, thereby indirectly measuring the difference in visual demand between these two tasks. We used the Eye Trac to measure the number of saccades made by keyboard musicians first while reading the standard Eye Trac text, and secondly by reading musical notes which have been reproduced to simulate the standard text as closely as possible. Both graphical and statistical analyses were performed on the data obtained during testing, and both dramatically show the difference in visual demand. The mean number of saccades per second was significantly higher for reading music (5.032) as compared to reading text (3.529), and the overall time required to complete each task also was very different (16.4 seconds for text, 120 seconds for music). Statistical analysis predicted that the probability that the data occurred by chance was .0001.

INTRODUCTION

There is a well known saying that music is the universal language. It is the one medium that is common to all peoples and that transcends all races and tribal barriers. This saying is so well known that it is almost considered a cliche.We honor our musicians by sitting in stuffy bars to listen to some rock and roll or jazz; we sit in dignified houses of the arts listening to symphonys play the music of composers who have long been dead; we stand and yell in our civic auditoriums while listening to the crooning of a Mel Torme or the cacophony of the Screaming Blue Messiahs.

But despite our infatuation with this media we know surprisingly little about the motoric and cognitive processes that go on in playing and listening to music. As one of the few authors on this subject states " The question of how we study and understand such processes has not really been addressed by mainstream contemporary research into music perception."[6] The motoric aspects of reading music are divided into two sets, those that the eyes make that enable the musician to extract meaning from notes (input), and those movements (output) that enable the musician to interpret the notes in the form of a specific sound from his or her voice or instrument. This study will focus upon the former.

The analogy to reading music is of course reading text, and in this area there is a wealth of information in the psychological, ophthalmological, and educational literature concerning the movements our eyes make. But there are no published articles that the authors could find concerning the eye movements that musicians make while reading their "language". The work in this area that has been completed through the present has been performed by graduate students in psychology and philosophy while working on their doctoral dissertations. The number of dissertations that specifically address the question of eye movements while reading music number less than five.

In this study we will summarize the work that has been done up to the present in reading music. But our interest has been to attempt to compare the eye movements that we make while reading text and while reading music. To simplify our methods we have chosen to concentrate strictly on the number of saccades individual musicians make while performing these two tasks. We will also summarize the work that has been done to date concerning the cognitive aspects of reading text and music and their differences. We hope this study will add to the information about how we read, play, and enjoy music.

CHAPTER 1 RELATED LITERATURE

Eye movements emanate directly from the action of the extraocular muscles. The voluntary movements of our eyes are controlled by Broadman's center #8, which occupies a portion of the frontal lobe just anterior to the frontal gyrus. Involuntary movements, or reflexive movements originate in the occipital cortex and midbrain. Broadman's area and the reflex centers send signals which are based upon previous visual information, down to the extraocular muscle nuclei, which are located in the midbrain centers. These nuclei are the control centers for the muscles and govern their appropriate movements. The precision of these movements is controlled by the cerebellum, which computes the target position according to visual and vestibular information. The types of movements which our eyes make are[1]:

Fixation movements These are reflexive movements which maintain the image of a stationary object upon the fovea.

Saccades High velocity, all-or-none movements that move the fixation to a new point of interest in the visual field.

Pursuits Reflexive movements that follow a moving object to maintain its image on the fovea.

Versions Reflexive or voluntary movements of the two eyes in the same direction.

Vergences Movements of the eyes in opposite directions, as in convergence and divergence.

The eye movements that have been found to relate most to our reading skills are the fixation, the saccade, and the regression. The fixation, as stated above maintains the image of a stationary object upon the fovea. On outward appearance the eye appears to be perfectly stationary during the fixation, but it is actually made up of small tremors, drifts and microsaccades, whose amplitudes are less than an angle of two minutes of arc. These movements help to maintain the accuracy of fixation and provide a changing image to the retinal cells, preventing image extinction. Our eyes respond to changing information, and a perfectly stable image projected on the retina would quickly saturate the rods and cones, leading to a fading of the image (extinction). The constantly changing stimuli provided by these minute movements allow the photoreceptors to regenerate.

It is during the fixation that we extract visual and cognitive information about an object, or in the case of reading, from the text. The time spent in fixation occupies approximately 90 percent of our total reading time. The average duration of a fixation varies from 200 to 400 milliseconds and it is influenced greatly by the difficulty and comprehension requirements of the text[2]. The average adult number of fixations in reading text is 75 to 85 fixations per 100 words, but again this is influenced by the complexity of the text. Finally, it has been demonstrated that inefficient readers generally have an excessive number of fixations during reading.

Much research has been performed during the last 20 years to analyze the temporal and cognitive aspects of the fixation. Rayner[3] has found that we extract the majority of the visual information from a word during the first 50 milliseconds of the fixation, although information extraction can occur throughout the fixation. After the first 50 milliseconds it is assumed that higher somatic and syntactic processes take place, since it takes 60 milliseconds for the visual signals to reach the brain centers. During the first half of the fixation the difficulty of the word can lengthen or decrease the total duration time. Information obtained during the second half of the fixation influences the duration of the subsequent fixation, and the length of the upcoming saccade. Finally, the neural signals for the upcoming saccade are sent during the last 30 milliseconds of the fixation.

Saccades are rapid eye movements from one point of fixation to another. Voluntary saccades are controlled by Broadman's area #8 in the frontal lobes. Reflexive saccades are made up of two movements, which are controlled by different areas of the brain[4]. The first are the fast, rapid fire movements which move the eyes the majority of the distance required. The signals for these movements emanate from the superior colliculus and the pontine control center. The second movements are slower movements which accurately move the eyes the last few degrees and help maintain that position. The neural signals for these movements originate in the medullary cortical control centers. In movements that require less than 30 to 40 degrees of change the fast twitch saccade moves the eye the complete distance, and the slow moving saccade maintains this position[5]. In angles greater than this the slow twitch signals moves the last 1 to 10 degrees and then maintains the eyes in that position. During the time between moving from point to point there is a region of time occupying a maximim of 100 milliseconds in which suppression of the visual field occurs. This serves to allow rapid information extraction at each point of regard, and eliminates the confusing images of a blurry, fast moving world that would otherwise be obtained during the saccadic movement. Saccades immediately follow the fixations during reading and serve to allow sequential visual input of the written text. Their amplitude can range from 2 to 60 degrees of movement, they acquire a velocity of 80 to 120 degrees per second (that's fast!), and take place in 20 to 50 milliseconds. The saccadic amplitude covers an average of 6 to 10 letters (1.33 - 1.55 words) but this can be influenced by the word frequency and the semantic type style. They are not influenced by linguistic factors though, which only affect the duration of fixation.

Regressions consist of right to left eye movements (saccades) during reading and normally account for 10 to 20 per cent of all eye movements and 20 per cent of all saccades. They can occur as a corrective eye movement following an inaccurate saccade, or after a return sweep to the beginning of the next line. A regression may also be a separate saccade backwards in the text to verify or reexamine textual elements or words. As with fixations, a large number of regressions indicate an inefficient reading skill level, as the reader has to continually backtrack to obtain essential contextual information. Dyslexia can account for regressions totaling up to 75 percent of all eye movements during reading. Generally, percentages of regressions greater than 20 percent suggest an inefficient reading process.

A glissade is a corrective eye movement that occurs after an over or under shoot (inaccuracy) of a return sweep or a saccade. It consists of a slower and smaller staccato-like movement and it occurs most often after a return sweep to the beginning of the next line. The number of glissades varies from reader to reader. An individual who has accurate eye movements and efficient reading skills will have fewer glissades, and as stated above, fewer fixations and saccades.

THE HISTORY OF RECORDING EYE MOVEMENTS

The earliest studies of eye movements in reading were those obtained by direct visual contact of the eye. According to Yarbus[6], Javal used a mirror to observe the images of the eye as early as 1879. In addition, microscopes were used to study eyes in a fixed position. A later method included the use of mechanical connections between the eye and the recording instruments. Yarbus defines these devices as:

A) The first type utilized the convexity of the cornea: the movement of the cornea was transmitted by a lever or balance arm. The fulcrum in which the lever rotated was fixed on the subject's head. One polished end of the lever, under slight pressure, touched the anesthetized surface of the eye. The other end made the record on a moving paper tape. The subjects head was usually held in a headrest. This method was used by Ohm(1914,1916,1928) and Cords(1927).

