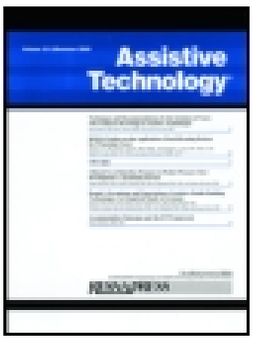

Assistive Technology

The Official Journal of RESNA

ISSN: 1040-0435 (Print) 1949-3614 (Online) Journal homepage: https://www.tandfonline.com/loi/uaty20

The challenge of reading music notation for pianists with low vision: An exploratory qualitative study using a head-mounted display

Bianka Lussier-Dalpé, Catherine Houtekier, Josée Duquette, Marie-Chantal Wanet-Defalque & Walter Wittich

To cite this article: Bianka Lussier-Dalpé, Catherine Houtekier, Josée Duquette, Marie-Chantal Wanet-Defalque & Walter Wittich (2019): The challenge of reading music notation for pianists with low vision: An exploratory qualitative study using a head-mounted display, Assistive Technology, DOI: 10.1080/10400435.2019.1661315

To link to this article: https://doi.org/10.1080/10400435.2019.1661315

Published online: 17 Oct 2019.

ASSISTIVE TECHNOLOGY
https://doi.org/10.1080/10400435.2019.1661315

Taylor & Francis
Taylor & Francis Group

The challenge of reading music notation for pianists with low vision: An exploratory qualitative study using a head-mounted display

Bianka Lussier-Dalpé, MSc, CLVT[a], Catherine Houtekier, MSc[a], Josée Duquette, MSc [a], Marie-Chantal Wanet-Defalque, PhD[a,b], and Walter Wittich, PhD, FAAO, CLVT [a,b,c]

[a]CRIR Research Services – Institut Nazareth et Louis-Braille du CISSS de la Montérégie-Centre, Longueuil, Québec, Canada; [b]School of Optometry, Université de Montréal, Montréal, Québec, Canada; [c]CRIR Research Services – Centre de réadaptation Lethbridge-Layton Mackay du CIUSSS du Centre-Ouest-de-l'Île-de-Montréal, Montréal, Québec, Canada

ABSTRACT

Reading musical notation while interpreting it on a musical instrument poses problems for musicians with a visual impairment (VI). This study sought to describe the visual aids, adaptations and compensatory strategies used by five amateur pianists with low vision when reading music, to identify the problems they face when using these aids, and to verify whether a head-mounted display (HMD) such as eSight Eyewear can be used to overcome some of them. In this exploratory study, the participants read and interpreted two excerpts of musical notation using eSight Eyewear. The data, collected through interviews, were coded using a qualitative method and a phenomenological approach. The results suggest that musicians with a VI use various visual aids, adaptations and compensatory strategies. However, these approaches are not without significant problems, particularly when they involve magnification. On the other hand, eSight Eyewear allows users to adjust magnification, have their hands free and use adapted musical notation. Many magnification-related problems are overcome with this HMD, which can be used to simultaneously read and interpret standard musical notation. However, reading sheet music with such a device remains a complex task, given the need to control head movements accordingly.

ARTICLE HISTORY
Accepted 21 August 2019

KEYWORDS
assistive technology; electronic aids to daily living; low vision; magnification; music; recreation; visual impairment

Reading musical notation is an essential skill for anyone studying music (Madell & Hébert, 2008). A visual impairment (VI) limits one's ability to read musical notation and compromises many aspects of playing a musical instrument; yet, for many people, music is an essential part of cognitive development. Persons with a VI should therefore be able to access music, both in its interpreted and in its written form (Hersh & Johnson, 2010). Persons with a VI face well-documented problems reading textual material. Various means for improving their performance have been identified, including the use of visual aids (Wolffsohn & Peterson, 2003) and modifying the visual presentation of the text (Foley, 2008). In comparison, the challenges inherent in reading music are not well known, and few means have been identified to help a musician with a VI read music. Reading a text and reading musical notation requires different visual abilities, due to differences in the way the information is presented visually and differences in the reading task itself (Comeau, 2010; Madell & Hébert, 2008). The main two issues faced by persons with a VI highlighted here are the visual presentation and the task of reading musical notation:

Visual presentation of musical notation

The musical staff, consisting of five horizontal lines, serves as the frame of reference for localizing almost all the signs of musical notation (Gudmundsdottir, 2010; Read, 1979). Essentially, pitch is represented by the vertical position of notes on the staff, and time is represented by the horizontal position of notes. However, it is equally necessary to distinguish these elements in order to identify the relative length of a note: for example, a full or empty head, the form of the stem (whether it is present or not, and if there are flags or beams), or the presence of a dot (Gudmundsdottir, 2010; Housley, Lynch, Ramnath, Rogers, & Ramanathan, 2013; Read, 1979).

Accessing this graphical presentation of music requires both detail vision and global vision (Housley et al., 2013). A musician therefore requires good acuity to identify both the pitch and the length of notes (head, stem, flag, beam, dot). Reading music also requires global vision. While the visual presentation of text is essentially linear, musical notation represents music both horizontally (length) and vertically (pitch). Studies of ocular movement have found that reading music involves more multidirectional movement than reading text (Udtaisuk, 2005). For example, musical scores for piano are presented on two staves (for the left and right hands). The staves are one above the other, showing notes to be played simultaneously. So when pianists advance through musical notation, their eye movements must alternate between the two staves (Dormehl, 2017; Furneaux & Land, 1999; Udtaisuk, 2005).