B) The second type also used the convexity of the cornea, but this time the movement was transmitted, not to a lever, but instead to an rubber balloon filled with air. The balloon was fixed so that it pressed slightly against the anesthetized surface of the eye. Movement of the eye altered the pressure inside the balloon, and the movement was recorded.

C) In the third method, small cups resembling contact lenses were used. In the center of the cup was an aperture or window through which the subject looked at the object to be perceived. The cup was affixed to the anesthetized eye like a contact lens. A lever or thread was attached to the cup through which eye movements were transmitted to the recording system. Delabarre(1898) and Huey(1898,1900) used cups made of plaster of paris, which Orschansky(1899) used aluminum cups.

D) Various types of modified contact lenses have also been used. In 1899 Orchensky used a scleral contact lens that had a small mirror mounted on it. A beam of light was focused on the mirror, and the reflected beam was put on a screen. As the eye changed position, the angle of reflectance changed and so the beam would move. Orchensky studied the directions of eye movements in this way. Yorbus resurrected this technique in a series of studies in 1965. He used a convergent mirror to reflect the light and thus obtained a more focused beam. In a more mechanical nature contacts have been used that have had fine threads attached to the four principal meridians. Any eye movements would create tension on one or more of the strings and cause either mechanical or electrical signals for the equipment to measure. The instrument would then translate these signal into recordings on graph paper.

The major disadvantages of the visual and mechanical systems were inaccuracy of measurement as well as subject discomfort. Other more practical methods of studying eye movements include the Photograph Studies of Dodge and Cline(1901), and Stratton(1902,1906), The Motion Picture Studies of Korslake(1940), and Higgins and Stultz(1953), The Time Lens Studies of Haberich and Fischer(1958), and The Photoelectric Method of Recording Corneal Reflexes by Cord and Wright(1948,1949)[7].

By far the most sophisticated and accurate devices for recording eye movements came in the 1940's with the development of biometric devices such as the Eye Trac. With these devices infrared beams are directed to the nasal and lateral limbal areas of each eye. The light reflected from the each globe is measured by two corresponding light receptors (diodes) which compare the amount of reflecting light from each. When the eye is in the primary position both beams fall on the sclerolimbal regions, and the light reflected back is equal. The diodes generate a current only if there is a difference in light reflectance, which occurs when a horizontal movement is made. In this case one beam falls upon the sclera, and one upon the iris. The current generated causes the deflection of a pen on a sheet of graph paper. An eye movement in the opposite direction creates a current, and so a pen deflection in the opposite direction. The current successor the the Eye Trac is the Visagraph, which also uses photoelectric monitoring of the eye movements. The Visagraph is a biometric device that utilizes current computer technology. This device also uses measurements of reflected infrared beams, as the former devices used, but the diode currents generated are analyzed by an Apple computer. The software enables the examiner to quickly assess the average number of fixations, saccades, regressions, reading speed, and many other variables. The Eye Trac and Visuograph can only measure horizontal eye movements though, but you can use the same principles to measure vertical eye movements.

PROCESSES INVOLVED IN READING TEXT

Understanding and identifying all the processes that we undertake while we read is a difficult task because reading is such a complex process. It involves the physical, neurological and temporal aspects of our eye movements that make it possible for us to visually take in the information on the page. But it also involves all the higher cognitive processes that make it possible for us to identify and relate the meanings of words, sentences and paragraphs. The physical aspects of our eye movements in the reading process is an area that has been extensively studied.

There is still a lot of ongoing research into the temporal and cognitive aspects of our eye movements during reading, but Rayner in his book Eye Movements in Reading[8], summarizes the current literature and proposes a model as to what our eyes do during the reading process. As stated before in this paper, in the first 50 milliseconds of the fixation we visually take in the majority of information about a word. The number of letters that our eye can see during a span of fixation is around 18 letters, and this is termed the Perceptual Span. Studies by Jacobs and Morrison[9] demonstrate that this span changes little within the normal span of reading distances and with variations in print style. The Perceptual Span[10] is asymmetric about the point of fixation though and averages 3 to 4 letters to the left of the point of fixation, and 12 to 15 to the right (for readers of English). The left to right directions of this distribution varies between different languages (ie. Hebrew reads from right to left, so the distribution of the symbols in the perceptual span would be reversed) but the span is constant.

Within the Perceptual Span there is a foveal "cone" of clear vision that covers 5 to 8 letters at one time, and this area is called the Semantic Span. These are the letters that we can directly identify, extract information from, and cognitively process. This foveal information is processed during the first milliseconds of the the fixation time. Rayner estimates that our eyes scan letters in the Semantic Span at a speed of 10 milliseconds per letter. The remaining letters in the parafoveal region occupy an area that is called by Harold Solan[11] as the Span of Useful Information. Because visual acuity drops outside the foveal zone we cannot directly access meaning from these letters but we can take in useful information about word length and shape which helps us to anticipate the upcoming text. This information is used along with the foveal information on text complexity to determine the next saccadic amplitude and the next point of fixation. Information taken in during the first half of the fixation determines these parameters. If the reader incorrectly estimates the next point of fixation, he or she will make a small glissade or a regression to the appropriate point of fixation for maximal extraction of text information.

Word identification takes place within the foveal zone but it also occurs in the beginning of the parafoveal zone, usually in the first 3 to 4 letters to the right. Crisp vision is not available here but it is good enough for us to identify small words or the beginning of longer words. If the word is short, such as "at", or "the", we can usually process them without requiring a direct fixation. Rayner and McConkie[12] in a study in 1976 found that we fixate smaller words much less frequently than longer words. Additional parafoveal information such as word length and letter shape (ie. the descending tail of a lower case "g") may give us enough clues to enable us to identify a word. If it is too long for us to recognize, this information is used to help us to anticipate the next word and to more quickly identify it during the subsequent fixation.

Studies have shown that the parafoveal information is essential for smooth eye movements and rapid reading. Rayner set up a study in which subjects read text in which only the foveal information was available to them. Without the parafoveal clues the foveal scanning speed dramatically decreased and the durations of fixation were significantly longer. So during reading it seems that we process overlapping chunks of information, directly identifying words in the foveal region, and indirectly identifying or anticipating upcoming words in the parafoveal region. Again, this information is used during the first half of fixation to determine the upcoming saccadic amplitude and the next point of fixation.

Following the first 50 milliseconds of fixation and into the second half of the fixation, information continues to be extracted from the text. This information travels through the visual system to the visual cortex. From there the visual information is disseminated to associative and higher cognitive centers for word identification, contextual analysis, memory and relational processes, and all the myriad other cognitive processes associated with reading. Finally, we enter the "point of no return". Before this the fixation duration can be voluntarily extended, but the "point of no return" represents the commitment of the visual centers in the brain to perform the next saccade.

STUDIES ABOUT READING TEXT

In 1969, Bakan[13] suggested that a connection exists between lateral eye movements and activity of the Cerebral Hemisphere contra-lateral to the direction of the eye movement. This hypothesis is supported with research by Gatlin and Ornstein(1972)[14] who utilized EEG recordings to designate the location of brain activity as a function of the type of cognitive demand. They concluded that the left hemisphere mediates verbal and mathematical functioning, while the right hemisphere mediates spatial and musical functioning. To prove a connection between the type of demand (ie. music or math,) and the effect on lateral eye movements, Weiten and Etaugh(1974)[15] devised an experiment which demonstrated that verbal and numerical questions designed to activate the left hemisphere, elicit a significantly greater percentage of lateral eye movements to the right than do spatial and musical questions, thought to engage the right hemisphere.