CONTACT Bianka Lussier-Dalpé, MSc, CLVT bianka.lussier-dalpe.inlb@ssss.gouv.qc.ca CRIR – Institut Nazareth et Louis-Braille du CISSS de la Montérégie-Centre, 1111 Rue Saint-Charles Ouest, Longueuil, QC, J4K 5G4, Canada.

The task of reading musical notation

Reading music is defined as "The act of decoding the symbols of staff notation using a musical instrument" (Gudmundsdottir, 2010, p. 331). It therefore involves three specific challenges: (1) reading the notes at an intermediate reading distance (50 cm to 70 cm), (2) having the hands free to play the music, and in the case of playing piano (3) occasionally glancing down at the hands/keyboard. When the musician has a VI, magnification (with different means) and memorization are recommended to facilitate the reading of music; however, they increase cognitive load and task complexity (Bouabid, 2013; Coates, 2012; Housley et al., 2013; Jacko, Choi, Carballo, Charlson, & Moore, 2015), in addition to dealing with challenges such as glare caused by spotlights in concert halls, or poor ligihting in a rehearsal rooms.

Magnification, achieved by reducing the eye/notation relative distance, is possible by bringing the notation closer with an adapted lectern (Clark & Murphy, 1998; Labbett, 1995; Whittaker, Scheiman, & Et Sokol-McKay, 2016), or by bringing it closer with one's hands. However, the lectern usually needs to be custom-made, since there are few adapted models on the market (Clark & Murphy, 1998; Labbett, 1995). When the reading distance needs to be particularly close, it becomes impossible to read the score while playing the piano. The musician needs to get close to the notation, read and memorize it before it can be played, increasing the task's complexity (Bouabid, 2013). **Optical or electronic aids** can be used to magnify the score (Coates, 2012; Labbett, 1995; Whittaker et al., 2016). However, since most of these aids are designed to facilitate the reading of text, they present certain problems when reading music (Coates, 2012; Housley et al., 2013). A table-mounted video magnifier provides access to the details in the notation, but the musician needs to stop playing to move the music on the CCTV platform (Clark & Murphy, 1998). There are few aids that can be used hands-free and at an intermediate reading distance (50 to 70 cm). The notation can be magnified by enlarging it with a photocopier, music publishing software or a handwritten transcription (Coates, 2012; Labbett, 1995)]. However, the resulting number of pages requires frequent page-turning, which interrupts the playing (Coates, 2012; Housley et al., 2013).

More recently, digital sheet music has opened up new opportunities for VI musicians. Apps can display the musical notation on the screen of a computer and scroll with a pedal, freeing hands when turning pages. Some application designers have adapted their product to customers with low vision. For example, MusicReader PDF (Leoné MusicReader, 2019) and eStand (https://www.estand.com/info2/) applications allow you to adjust the size of a score and scroll it half a page at a time (eStand Inc., 2019). The ForeScore application (https://forscore.co) allows to adjust the size of the notation while redistributing it (reflow), which would allow to triple the size of the original score (forScore, 2019). Nevertheless, the magnification offered by these products is not enough to suit all people with low vision. Finally, the Lime Lighter (Dancing Dots, 2019) is specifically designed for customers with low vision and can expand up to 10X. The pedal allows the movements through the notation either: from the beginning to the end, by system or by measure. With a high magnification, it becomes complex to navigate through the musical notation, and users must have access to digital partitions in MusicXML format (a scan may be necessary).

Memorization or alternative means. In addition, Clark and Murphy (1998), as well as Coates (2012) encourage **memorization**, oral instruction and the use of recordings. However, memorization requires some preliminary work before interpretation, and the last two methods require an intermediary between the musician and the notation. There is still access with braille music notation (Braille Authority of North America, 2015). However, muscial braille notation must be read using at least one hand, so it cannot be read and interpreted simultaneously (Bouabid, 2013). Thus, persons with low vision would usually tend to use visual access to music sheet whenever possible.

Given these obstacles to reading musical notation, the objective of this study was to explore the opportunities offered by a head-mounted display (HMD) such as eSight Eyewear. An HMD is an electronic visual aid that presents information on screens placed directly in front of the eyes (Ehrlich et al., 2017). Users move their heads rather than their eyes to explore their environment. They can modify the image (enlarge it, change the contrast, apply color filters, etc.) using a control panel (Geruschat, Deremeik, & Whited, 1999). Users can adjust the magnification and use various work distances (Harper, Culham, & Dickinson, 1999). Once the necessary adjustments have been made, the user's hands are free. HMDs first became available for persons with a VI in the late 1990s: LVES (Massof & Rickman, 1992), V-Max, Jordy and Jordy II (Louise E. Culham, Chabra, & Rubin, 2009; Geruschat et al., 1999). However, their use has been limited by problems encountered in the technology's development (Francis, 2005), the impossibility of incorporating peripheral vision (Peterson, Wolffsohn, Rubinstein, & Lowe, 2003), and its relative comfort, weight, appearance and cost (Francis, 2005; Harper et al., 1999).

The technical specifications for eSight Eyewear have previously been presented in more detail (Wittich et al., 2018). The study device was a second-generation device with a high-definition camera and two Organic Light Emitting Diode (OLED) screens mounted on a frame that is comparable to a pair of fully-enclosing sunglasses. The remote control contains the processor and the battery. Magnification factors range from 1.3 X to 12.3 X (21.2 to 2.3 degrees horizontal field) (Wittich et al., 2018), the automatic fine-tuning takes place in real time and this HMD offers magnification at near (from 30 cm) as well as intermediate and distance vision. The user's prescription can be integrated into the device. The screens are positioned in immersive view or are inclined to occupy only the upper part of the visual field (VF). Even though users benefit from magnification immediately when wearing the device, to optimally operate it and master its use may take several months. To this end, eSight Corporation has developed eSkills, a program for developing the required visual skills (eSight Corporation, 2015).

Given the small number of assistive devices with the potential to substantially improve the reading of musical notation while playing a musical instrument, and given the hands-free nature of this HMD, we decided to explore the potential benefits of using this technology for individuals with VI that play the piano. Our study had three objectives: 1) To describe

the visual aids, adaptations and compensatory strategies used by pianists with a VI to read music. 2) To describe the problems faced by pianists with a VI when using these visual aids, adaptations and compensatory strategies to read music, and 3) To describe the perceptions of pianists with a VI of their visual access to music read with this HMD.

Material and methods

The study's protocol complied with the Declaration of Helsinki (Williams, 2008) and was approved by the scientific and ethics committee of the member facilities of the *Center de recherche interdisciplinaire en réadaptation du Montréal métropolitain* (CRIR#1111–1115).

Participants

This is a qualitative and exploratory study based on a phenomenological approach, exploring the perceptions of individuals in a heterogeneous group in order to identify and describe a shared phenomenon (Hesse-Biber & Leavy, 2010). A convenience sample of five participants was recruited in a visual impairment rehabilitation center, the *CRIR/Institut Nazareth et Louis-Braille du CISSS de la Montérégie-Center*, Longueuil, Quebec, Canada, by sending a message to program directors as well as an announcement using the distribution lists of various community-based organizations in VI. The inclusion criteria were: 18 to 65 years of age; a VI diagnosis received at least two years prior to the study; an assessment completed in the last two years by an optometrist specialized in low vision; a VI of 6/18 to 6/120 after correction and a VF greater than 30°; the ability to play the piano and to identify the pitch and duration of notes on a score; the ability to use various visual aids, and sufficient knowledge of French to verbally answer interview questions.

Materials and procedure

The participants all signed a consent form prior to taking part in the project. Data on their vision (date of the assessment, pathology, refraction correction, visual acuity at distance and close vision, and visual field) were collected from the optometry assessment report. A questionnaire developed by the lead author asked participants to report socio-demographic data and musical profiles. These profiles included the age at which the participants began playing music, their experience, and their level of knowledge in musical theory (scales, chords, sight reading, etc.), based on a four-point Likert scale (1 = no knowledge of musical theory; 4 = extensive knowledge of musical theory). A two-part semi-structured interview was used to collect data on the participants' perceptions before and after using the HMD. The first segment described the various visual aids, adaptations and compensatory strategies used to read music (Objective 1) as well as the problems identified during their use (Objective 2). After the subjects had tried eSight Eyewear, a second segment dealt with reading music with the help of this aid (Objective 3). The questionnaire and interview were administered by the lead author. The interviews were recorded and verbatim transcripts were prepared for analysis. During the experimental phase, each participant took part in an individual meeting lasting approximately two hours. The meetings were organized in five steps: (1) verbal administration of the questionnaire on the participant's socio-demographic and musical profile (10 minutes); (2) the first part of the semi-structured interview on the means used to read music and the problems encountered (20 minutes); (3) a trial of the HMD: presentation, installation of the HMD based on the correction in the optometrist's report, adjustments to the parameters, and instruction on use with some exercises in the eSkills program (30 minutes); (4) trial use of the HMD to simultaneously read and play scores that each participant already knew (20 minutes), followed by an excerpt selected by the interviewer (20 minutes) (Agay, 1997; Schumann, 1996); and (5) the second part of the semi-structured interview on reading music using the HMD (20 minutes).

The choice between the two sheet music excerpts was made by the lead author according to her assessment of each participant's sight reading abilities. Both excerpts included a variety of musical symbols (nuances, accents, alterations etc.), and each consisted of two pages, arranged side by side and printed in a standard format, eliminating the need for page turns. The notation had to be read at a distance corresponding to a standard position to read the music and could vary between 50 to 70 cm. Room lighting came from fluorescent ceiling bulbs. In some cases, a fluorescent accent lamp (Ott Lite, Tampa, Florida) had to be added to improve visibility with the HMD.

Data analysis

The data were jointly analyzed by two evaluators, one of whom was the lead author. The Creswell (1998) approach was used. As the first transcripts were read, segments of significant texts related to the research objectives were identified and used to develop an initial system of codes. Then all the transcripts were read, and this system of codes was modified and applied to all the data. Ultimately, the codes were obtained in two different ways: those used for Objective 1 were inferred from the data, while those used for Objectives 2 and 3 were inspired by the Quebec User Evaluation of Satisfaction with assistive Technology (QUEST) questionnaire 2.0 (Demers, Weiss-Lambrou, & Ska, 2000), a tool used to assess user satisfaction with a technical aid. To ensure the scientific rigor of the study, the approach complied with the scientific criteria specific to qualitative methods (Poupart, 1997).

Results

Participant characteristics

Five amateur pianists with a VI (three women and two men) took part in this study. Table 1 presents a profile of their socio-demographic and visual characteristics and their level of musical knowledge. Two participants were in their 20s and the other three were in their 60s. They had a variety of visual diagnoses. Four participants had had a visual impairment since birth and the fifth since the age of 20. Their distance visual acuity in the better eye varied from 0.8 to 1.54 logMAR (equal to 6/37.5 and 6/210), and their near visual acuity varied from 0.8 to 1.88 logMAR (equal to 0.5 M at 8 cm and 12 M at

Table 1. Socio-demographic and visual profile of the participants.