What do these findings reveal about how reading music differs from reading text? First we must look at how we read text. In 1964, Taylor[16] differentiated reading ability into several skills. The first is the span of perception and is defined as a Lateral Arc of approximately 180 degrees which includes both peripheral (the area surrounding the spot of clearest vision), and foveal vision (the spot of clearest vision) as well as three-dimensional or depth appreciation. Recognition of print is confined to foveal and parafoveal vision which is only a part of the total perceptual span.

A second skill stated by Taylor is the "Span of Recognition" and is defined as the amount of print which can be perceived and organized during a single eye stop (fixation). Many methods have been suggested for measuring the span of recognition, but the only objective and accurate way to measure the average span of recognition is to obtain an eye movement photograph or movement printout while the individual is reading. According to Taylor "having a wide span of recognition is a great asset to the reader because it enables them to make fewer fixations when reading, thereby increasing speed and decreasing visual fatigue." Taylor has introduced a table (source #16 in bibliography) by which reading skills can be evaluated according to grade level based on the number of fixations per 100 words read. (See below)

TABLE 1

MEASURABLE COMPONENTS OF THE FUNDAMENTAL READING SKILL

GRADE LEVEL	1ST	2ND	3RD	4TH	5TH	6TH	JR. HGH	H.S.	COLLEGE
Fixations per 100 words	240	200	170	136	118	105	95	83	75
Regressions per 100 words	55	45	37	30	26	23	18	15	11
Average span of recognition (in words)	0.42	0.59	0.59	0.73	0.85	0.95	1.05	1.21	1.33
Average duration of fixation	0.33	0.30	0.26	0.24	0.24	0.24	0.24	0.24	0.23
Average rate of comprehension (in words per minute)	75	100	138	180	216	235	255	296	340

Similar findings were found by Gilbert[17] who tested the perceptual abilities of 76 college juniors and seniors as a function of the number of fixations made while reading sentences. Gilbert found that both good and poor readers make more errors when they read with four fixations per line than when reading with only two fixations per line, and poor readers yield a far greater number of fixations per sentence than do good readers. Both Taylor and Gilbert's Studies prove that decreasing the number of fixations when reading improves the speed and accuracy of the individuals reading ability.

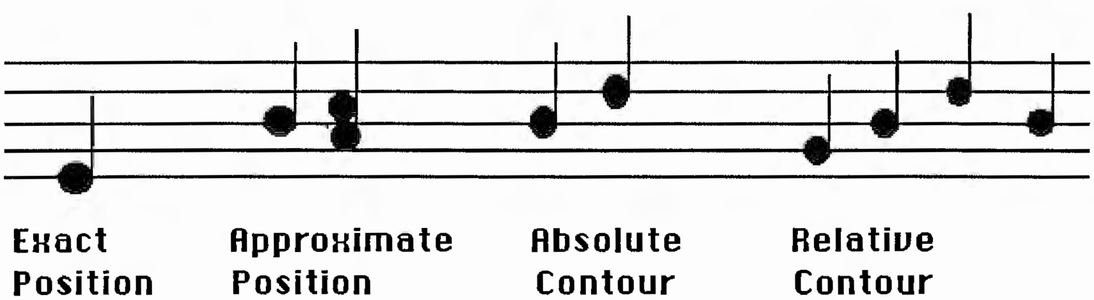
PROCESSES INVOLVED IN READING MUSIC

As stated before in this paper there is a paucity of information in the literature concerning eye movements and the cognitive processes that go on while reading music. But one researcher, John Sloboda, at the University of Kent has published a number of articles in the psychological literature that sheds light on the cognitive processes that go on while reading music. Until his studies came along it was assumed that reading music consisted of a visuomotor activity initially, with the cognitive aspects such as phrase recognition occurring only after the individual notes were played. Talented musicians of course were aware of a cognitive processing that goes on before and while the notes are being played, but it wasn't until Sloboda's work that these cognitive processes began to be understood.

To begin with, the most elemental forms of reading Sloboda talks about are four clues that the musician uses to read notes and to anticipate those that are upcoming. These clues are the Exact Position, the Approximate Position, the Absolute Contour, and the Relative Contour[18]. In his initial studies he tachistiscopically flashed a progression of notes on a staff to novice and experienced musicians. The more experienced musicians used these clues to more correctly reproduce the notes after they had been flashed. The first of the four visual clues is what Sloboda calls the Exact Position, and he defines it as exactly where the note lies in the staff. To identify the Exact Position notes must lie within the foveal cone of vision. In reading text we use parafoveal clues such a letter and word shape to anticipate upcoming information. The parafoveal zone is also used while reading music, but musicians look at the Approximate Position of the upcoming notes in the staff to provide clues for upcoming musical information. Absolute Contour clues also are accessed in the parafoveal region. This is the vertical relationship of one note to another. Before a musician determines the exact position of a note the Absolute Contour gives him clues about which direction, either descending or ascending, the music is going to take in the next 8 to 15 beats. As you may recall, 8 to 15 letters to the right of the foveal zone is the extent of the parafoveal zone in reading text. This zone has the same dimensions in reading music. Keyboard players use these clues in order to anticipate if they should change hand position in order to play higher or lower notes along the keyboard.

The fourth clue musicians use is the Relative Contour. This requires at least three notes, and it aids the musician in identifying ascending or descending passages within the music, or when a change of direction is going to take place. Many times a phrase, or sequence within the music ends with a change of direction, and Relative Contour helps the player to anticipate when to pause or give emphasis to a note or notes when a phrase is about to end. Relative Contour is the most global clue used by the musician. The global relationships of these four clues is illustrated in the diagrams:

Increasing Global Features ↑		Decreasing Global Features ↓
	Relative Contour	
	Absolute Contour	
	Approximate Position	
	Exact Position	



Finally, on a higher cognitive plane, musicians can identify specific musical structures and patterns that aid them in playing, such as dominant chords or arpeggios.

In a classical experiment with chess players in 1923 Chase and Simon[1] showed chess piece patterns for a fixed period of time to chess novices and experienced players. The experienced players were superior in reproducing the piece placement when recognizable chess patterns were

used, but were equal in ability to the novices when random, unintelligible patterns were used. Referencing these studies they hypothesized that experienced players develop cognitive strategies for pattern recognition. In many studies it has been shown that experienced musicians are superior to novices in recalling musical patterns. Sloboda set out to prove that
musicians also use such strategies (as in the chess studies) while reading music. Again, he was out to find evidence that reading music involves cognitive as well as visuomotor processes.

When the passages were exposed for 2 seconds the experienced musicians were noticeably superior to the novices in recalling the passages, but at 20 millisecond intervals the performances were equal. By this information Sloboda concluded that musicians do not have an innate faster scanning rate but they must have more efficient coding and storage mechanisms. These mechanisms take more time, explaining their superior performances at the two second intervals. Halper and Bower[6] investigated the role that musical sense plays in pattern recognition. They found that musicians did perform better than novices when logical or recognizable musical patterns were exposed, but that the performances were the same when random patterns were flashed. They obtained essentially the same data that the former chess studies did, only pertaining to music.

In 1976 Sloboda studied the effect that misprints of note position have upon performance. He provided a copy of piano music to his subjects in which one or two notes were purposefully miswritten in such a way as to make the resulting sequence that contained them sounded blatantly wrong musically. He asked the subjects to play the pieces note for note. During the first reading of the music 38 % of the pianists failed to play the miswritten notes. They automatically played a note that was more appropriate with the sequence played and all were not cognizant of this fact. During the second reading 40 % of the subjects substituted more "correct" sounding notes for the misprints. Here is solid evidence that musicians do cognitively examine the sequences and patterns in the music as they play the notes and not afterward as was previously thought. And the 2 % increase in passing over the misprints suggests that musicians learn more about music infrastructure and pattern as they play a piece repeatedly.

Professional musicians use all of the clues mentioned in the last few pages to interpret a piece of music, and the result is a sound that is pleasing to our ears. They use their knowledge of patterns and their parafoveal clues to anticipate the ending of musical phrases and then use interpretative tools such as pauses, dynamics, and stress to interpret the music.

Another concept Sloboda introduced regarding the ocular and cognitive aspects of music reading is that of the Eye Hand Span (EHS). It has been known for many years in prose reading that if a projected passage is suddenly turned off, a subject will not immediately stop but will continue on for 5 to 6 words. This is the Eye Voice Span (EVS), and the length of it is influenced by the cognitive complexity of the passage read. In music this phenomena is the Eye Hand Span and it averages 5 to 7 notes ahead of those suppressed. This concept is roughly equivalent to the perceptual span that we talked about before in reading. Sloboda found that the musicians who made many mistakes in the music had an EHS of 3 to 4 notes, while the accurate reader had spans of 6 to 7 notes. As in reading, the nature of the music influences the EHS greatly. With logical and coherent musical passages experienced musicians had longer spans than novices, but the spans were identical when randomly scattered notes were played. Getting back to phrase boundaries, it was found that the more accurate players ended at the end of phrases 72 % of the time compared to the 32% of inaccurate readers. So again Sloboda presented good evidence that it is the cognitive knowledge of music that is crucial to reading, and good musicians attend to the patterns (phrases) and structures within the music as they play.

STUDIES ON READING MUSIC

In 1976, John Sloboda[19] performed four experiments to examine the way in which experienced musicians differ from non-musicians in their recognition of briefly exposed pitch notation. Experiments I and II, using Tachistascopic Method of flashing a five line musical bar with five letters randomly placed on it, demonstrated that musicians are superior to non-musicians in their immediate written recall of stimuli containing 3 or more notes, but only when the stimulus is exposed for 150 ms or more. These results are accounted for well by a model proposed by Coltheart(1972) for letter perception under conditions of brief exposure. In this model, two coding processes act simultaneously on the stimulus, one a fast visual coding, and the other a slower, but more permanent abstract (or name) coding. In this case, non-musicians appear to be lacking a second, abstract, coding which musicians possess.

Sloboda's experiments III and IV attempted to find the nature of the abstract code for musicians by presenting interference in the form of a different auditory stimuli than what was presented visually. Neither concurrent letter naming or interfering auditory stimuli appeared to cause a decrease in the original visual task, suggesting that musicians may not have been using simple naming or pitch transformations in coding the visual input.

A second study by Sloboda(1978)[20] had musicians and non-musicians make written reports of briefly presented displays of pitch symbols (notes) on a five row bar. While musicians were not superior to non-musicians at identifying individual notes, (detailed analysis), they were superior at retaining information about the contour order of the note sequences (global analysis). In addition, manipulation of task difficulty by requiring whole or partial report of the displays had a significant effect on performance, only when global, rather than specific, response measurements were taken, with musicians scoring much higher (2.648 on a scale of 3.000 being highest) versus the non-musicians (2.118 out of 3.000). The results agree with the theory that Global Analysis precedes detailed analysis in perceptual testing.

Schmidt(1981)[21] proposed a study to determine if it was possible to measure the eye movement patterns of 32 undergraduate woodwind instrument performers while they "sight read" (the ability to perform new music at reasonable speeds and with expression, so that the first reading is like that of a concert performance[22]). A three way A.N.O.V.A. Test of Schmidt's work concluded that: (1) eye movement patterns of musical instrument performers can be accurately measured as they sight read. (2) It was possible to use the Eyetrac* Eye Movement Monitoring System to detect, measure, and record the eye movement patterns of the subjects. (3) Sight reading expertise of the subjects significantly affected the mean number of eye regressions per second. (4) The type of instrument played (flute, clarinet, or alto saxophone) had no significant effect upon the mean number or duration of regressions or fixations. (5) The complexity of the music asked to sight read greatly affected the number of fixations per second and the mean duration of those fixations (increasing and decreasing, respectively). However, the complexity of the music had no significant effect on the number of regressions made.

An explanation of this increased eye movement ability of musicians was suggested by Herrick and Rainbow(1982)[23]. They tested 20 active musicians (8 years performing experience required) and 20 non-musicians (no more than elementary school music instruction) and presented two different five note melodies to each ear via headphones. after the two second melodies were heard, a bar graph with five notes was presented visually: The subjects scored one point if they identified the music as one of the melodies presented, and a second point if they were able to match the ear in which it was heard. Observed eye movement patterns during testing varied significantly between musician and non-musician groups. Musicians tended to exhibit non-movement eye behavior during dichotic processing. This suggests a bi-hemisphere processing strategy. Non-musicians demonstrated a general left eye movement in all processing. This suggests a right hemisphere processing preference. Results of this study lead to the conclusion that musicians show evidence of strategies that differ from non-musicians. Musicians appear to employ a bilateral processing of information that non-musicians lack. As evidenced by their significantly higher scores on the experiment mentioned above.

CHAPTER II METHODS

As has been stated before, there have been many studies performed on subjects reading either text or music, but none in which the eye movements of these two tasks were compared. The purpose of our study was to find out if there are differences in specific eye movements, in our case saccades, between the two tasks. Our hypothesis was that there would be a significantly larger number of saccades per second when the subjects read and played the musical selections versus when they read the text.

For our experiment we chose to use the Eye Trac to measure the numbers of saccades when our subjects read text and music. Subjects were chosen among the students and faculty of Pacific University. Subjects were required to have 20/20 near vision and to have at least 2 years of experience on the keyboard.

Positioning the subject in the Eye Track consisted of setting the chin in the chin rest and adjusting the head rests against the temples. Aligning the eyes with the infrared receptors and beams consists of aligning the purkinje images of the subjects' eyes in the operators screen and adjusting the lights to coincide with the pupillary centers. This is achieved through adjusting the horizontal and vertical adjustment controls. Centering and amplitude of the pens on the graph paper is then done by having the subject look at targets on a standardized Eye Trac set up card, looking at a central target and then alternately between a target on the left and the right.

Once alignment and optimal amplitude was achieved the subjects silently read the selection of text. We recorded their eye movements as they read. The subjects were asked to read at a comfortable pace and to pay attention to the context of the piece. After finishing, a short standardized contextual quiz was given them to determine if the subject was truly reading or just skimming the material. The eye recordings were judged to be invalid if the subject had greater than a 40 % error rate on the quiz. Subjects were then realigned in the Eye Trac and then were asked to read and play a short piece of music that was written by the experimenters for this study. All attempts were made to make the visual and cognitive demands of the musical task equal to that of the Eye Trac text card. The music was written in such a way that:

1. The number of notes per line equaled the number of letters per line.

2. Average horizontal width of the letters were calculated to be 2 millimeters. The notes were written with a circumference of 2 millimeters, and so the visual angles of the two tasks were equal. The Snellen demand for the letters and notes was 20/80.

3. Average vertical distances between the notes and letters were written to be as equal as possible. This was difficult as the nature of musical notation necessitates changes in vertical placement within the staff.