P	Age	Sex	Main visual diagnosis	Distance VA logMAR (notation 6/)	Near VA logMAR	Visual Field (degrees)	Level of musical skill
1	62	M	Oculocutaneous albinism	OD 1.00 (6/60) OS 0.80 (6/38)	0.82 (0.6 M at 9 cm)	OD 120 × 80 OS 130 X 75	4
2	65	F	Chorioretinitis: vitiliginous chorioretinopathy "birdshot"	OD 2.26 (6/1080) OS 1.54 (6/210)	1.88 (12 M at 16 cm)	OD 3 × 10 OS 8 -X 5	2
3	24	F	Aniridia	OD 0.70 (6/30) OS 0.80 (6/38)	1.05 (1 M at 9 cm)	OD 120 × 100 OS 100 X 80	3
4	61	F	Oculocutaneous albinism	OD 1.00 (6/60) OS 0.78 (6/37.5)	0.80 (0.5 M at 8 cm)	OD 60 × 40 OS 65 X 60	4
5	20	M	Dominant optic atrophy, Kjer's type	OD 1.20 (6/96) OS 1.30 (6/120)	1.30 (1 M at 5 cm)	O D 125 × 102 OS 132 X 100	3

P = participant; M = male, F = female; VA = visual acuity; VF = visual field; logMAR = logarithm of the minimum angle of resolution; OD = right eye; OS = left eye

16 cm). Their self-reported musical skill varied from *average* to *very high*. One participant (P2) had a VA and a VF that fell short of the selection criteria; however, the research team decided to include this person in the study, given the rarity of visually impaired individuals that were qualified, available and interested to participate in this study. Another participant (P1) had taken part in a parallel study involving eSight Eyewear (Wittich et al., 2018), in a context other than reading music. All five participants had received rehabilitation services for visual impairment in the past and said that they were familiar with various visual aids. Their type of musical training varied, but all participants had taken piano lessons for over five years.

Coding the data

The analysis of the transcripts yielded 33 codes that were grouped into three categories (visual aid; adaptation; compensatory strategy) and nine themes (see Table 2). The same themes were used for Objectives 2 and 3, for different purposes. Direct quotes are provided in *italics* within the text, followed by the participant number (e.g., P2).

What means are used by pianists with a VI to read music?

The data demonstrated that visual access to musical notation is facilitated by magnification, by means other than magnification, or by non-visual means.

Magnification

Magnification is obtained by various means. This may involve reducing the distance between the eyes and the musical notation, either by approaching the score with a visual aid (lectern) or through a compensatory strategy (leaning toward the score or holding it in one hand to bring it closer). Magnification achieved by increasing relative size was possible with an adaptation, by using a photocopier to enlarge the score. Lastly, angular magnification or projection was achieved using various visual aids: microscope glasses, bioptic telescope glasses, a magnifying glass, or various mainstream technologies, such as electronic tablets.

Table 2. Definitions of the themes and categories.

Themes	
Magnification	Visual aid, adaptation or compensatory strategy aimed at improving the musical notation's visibility by increasing its size on the retina (relative magnification by size or distance, or by an optical or electronic aid).
Other	Visual aid, adaptation or compensatory strategy aimed at facilitating visual access to the reading of music, other than by magnification.
Non-visual	Visual aid, adaptation or compensatory strategy aimed at providing access to the reading of music in a non-visual manner.
Effectiveness/Ease of use	Participant's perception of whether this visual aid, adaptation or compensatory strategy: (1) does or does not allow visual access to the reading of music to meet his or her needs, and (2) is easy to use or renders the task more complex by adding difficulties (e.g. looking back and forth between the score and the instrument, losing one's place on the score, etc.).
Visibility of the musical notation	The participant believes that this visual aid, adaptation or compensatory strategy provides sufficient access to the musical notation to identify its components (detail vision, global overview, image quality, etc.).
Musical performance	The participant's perception of the degree to which this aid, adaptation or strategy allows him or her to simultaneously read and interpret the musical notation on the piano, not as a function of the quality of the musical interpretation but rather of the participant's visual ability to execute the task (e.g. keeping both hands on the instrument, not interrupting the performance to follow the musical notation, etc.).
Comfort	The participant's perception of his or her degree of comfort using the aid, adaptation or strategy (comfort in the posture adopted at the piano and absence of pain, ocular fatigue, nausea or unpleasant effects, etc.)
Ease of adjustment	The participant believes that the adjustments to and/or the preparation of the visual aid, adaptation or compensatory strategy require time and a reasonable effort before the musical notation can be read and performed.
Dimension/weight/appearance	Participant's level of the satisfaction with the dimensions, weight or appearance of the visual aid, adaptation or strategy and the perception of its esthetics and social acceptability, i.e. whether the participant will be comfortable using it around other people.
Categories	
Visual aid	Optical, electronic or non-optical system used to facilitate visual access to musical notation. The system may be dedicated to use by persons with a visual impairment (adapted lectern, telescope, magnifying glass) or intended for the general public (tablet or application).
Adaptation	Modifications made to the musical notation to facilitate visual access to it. This applies to either the overall notation (e.g. photocopy enlargements) or to some of its components (e.g. to reveal certain details). Includes non-visual adaptations (e.g. a third party describes the musical notation).
Compensatory strategy	Behavior modifications to facilitate access to the reading of music. The strategy aims to improve the visibility of the notation (e.g. holding the score with one hand to bring it closer to the eyes) or limit the task's visual requirements (e.g. memorizing or anticipating certain components of the musical notation).