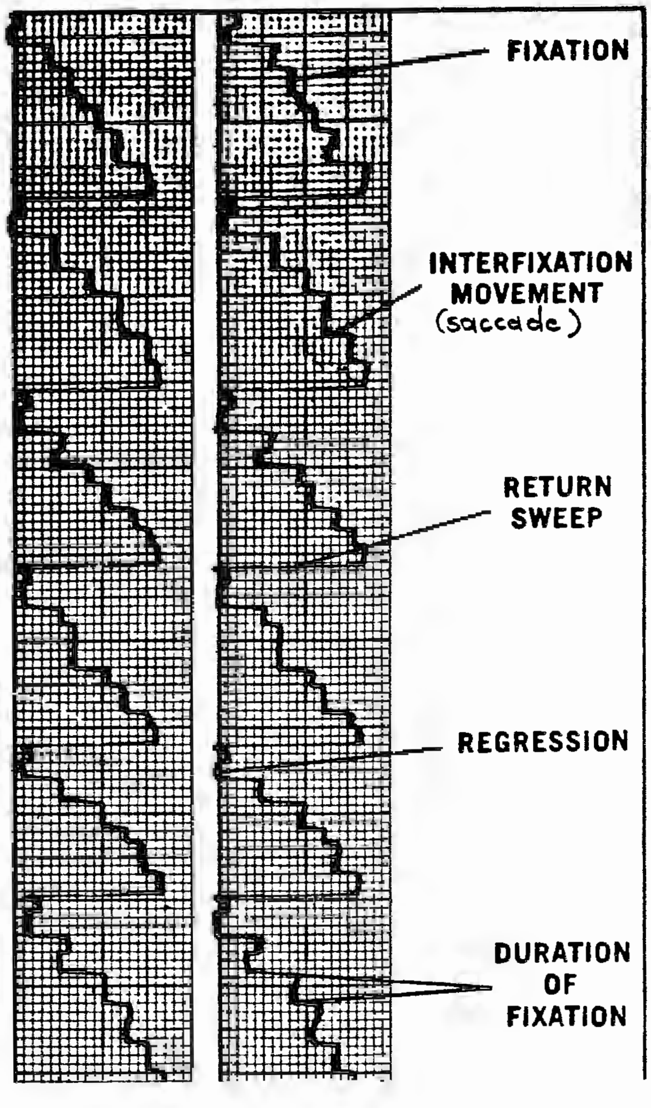
4. Context was provided in the music by writing simple and well known melodies into the musical passages and separating them with randomly chosen notes. Subjects were asked to play the pieces at a tempo that was comfortable for them, and to listen for these melodies. A short quiz on the melodies was given after completion of the piece.

5. To simplify the data collection the music was written with no measure bars, no tempo or key signature information, and no change in length of the notes.

6. Because written and musical languages are so different it is difficult to tell exactly if the cognitive demands for the two tasks were exactly equal. We chose to use a third grade reading level card for the text. This was because in the third grade text, the distance between the corresponding notes in the musical text were large enough for the Eye Trac to measure distinctions between fixations and saccades. To give an approximation of the cognitive demand the musical piece was written to be played by one hand only. The musical piece could easily be played by a musician who had had 6 to 12

months of experience. Third grade text is still very simplistic and we felt the cognitive demands, especially when performed by college students and musicians of greater then 2 years experience, to be easy for these individuals, and to be approximately equal to the cognitive demands of the music.

To read saccades and fixations on the Eye Trac tape is a simple process. Vertical lines correspond to fixations (ie. when the eye is notmoving) and horizontal lines correspond to saccades. The deflection on the tape is opposite that of the eye movements. In other words, the reading direction is graphed out on the paper on a right to left direction. Therefore any left to right movement corresponds to a regression. An example of the Eye Trac graph paper is on the left. Total number of saccadesduring the reading of the text were counted and recorded. Because there were so many saccades involved in reading the musical text a calculation was made to estimate the total number of saccades. The time it took the subject to play the piece was recorded. The speed of the tape in the Eye Trac is 2 boxes per second. The number of saccades was counted in 3 to 4 different blocks of 4 centimeters each and the means were calculated.



This number was divided by 4 to obtain the average number of saccades per second. A one-tailed (directional) T test was performed using the Statview 512 statistics program. The assumption of our hypothesis was that there would be a significantly larger number of saccades per second when the subjects read and played the musical selections. The degrees of freedom were automatically calculated by the program based on the small number of subjects our data was derived from.

The statistical program calculated the various indices of variability, and in the T test compared the mean number of saccades for reading music and reading text for each individual and for the group as a whole.

RESULTS

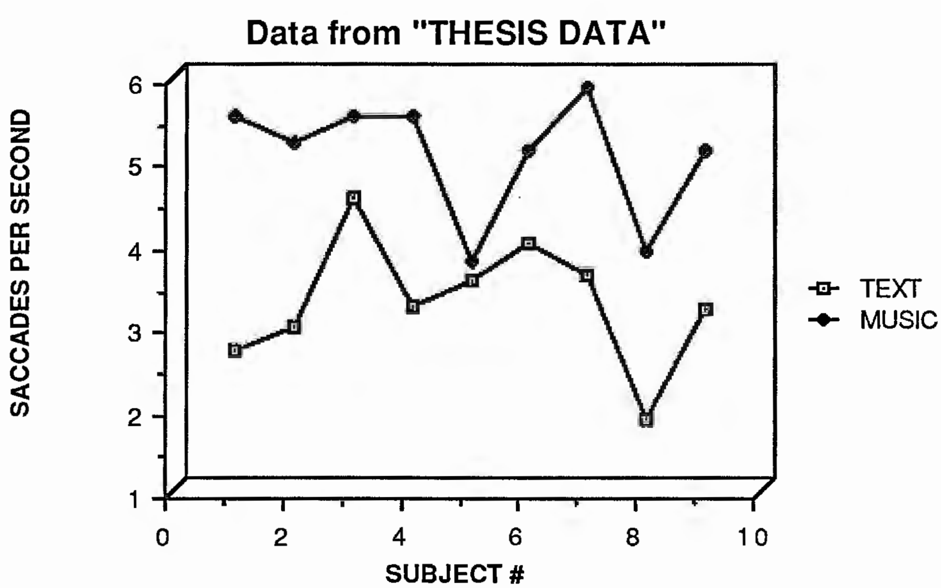
Our subject population consisted of nine subjects, five females and four males, all pre-presbyopes, whose ages ranged from 26 to 34. All of our subjects demonstrated 20/20 near vision (with best near correction), had greater than two years experience on the keyboard, and all easily passed the quiz on the comprehension of the text (mean equal to 81 % correct on the quiz). Based upon the criterion of a 60% passing rate (as described in the methods section) we accepted as valid the eye movements during reading text. There was less success with the results of the musical quiz. Two of the subjects correctly identified 3 of the 4 melodies that were written into the music, but the mean score was correct identification of only 1.55 of the 4 melodies. One of the factors that may have caused the low mean score was that the musicians were only given one reading of the musical text. This combined with the factors that the music had no measure bars, no tempo or key signature information, and no change in length of the notes, made it so that we essentially eliminated all of the clues that musicians and listeners of music typically use to identify melodies. This made it much more difficult to identify the melodies in the piece. We feel that these factors caused the low scores in musical quizzes and that the low scores in melody identification were caused more by a flaw in the quiz design. The eye movements obtained when reading music were still very usable.

In all but one of the subjects there was a large difference between the mean number of saccades in reading music compared to reading text. The mean number of saccades found when the subjects read the Eye Trac text was 3.26 per second. The corresponding mean number of saccades obtained when the subject read and played music was 5.03. The smallest difference among the subjects occurred in subject number 5, who had a difference of .22. The largest difference occurred in subject number 1 who had a difference of 2.33. Most of the subjects averaged differences in saccades per second from 1.50 to 2.00 saccades per second. The statistical analysis gives us a mean difference between reading text and reading music of 1.73 saccades per second.

When we ran these numbers through a one-tailed T test we found the means to be significantly different. The analysis of the one-tailed T test demonstrated a level of significance of .0001. This means that there is a one in a thousand chance that this difference could be attributable to chance, so we can conclude that there is a large significant statistical difference between the mean saccades per second between the two sets of data. The raw data and the statistical analysis are contained in the tables in the appendix.

The graph below demonstrates the differences found between the means. It compares the calculated saccades per second between reading text, the numbers on the lower lines, with the calculated numbers of saccades per second when the musicians read music. With the exception of subject #5, a large difference can be seen between the calculated saccades per second in reading text versus music. It graphically demonstrates the large difference between the calculated values of the saccades per second.

GRAPH #1



Although we did not run a statistical analysis on this we also noted a large difference in reading time between reading text and reading music. Average reading time for the text was 16.4 seconds, while for reading music it was 120 seconds. The statistical differences between these numbers seem obvious.

We made no attempt in our study to find a correlation between the age, sex, and number of years of experience of the musicians, with the average number of saccades per second in reading text or music. This would be valuable data, especially the latter factors, and should be included in a follow up study.

DISCUSSION/CONCLUSIONS

As our survey of literature concerning eye movements and music has demonstrated, many studies have been performed to see how we read music and read text. Psychologists have been particularly interested in the memory systems, the span of recognition, and in the perceptual aspects of how we process visual information. For the optometrists and ocular experts the interest lies more in the analysis of the extraocular eye movements such as the saccades, fixations, and regressions. Although both professions have performed studies regarding eye movements while subjects read either text or music, neither have ever explored the basic differences between the actual eye movements that are made while performing the two tasks.

The purpose of this study was to show the differences between reading text and reading music. By counting the number of saccades, fixations, and regressions while reading passages of similar difficulty we have shown that:

1. Eye movements of musicians can be monitored and recorded using the Eye Trac. Our study supports this conclusion that was made by Schmidt[21].

2. The mean number of saccades per second is dramatically different with musicians making many more saccades per second while reading music (mean is 5.032) versus reading text (the mean is 3.529), using our text and music tasks. Our music and text cards were written so that the task demands would be as equal as possible.

3. Our statistical analysis (included in abstract A4) show that the mean saccades while reading music are significantly higher with the probability of error being less than .0001 per cent.

A visual analysis of the actual Eye Trac recording shows a much different pattern between the demands of reading text versus reading music. Reading text yielded the typical pattern eye movement patterns seen while the subjects read text, which is long saccades followed by long fixations (see graph in appendices). Reading music yielded smaller saccades with short fixations, accompanied by many small regressions. The recording pattern resembled a nystagmoid pattern of searching as the eyes progressed across the musical staff. The reasons for this type of pattern are as yet unclear. It could be a feedback system is taking place. As the musician identifies a note and prepares to play it on the keyboard the eyes move on to identify the next note. When the note is played though, the musician receives feedback through the auditory system. The eyes may be returning to the prior note to recheck its accuracy.

Also noted were the actual times required to read each passage. A significantly longer time was spent reading the music (averaging 120 seconds) whereas the text was read much more quickly (averaging 16.4 seconds). There are a number of possible explanations for this difference:

1. Subjects have been reading text for a longer period of time than reading music, demonstrating a "practice effect". Their skills in reading text may be more proficient than in reading music. But studies have shown[1] that the perceptual spans are constant between the two media. This explanation seems unlikely.

2. When reading text, we combine bits of information (letters) that are seen not as discrete symbols, but as a whole (a word). It is impossible to do this when reading music, because the notes must be played individually, and on a specific pace or tempo. The musician must identify each note, and cannot string several together to be read as a whole. This correlates with the fact that there are many more fixations and saccades when reading music. This is especially evident when the subject is asked to sight read an unfamiliar passage.

The question as to why musicians cannot take in chunks of information when reading musical text, as they do in reading literature, remains to be answered by further investigation. A clue can be found though in looking at the precision of the task that is involved in playing music. As was described above a reader of text has a learned vocabulary, or a memory of combinations and arrangements of letters from which the reader can extract meaning. Very frequently used words, such as prepositions (the, in, of) can be skiped over by an accomplished reader. As was described before, Rayner and McConkie[10] found that we fixate such connectors much less than we do larger words.

But such connective phrases do not exist in music. In order to correctly play the piece it is imperative that the musician pay attention to where each note lies within the staff, and there can be an infinite combination of such pitches. This requires a high level of concentration by the musician on each note. Our perceptual systems have a "zoom in" capability to pay particular attention to small details and a "zoom out" capability that allows us to take in the large picture or. It seemed that reading our musical text required greater concentration and that a player had to "zoom in" more than in reading the Eye Trac text. Sight reading a unfamiliar piece of music would be comparable to reading a text on mathematics for the first time, in that a higher level of concentration is required. This may be an explanation of the larger number of saccades per second in reading our musical text. Increased concentration is usually followed by smaller bits of information taken in per fixation. Therefore, the greater level of concentration required, more saccades are required to sequentially take in the information.

Another important aspect of reading music is that it is indelibly connected to the act of playing the music. Time must be spent in cognitively analyzing the musical language and time must be also spent in signaling the appropriate muscles to depress the appropriate key. Sloboda[9] states that in his experience there is no such thing as a person who can truly read music cognitively. The meter, tempo and even major themes may be recognized by an accomplished reader, but to truly read the music it must be played. The motoric aspects of playing add to the time of each fixation, because a musician cannot read too far ahead of the notes he is playing without making errors in his playing.

And music is also an "experiential" language, not only for the listener but also for the musician. As Sloboda has shown, a musician cognitively analyzes the music as it is read, but the musician must also evaluate his or her precision in playing through feedback via the auditory system.

Follow up studies in this area should be directed to:

1. Providing a more "real world" stimulus for reading music. In our study we omitted measure bars, note tails, key signatures, bass and treble lines (for keyboard musicians) which were left out so as to simplify data collection.

2. Using a larger subject population with a specific amount of musical experience, or incorporate a method of grading experience. We asked subject how many years they had been playing the keyboard, but years playing is not a good yardstick of the experience of a musician. Other factors such as lessons taken, natural talent, desire to work on the instrument, all affect these measurements.

3. Making a comparison of musicians versus non-musicians to see how they differ in the way they read text. Are accomplished musicians better readers than non readers, or can you compare the two?

4. Studying the effects of note size and practice upon the mean number of saccades while reading music. There have been many such studies in the subject of reading text, but none to date concerning reading musical text.Information such as this could have direct application in changing the print size of music to maximize reading efficiency.

5. Analyzing to a greater degree the nystagmoid eye movements observed in our study. Also evaluating the vertical eye movements that keyboard musicians make while reading passages containing bass and treble staffs.

This study has shown that the eye movements while reading music are significantly different from those involved in reading text. We have shown that reading music requires many more saccades, fixations, and "microregressions" than reading text does. It is thereby imperative that musicians have fine-tuned oculomotor skills in order to be able to see and identify each individual note on the musical staff. It follows that programs such as vision therapy that will increase the reading efficiency of a musician should make these individuals better sight readers and better readers of music in general. Follow up studies should be performed to test this hypothesis. But again, as we have stated in this paper, reading music is a complex process that involves the cognitive, motoric, and auditory systems, and further studies must be performed to test this hypothesis.

Music is the universal language, and millions of individuals have studied the rules and nuances that make up this language. But we are only beginning to understand the processes that enable us to take in information from those strange dots that occupy the musical staff, and those processes that enable the musician to bring into the world this special language seems so sweet to our ears. Much more research needs to be done in this field. The authors hope that this paper will add to the knowledge in this field as well as wheting the intellectual appetite of fellow musicians and optometrists to pursue further research into the eye movments that are involved in reading music.

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GRAPH 2 - RAW DATA ON SUBJECTS

DATA					
SUBJECT NUMBER	1	2	3	4	5
SEX	F	F	M	M	F
AGE	26	28	33	32	26
# YEARS PLAYING	4	3	25	4	4
NEAR VA	20/20	20/20	20/20	20/20	20/20
TEXT READING					
TIME REQUIRED (SECONDS)	16.5	19.8	14.7	15.25	14.7
# SACCADES	44	58	66	49	52
# SACCADES / SECOND	2.67	2.93	4.49	3.21	3.53
TEXT QUIZ					
# CORRECT	8	7	7	8	8
% CORRECT	80	70	70	80	80
MUSIC READING					
TIME REQUIRED	1:28	1:31	2:41	1:58	2:02
# SACCADES / SECOND	5.5	5.17	5.5	5.5	3.75
MUSIC QUIZ					
# CORRECT	1	0	1	3	1
% CORRECT	25	0	25	75	25

This graph shows the raw data for subjects 1 - 5. Both text and music information is given.