Table 3. Visual aids, adaptations and compensatory strategies used.

	Magnification	Visual access other than by magnification	Non-visual access
Visual aids	Lectern with articulated arm Bifocal glasses Bioptic telescope glasses Magnifying glass Electronic tablet	iPad application used to scroll through the musical notation	
Adaptations	Photocopy enlargement	Digitization of the score to increase the contrast Framing, with different colors, items that are difficult to see	Music read by another person
Compensatory strategies	Changing body position to reduce the eye-score distance: • Advancing the head • Holding the score in one hand and playing with the other, then changing hands	Creating personal points of reference (counting measures)	Partial or total memorization Using musical knowledge to anticipate what comes next Playing by ear

Means other than magnification

Some adaptations and strategies (see Table 3) were intended to facilitate visual access to reading music by means other than magnification. These improvements apply either to all of the musical notation (e.g., increasing the score's contrast) or just to certain parts (e.g., highlighting alterations, such as by underlining them, or adding color).

Non-visual means

All the participants used non-visual strategies and adaptations, in different forms and to varying degrees. For example, one participant played only from memory since losing her sight, while others would memorize only those parts of the musical notation that are difficult to identify visually. Other strategies relied on using hearing and the participant's musical knowledge. Various aids, adaptations and strategies were used depending on the context (learning, a concert, at school, at home, etc.) or in different combinations. Some of these combinations were simple (e.g. combining several types of magnification): *"I make photocopies at a 2X enlargement and use a lectern a lot, but I still get very close to the lectern." [P5]*. Other combinations were more complex (e.g. adjusting the work distance according to how well a piece has been memorized). The result was a complex and creative use of various means that provide the pianist with some access to reading music.

What problems do pianists with a VI have when using visual aids, adaptations and compensatory strategies to read music? The use of an aid, adaptation or strategy may result in many problems related to its effectiveness and ease of use, how easily it can be adjusted, its comfort in use, and its weight, dimensions and appearance.

Effectiveness and ease of use

In terms of effectiveness and ease of use, these difficulties (see also Table 4) were related to the visibility of the notation and to musical performance. Concerning visibility, the use of various forms of magnification was required, but this also becomes problematic because it affects global vision. Despite the magnification, there are times when certain details of the notation cannot be identified. So the visibility of details and of the notation in its entirety is compromised. On the other hand, certain visual aids or adaptations allow some visual access to the notation, but they compromise performance. To follow written music when using magnification, occasionally it is necessary to use one's hand. Since only a small part of the notation is visible at any given time, the use of one hand becomes necessary to follow it, change from one measure to the next on the tablet (here defined as an aid), change pages (here considered an adaptation) or hold the booklet (here considered a strategy). Taking one hand off the keyboard necessarily affects one's performance. This problem arises independent of the means used for magnification, given the following examples:

Aid: *"[With the iPad], I can only read one measure at a time: I play the first measure, and then I have to slide the image on the screen to change measures, etc. So the reading is less fluid. I always need to follow with my hand." [P5]*

Adaptation: *"I needed to really enlarge my scores a lot and turn [pages] two or three times more often than the other students, so it ruined the flow. I had trouble following." [P3]*

Strategy: *"I virtually had to learn it by heart by reading my score, holding it in my right hand and playing with my left hand. Then I played with my right hand while holding the score in my left hand." [P4]*

Ease of adjustment

Using these means requires investing time and effort before the music can be performed. This has an impact on motivation, in particular when new pieces are being learned, since there are several stages to adapting a score. When the music cannot be read and performed simultaneously, the notation must be memorized before it can be played.

Comfort, weight, dimensions and appearance

Some participants were uncomfortable because using an aid or a strategy (such as leaning closer) causes poor posture. Participants also spoke of problems associated with the weight, dimensions and appearance of the visual aid or the adaptation. For example, an articulating arm mounted on a stand cannot be carried back and forth between school and home. Large scores are considered too apparent; one participant's discomfort with using them in public caused her to give up on them. The decorum in classical music encourages restraint, so the reading distance may present a problem: *"In concert, you can't be hidden behind your score. Everyone is dressed in black, with a black tie, black shirt, you don't want to stand out too much from the group." [P1]* Ultimately, even though they had numerous means at their disposal, the participants all said that they still had problems reading music: *"I haven't found a solution that is truly comfortable. It would be better if it were still closer, if I didn't have to scroll through it, if I could see the whole page." [P1]*

Table 4. Difficulties encountered when reading music and access to reading music without and with eSight Eyewear.

		Without eSight Eyewear Reported difficulties when reading music			Trial use of e-Sight Eyewear	
		Aids	Adaptations	Strategies	Advantages	Disadvantages
Effectiveness/ ease of use	Visibility	Magnification factor limited by what is offered by the optical aid	Photocopy enlargements are rarely optimal	Approaching the score prevents global vision of it and the instrument	Access to global vision Access to detailed vision Adjustable magnification factor Standard reading distance Image quality	Difficulty finding one's place Image stability compromised by head movements Image quality reduced with higher magnification
		Dissatisfaction when reading music as a result of being unable to achieve the required balance between global vision and detailed vision				
	Musical performance	With a tablet, one hand must be used to move from one measure to the next	Magnification means that the pace is interrupted by more frequent page turning	Obliged to hold the score in one hand in order to see it	Both hands are available for playing Simultaneous reading and performance	Difficulty related to moving eyes between the score and the instrument
		With magnification, performance is affected by the need to use one hand to follow the musical notation				
Ease of adjustment		Multiple stages required before an adapted score can be viewed on a tablet	Photocopy enlargements must be organized beforehand	Disjointed process makes the reading less fluid	Standard scores can be used	–
		Time and effort must be invested before the musical notation can be performed				
Comfort		Microscope glasses impose a short focal distance	Unable to find an adaptation that allows a standard posture	Uncomfortable posture and pain due to the need to get close	Reading distance allows a standard posture	Ocular fatigue Nausea Pressure on the forehead and nose limits length of use
		Musician must modify posture to gain visual access to the score				
Dimension/weight/ appearance		Poor esthetics of the aid used	Shyness over using greatly enlarged scores	Shyness over using a short score reading distance in public	Wearability Esthetically pleasing	Difficult to transport Too conspicuous
		Transportation logistics and fear of being stigmatized due to the dimensions, weight and appearance of the means used				

How do pianists with a VI perceive their visual access to reading music when using an HMD? These perceptions were also classified into three thematic areas: its effectiveness and ease of use, its ease of adjustment, as well as its comfort, weight, dimensions and appearance.

Effectiveness and ease of use

In terms of effectiveness and ease of use, the visual access to reading music afforded by an HMD was described in terms of the visibility of the notation and the player's musical performance. All the participants were able to read the musical notation with an HMD. One of the positive aspects concerned visual access to the details in the notation as well as to the overall notation: *"Being able to see both staves at the same time was wonderful … Not only was I able to see the two staves, I was even able to see part of a third one." [P3]* Being able to adjust the magnification factor allowed participants to set priorities, depending on the context, on their access to details or the overall notation: *"What I liked the most was that you can magnify as much as you like, you can see the entire piece or just small details, it's really impressive to be able to choose. With a photocopy enlargement, you have to move in closer." [P3]* Being able to read from a standard reading distance was also mentioned: *"With eSight, the score is far away, I don't need to get close to it, I only need to zoom in … What's great is to really have the right distance." [P5]*

On the other hand, the loss of global vision created by the aid generated problems finding one's place in the notation. During their trials, all the participants said that they occasionally lost their place in the score. Use of the HMD appeared to be more difficult when compared with the means the participants were currently using: *"If you move too quickly, you lose your place, but when you enlarge a score [using photocopies], you don't lose your place. It's visually easy." [P3]* Small involuntary movements of the head affect the stability of the image: *"I wouldn't want to have Parkinson's when playing with this thing!" [P2]*

There were also some negative comments about image quality, particularly when using a large magnification factor or a color filter: *"When you zoom in, it starts to flash." [P4] "Sometimes it flashes, particularly when using the black and white filter." [P5]*. In terms of music performance, given that the HMD does not require the use of hands, users can read and play the musical notation simultaneously: *"I can keep my hands on the keyboard. I advance by moving my head and I read, I play. I don't need to use my hands off the keyboard, as I do with the iPad." [P5]*. On the other hand, looking back and forth between the score and the instrument appears to be a complex task with an HMD: *"When I'm not sure that I have the right key on the keyboard, I need to look; then it becomes difficult to find my place in the score." [P1]*.

Ease of adjustment

In terms of ease of adjustment, all the participants believed that the HMD required minimal time and effort before they can play a score: *"You can read with the material you have in hand, it's normal, it doesn't need to be adapted." [P5]*

Comfort, weight, dimensions and appearance

Given that this HMD can be used with an intermediate reading distance, it is possible to adopt an appropriate and

comfortable posture when playing the piano. On the other hand, wearing these electronic glasses led to ocular fatigue, even some discomfort, particularly in the first few minutes of the meeting: *"At one point you feel nauseous." [P2]*. Participants had different comments about the HMD's dimensions and wearability: *"Esthetically, the glasses are cool, they're stylish. Honestly, they're quite nice." [P5] "I don't see myself in concert on a major stage. The eSight glasses would stand out too much!" [P1]*

After conclusion of the experiment, all participants expressed interest in having access to an HMD to read musical notation. However, the main barrier that was expressed concerned the financial investment necessary to become a device owner.

Discussion

This study sought to describe the visual aids, adaptations and strategies used by pianists with a VI to read music notation, to identify what problems remain despite such use, and to examined their perceptions of their visual access to reading music when they use a head-mounted electronic magnification device.

Aids, adaptations and strategies

Some of the means used by the study's participants have previously been discussed in the literature: an adapted lectern, microscope glasses and bioptic telescope glasses (Clark & Murphy, 1998; Labbett, 1995), enlarging the score using a photocopier (Clark & Murphy, 1998; Labbett, 1995), as well as memorization and oral learning (Clark & Murphy, 1998; Coates, 2012). On the other hand, this study has revealed that pianists with a VI also use adaptations that foster visual access by means other than magnification, and that they even use a combination of several aids, adaptations and strategies. The data revealed that consumer technologies such as electronic tablets are also used. It is known that, for reading texts, tablets are like dedicated electronic visual aids (Crossland, Silva, & Macedo, 2014; Morrice, Johnson, Marinier, & Wittich, 2017; Wittich, Jarry, Morrice, & Johnson, 2018). A survey of persons with a VI confirms that they are being used in everyday life (Crossland et al., 2014). In music, Housley et al. (2013) identified this potential and developed an application that allows tablets to display adapted musical notation. However, none of the articles have reported on the use of this type of application, or even the use of a tablet when reading music. Our participants, however, reported that such applications and technologies are indeed being used, and that they are useful.