GRAPH 2 - RAW DATA ON SUBJECTS

DATA						AVERAGES
	6	7	8	9		
SEX	F	M	F	M		
AGE	34	26	27	28		
# YEARS PLAYING	6	7	7	3		
NEAR VA	20/20	20/20	20/20	20/20		
TEXT READING						
TIME REQUIRED (SECOND	11.37	18.2	18.6	18.4		16.3911111
# SACCADES	45	65	34	58		52.3333333
# SACCADES / SECOND	3.95	3.57	1.83	3.15		3.25888889
TEXT QUIZ						
# CORRECT	8	8	10	9		8.11111111
% CORRECT	80	80	100	90		81.1111111
MUSIC READING						
TIME REQUIRED	1:48	1:59	1:40	2:14		2:00
# SACCADES / SECOND	5.08	5.83	3.875	5.08		5.03166667
MUSIC QUIZ						
# CORRECT	2	3	1	2		1.55555556
% CORRECT	50	75	25	50		38.8888889

This graph shows the raw data for subjects 6 - 9. Both text and music information is given.

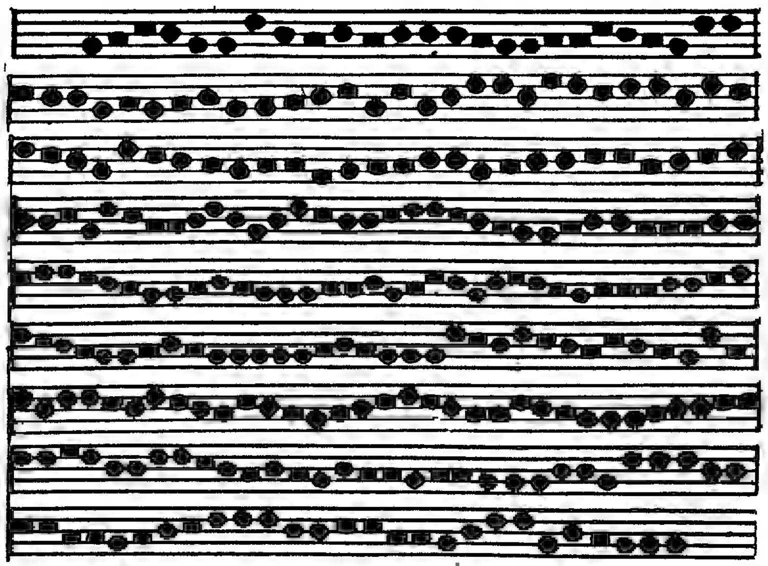
GRAPH 3 - COMPARISONS OF DATA

	TIME TO READ	TIME TO PLAY		SACCADES PER SECOND		
SUBJECT NUMBER	TEXT	MUSIC		TEXT	MUSIC	
1	16.5	2:08		2.67	5.5	
2	19.8	1:31		2.93	5.17	
3	14.7	2.41		4.49	5.5	
4	15.75	1:56		3.21	5.5	
5	14.7	2:02		3.53	3.75	
6	11.37	1:48		3.95	5.08	
7	18.2	1:59		3.57	5.83	
8	18.58	1:40		1.83	3.88	
9	18.4	2:14		3.15	5.08	

STATISTICS-SACCADES PER SECOND

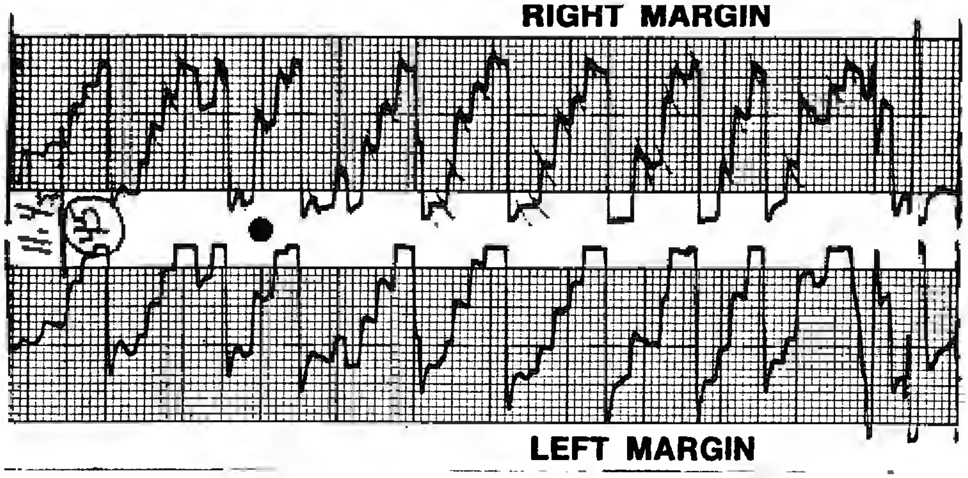
STATISTICAL						
ANALYSIS						-
	MEAN	STD. DEV.	VARIANCE	MINIMUM	MAXIMUM	RANGE
TEXT	3.259	0.764	0.584	1.83	4.49	2.66
MUSIC	5.032	0.733	0.537	3.75	5.83	2.08
	SUM #'S	SUM#SQRD	N			
TEXT	29.33	100.258	9			
MUSIC	45.285	232.159	9			
		T TEST	1 TAILED			
	DF	MEAN X-Y	PAIRED T	PROBABILITY		
	8	1.773	6.506	0.0001		

MUSIC TASK

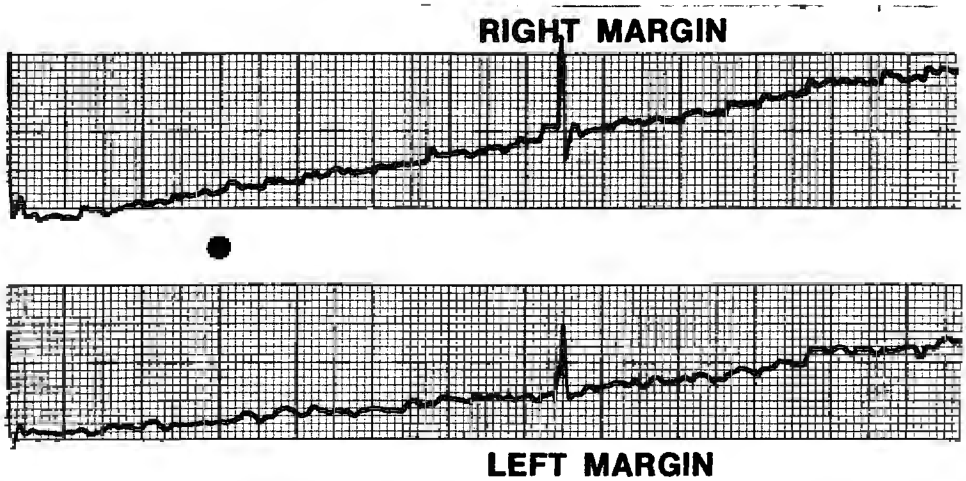


READING TASK

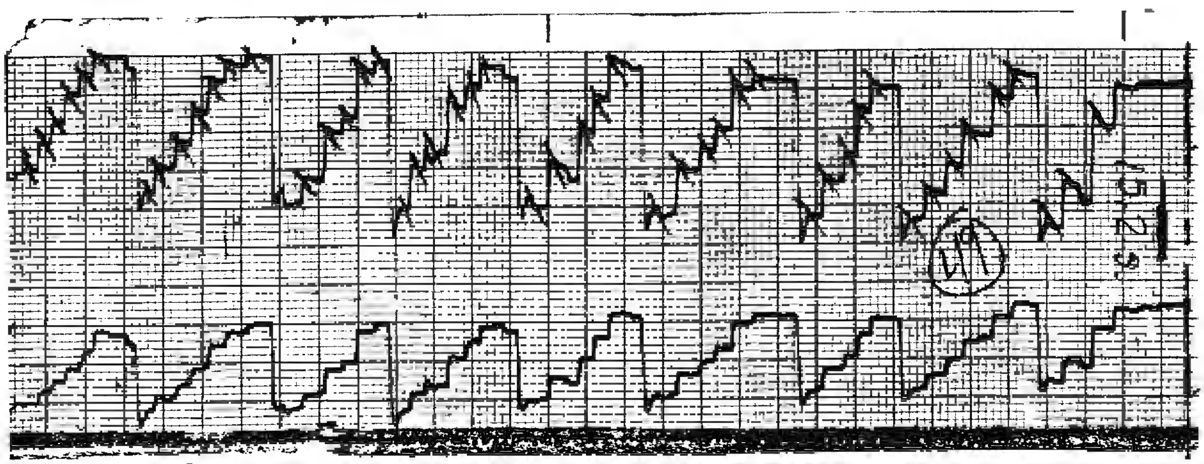
Susan likes to listen to music. She has over fifty records to play on her record machine. Most of her records are songs, but some tell stories. After school, Susan plays records for her friends. She keeps her records on a shelf above the record machine. She is careful never to scratch them with the needle. Susan has broken only one record.