Difficulties reading music

Despite the implementation of an amalgam of compensatory means, significant difficulties remained. The use of magnification is rendered more complex by the visual presentation of notation. Notation consists of components of varying size, and achieving a balance between the visibility of details and the overall notation appears to be a difficult task. It is known that large magnification limits global vision and affects one's ability to anticipate, which is important in music, since experienced readers generally read one measure ahead of what they are playing (Goolsby, 1994; Madell & Hébert, 2008). On the other hand, less magnification compromises one's ability to identify certain details in the notation. Among our participants, magnification also affected musical performance. Accordingly, Coates (2012) and Housley et al. (2013) mention that reading an enlarged score requires frequent interruptions to performance as the musician turns the pages of the score. Bouabid (2013) indicates that bringing the musical notation closer with one or both hands makes memorization necessary. Magnification therefore allows a certain access to the notation, but also causes secondary problems. On this subject, Jacko et al. (2015) indicate that adapting or memorizing the notation produces a delay and requires an intermediate resource between the musician and the notation. In our study, the participants adapted the notation themselves, which they found discouraging. Lastly, our results suggest that there are certain problems related to the adoption of an uncomfortable posture. In addition, obstacles to use of aids, adaptations and strategies are associated with the appearance of the devices used. Tuttle and Tuttle (2004) as well as Wanet-Defalque and Machabée (2009) indicated that the use of certain visual aids draws attention to the fact that the users have a VI, and some prefer not to use such aids for fear of being stigmatized.

Visual access to reading music with a head-mounted magnification device

eSight Eyewear can improve the visibility of musical notation, including by limiting the problems associated with magnification. First, this HMD allowed the participants to adjust the magnification factor. Culham, Chabra, and Rubin (2004) as well as Culham et al. (2009) underscore the importance of this feature in appraisals of an HMD used in various reading tasks and activities of daily living (ADL), since the user can choose to emphasize the visual field or a sufficient reserve acuity. Since musical notation has components of varying sizes that require detail vision as well as global vision (Housley et al., 2013), selection of a precise level of magnification allows the user to find this balance between the VF and the reserve acuity required to read music. Our participants liked the fact that the device's magnification factor could be adjusted in response to how well they knew the score; the literature reviewed does not discuss the functional potential of this particular innovation for pianists with a VI. It therefore appears that the preferred magnification factor for musical notation is influenced by several factors not identified in the literature: being able to adjust it appears fundamental.

Wearing an HMD has the additional advantage of allowing the user to read music at an intermediate reading distance, which is key, since few visual aids can be used to magnify at this distance. For some participants, it was possible to sight-read normally, meaning they could read while playing the instrument, without prior memorization. For others, this was a comfortable reading distance since the electronic glasses allowed them to read a score while adopting an appropriate posture. Furthermore, this HMD can be used to read standard musical notation without having to adapt it beforehand. Adapting scores beforehand is known to involve several steps and is an obstacle to engaging in a musical activity (Jacko et al., 2015; Smaligo, 1998). Flexible viewing distance

is further an advantage to see, for example, a conductor; however, whether the possible stigma of wearing an HMD in a concert situation might inhibit the use of such a device was not specifically addressed by our participants, and this aspect will require further study.

Our results nevertheless demonstrated that the participants still faced significant problems using the device. For example, while wearing the HMD, the notation is read by moving one's neck and head. However, these movements require accuracy, otherwise the device will not show the desired location on the notation. Another problem found during our study was associated with the fact that reading a score occasionally involves looking down at the instrument to determine finger positions (Gilman & Underwood, 2003; Madell & Hébert, 2008). With eSight Eyewear, moving between two different view targets in this way occasionally leads to losing one's place in the score. Similar problems with HMDs have been reported in the literature. Culham et al. (2004) compare the use of various optical aids and HMDs for ADLs, such as filling out a cheque and identifying food products. They found that their participants were systematically less successful at completing these tasks when they used HMDs. They explain that this result stems from the fact that these tasks do not require visual acuity as much as eye-hand coordination, stabilization of the head, and precise scanning with the head and the eyes. Francis (2005) also claims that oculomanual tasks are rendered more complex when using an HMD, since it exacerbates movements in proportion to the magnifying factor used. This means that the user must control movements of the neck and shoulders in order to maintain a stable image (Geruschat et al., 1999; Wolffsohn & Peterson, 2003). Despite some major problems, our participants spoke of two strategies that can be used to avoid losing their place in the score. One consists of looking below the HMD screens to see the keyboard using their habitual lower peripheral vision, taking advantage of the fact that the eSight device does not obstruct this portion of the musician's natural visual field, and thereby avoiding any movement of the head; the other involves making this a non-visual task by using one's ear and musical knowledge.