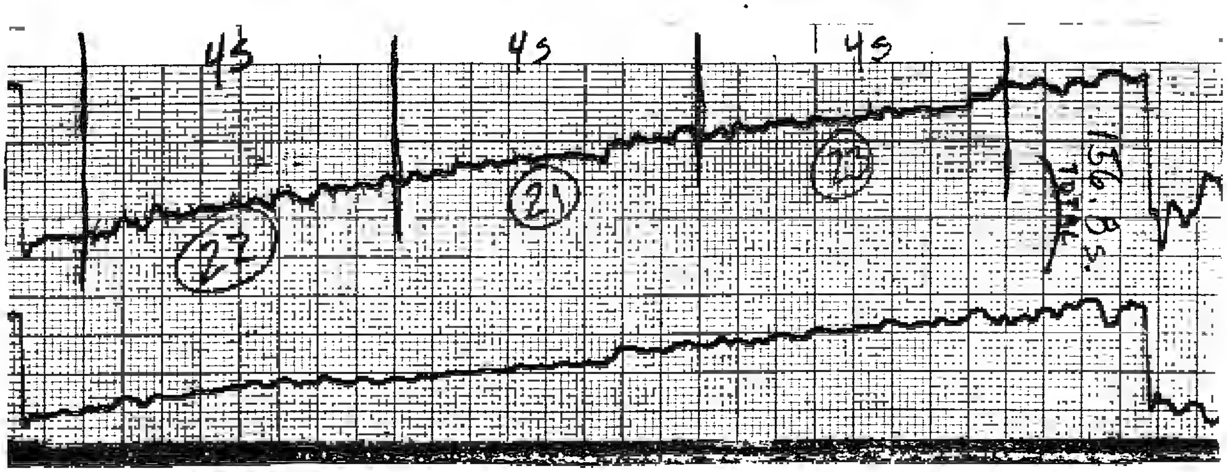
EYE TRAC RECORDINGS WHILE SUBJECT #1 READ TEXT



RECORDINGS WHILE SUBJECT #1 READ MUSIC



SUBJECT #2 READING TEXT



SUBJECT #2 READING MUSIC

COMPARISON OF SACCADIC EYE MOVEMENTS BY KEYBOARD MUSICIANS WHEN READING MUSIC VS. READING TEXT

Today we will be monitoring the movements of your eyes while you read text and while you read music. We will be using the Eye Trac, the equipment that is before you. Relax, and please follow all of our instructions. First we will adjust the Eye Trac to your head position and then we will begin. Once we have adjusted you please remain in the Eye Trac until we let you know that the testing is complete. Any questions?

Adjust the Eye Trac to obtain maximum amplitude deflection on the tape when the subject moves his/her eyes.

1. TEXT READING

____________________ (name) when you hear this note played (demonstrate) please read the passage of text that is before you. Read to yourself and not out loud. Read at a speed that is comfortable for you and pay attention to what the passage is saying. We will give you a short quiz on the context of the passage after you finish. Say the word "STOP" when you come to the end of the passage. (REPEAT THE INSTRUCTIONS)

SUBJECT READS THE PASSAGE
PUT QUIZ CARD BEFORE SUBJECT

Now for the quiz. Please read each statement (as researchers read them) and answer yes or no if according to the passage the statement is correct or incorrect. Take your time and do your best.

READ SENTENCES AND SCORE

2. MUSIC READING

Now for the music!

Please briefly look over this passage to position your right hand on the keyboard. The music is simple and only one hand will be required. (Keep your head in the Eye Trac - you will have to position your hand my feel and by ear.)

Again, when this note is played (DEMONSTRATE) please read and play this passage of music before you. Set a tempo that is comfortable for you, one in which you can read and play the notes accurately. While you play the music listen for any melodies that you may recognize. These melodies are the "musical context" for this piece, and you will be quizzed on them later. Say the word "STOP" when you finish.

SUBJECT PLAYS THE PASSAGE
SUBJECT CAN THEN COME OUT OF THE EYE TRAC

TEXT QUIZ

1. Susan likes to play the piano. ______
2. Susan likes to listen to music ______
3. She has over a hundred records. ______
4. Most of her records are songs. ______
5. Some of her records tell stories. ______
6. Susan plays her records at school. ______
7. She keeps her records on a shelf. ______
8. The record shelf is under the record machine. ______
9. Susan has never scratched a record. ______
10. Susan has never broken a record. ______

Music Quiz

1. All of the notes you just read were eighth notes. ______
2. There were 8 measures per line. ______
3. The range between the highest and lowest notes played was approximately an octave. ______

4. Please check the melodies you heard in this piece.

a. Leaving on a Jet Plane ______
b. Go Tell Aunt Rodie (the Old Grey Goose is Dead) ______
c. She'll Be Comin' Round the Mountain ______
d Beethoven's Ode to Joy ______
e. Twinkle Twinkle Little Star ______
f. Long Long Ago ______
g. Largo to Dvorak's New World Symphony ______
h. Scarborough Fair ______
i. Mary Had a Little Lamb ______
j. Blowing in the Wind ______

5. This piece of music is destined to: (circle correct answer)

a. become a mainstay in the repertoire of professional symphonies around the world.
b. be distributed my K-Tell records and be lost in obscurity.
c. be published in respected musical journals such as Mad Magazine.
d. None of the above - we were just kidding!
e. All of the above.
f. c and d (watch it!)
g. d and e (and you're in college?)

THAT'S IT, WE ARE DONE!! THANK YOU VERY MUCH FOR YOUR TIME!!

Informed Consent Form

1. Institution

A. Title of Project	Comparison of Saccadic Eye Movements by Keyboard Musicians When Reading Music vs. Text	
B. Principal Investigators	Steven Larson	357-5488
	David Robinson	648-4881
C. Advisors	Dr. Septon	357-6151 ext.# 2281
	Dr. Laukkanen	357-6151 ext.# 2451
D. Location	Pacific University College of Optometry Forest Grove, Oregon 97116	
E. Date	1989	

2. Description of Project

This project is designed to monitor and measure eye movements while reading music and while reading text. We will adjust your chin and head in the Eye Trac and have you first read one card of text, and then one card of musical text while you play the notes on the provided keyboard. We will give you a short quiz on the content of the texts after you read each.

3. Description of Risks

The Eye Trac is a non-obtrusive instrument (it has no parts that will come near your eyes) which uses low intensity infrared light to monitor the position of the eyes. No eye health hazards have ever been reported through its use, and it is widely used in research and as a vision therapy training device.

4. Description of Benefits

You will be participating in a study that is essentially the first of its kind. Besides some intellectual benefits, other benefits will be negligible.

5. Compensation and Medical Care

If you are injured in this experiment it is possible that you will not receive compensation or medical care from Pacific University, the experimenters, or any organization associated with the experiment. All reasonable care will be used to prevent injury however.

6. Alternatives Advantageous to Subjects

Not applicable

7. Offer to Answer any Inquires

The experimenters will be happy to answer any questions that you may have at any time concerning eye movements or this project. If you are not satisfied with the answers you receive, please call Dr. James Peterson at 357-0442.

8. Freedom to Withdraw

You are free to withdraw your consent and to discontinue participation in this project or activity at any time without prejudice to you.

I have read and understand the above. I am 18 years of age or over (or I am having this form signed by a parent or guardian).

Printed Name ________________________________

Signed ____________________ Date ______________

Address ____________________ Phone ______________

City, State, Zip ________________________________