Limitations & future directions

The size of the sample prevented attainment of data saturation (Drapeau, 2004); therefore the sample did not represent all profiles of pianists with a VI. Since the participants provided comments about the HMD after trying the device just once, we were unable to determine whether their opinions reflect their impressions after longer-term use. On this subject, Harper et al. (1999) suggest that a period of adjustment is necessary to achieve optimal use of an HMD. Several months of use would therefore be necessary before the use of such an HMD could be fully mastered. Our study did not permit the testing of this hypothesis. Since this study was carried out with pianists with a VI, the results are not necessarily generalizable to users of other musical instruments. Lastly, since this study employed a qualitative approach, it was based on the participants' perceptions, and provides no information on their objective performance in reading music. Few studies have addressed access to musical notation among persons with a VI. Since the use of an HMD to read music holds promise, a study involving a longer-term trial and a larger sample would be relevant, as well as a study with users of other types of musical instruments, with their different associated visual and postural requirements. Furthermore, tests could be performed of evaluation tools for the objective measurement of visual capacity while reading music. Lastly, as is the case for reading texts (Foley, 2008), better knowledge of certain factors associated with better music-reading performance would give persons with a VI better access to this type of reading, and would help clinicians provide them with better support.

Conclusion

Considering the scope of the problems encountered by persons with a VI when they read music and the potential of eSight Eyewear, this study suggests that pianists with a VI should consider using an HMD to read and interpret musical notation. The use of this HMD solved some significant problems caused by magnification, since it allows users to adjust the magnification factor and use an intermediate reading distance, and frees up users' hands. Lastly, the problems identified during the use of these electronic glasses suggest that persons who want to use them to read music could benefit from training on their use.

Acknowledgments

The authors would like to thank eSight Corporation for the free loan of one of their 2nd generation devices for the purpose of this study. We would like to thank Rob Hilkes for his efforts and integrity in making this study possible.

Disclosure

Please note that this study was not funded by eSight Corporation. eSight Corporation did not have input on the recruitment, study design, data collection, data analysis, interpretation or manuscript preparation.

Funding

This work was supported by the Institut Nazareth et Louis-Braille du CISSS de la Montérégie-Center; Fondation En Vue.

ORCID

Josée Duquette http://orcid.org/0000-0002-0258-1166
Walter Wittich http://orcid.org/0000-0003-2184-6139

References

Agay, D. (1997). *Berühmte Klaviermusik von Bach to Bartok = Famous piano music from Bach to Bartok*. Frankfurt, Leipzig, London, New York: C.F. Peters.

Bouabid, N. (2013). *La spécificité du déchiffrage pianistique chez les musiciens aveugles et déficients visuels: effets des représentations mentales des notations musicales sur la conduite de mémorisation* (Doctorat en musicologie). Université Paris Sorbonne, Paris Retrieved from https://www.theses.fr/2013PA040012

Braille Authority of North America. (2015). *Music braille code*. Retrieved from http://www.brailleauthority.org/music/Music_Braille_Code_2015.pdf

Clark, A., & Murphy, F. (1998). Teaching music to the visually impaired student in a standard school setting. *British Journal of Visual Impairment*, *16*(3), 117–122. doi:10.1177/026461969801600307

Coates, R. L. (2012). Accommodating band students with visual impairments. *Music Educators Journal*, *99*(1), 60–66. doi:10.1177/0027432112448478

Comeau, G. (2010). L'apprentissage de la lecture musicale. *Revue de recherche en éducation musicale*, *28*(December), 83–104.

Creswell, J. W. (1998). *Qualitative inquiry and research design: Choosing among five traditions*. Thousand Oaks, CA: Sage Publications.

Crossland, M. D., Silva, R. S., & Macedo, A. F. (2014). Smartphone, tablet computer and e-reader use by people with vision impairment. *Ophthalmic & Physiological Optics : the Journal of the British College of Ophthalmic Opticians (optometrists)*, *34*(5), 552–557. doi:10.1111/opo.12136

Culham, L. E., Chabra, A., & Rubin, G. S. (2004). Clinical performance of electronic, head-mounted, low-vision devices. *Ophthalmic and Physiological Optics*, *24*(4), 281–290. doi:10.1111/j.1475-1313.2004.00193.x

Culham, L. E., Chabra, A., & Rubin, G. S. (2009). Users' subjective evaluation of electronic vision enhancement systems. *Ophthalmic and Physiological Optics*, *29*(2), 138–149. doi:10.1111/j.1475-1313.2008.00630.x

Dancing Dots. (2019). The lime lighter: Music-reading solution for people with low vision. Retrieved from https://www.dancingdots.com/limelighter/limelightermain.htm

Demers, L., Weiss-Lambrou, R., & Ska, B. (2000). The Quebec user evaluation of satisfaction with assistive technology. *Technology and Disability*, *14*(3), 101–105. doi:10.3233/TAD-2002-14304

Dormehl, L. (2017). Eye-tracking glasses reveal what master pianists look at while they play [Blog entry]. Retrieved from https://www.digitaltrends.com/cool-tech/eye-tracking-video-piano-player/#ixzz4dxTvQpTw

Drapeau, M. (2004). Les critères de scientificité en recherche qualitative. *Pratiques psychologiques*, *10*(1), 79–86. doi:10.1016/j.prps.2004.01.004

Ehrlich, J. R., Ojeda, L. V., Wicker, D., Day, S., Howson, A., Lakshminarayanan, V., & Moroi, S. E. (2017). Head-mounted display technology for low-vision rehabilitation and vision enhancement. *American Journal of Ophthalmology*, *176*, 26–32. doi:10.1016/j.ajo.2016.12.021

eSight Corporation. (2015). *eSkills User Guide & Proficiency Program*. Ottawa, Canada: eSight Corporation.

eStand Inc. (2019). How does eStand help the visually impaired? Ontario, Canada: Author. Retrieved from https://www.estand.com/info2/index.php?name=companyfaq#visuallyimpaired

Foley, J. M. (2008). Psychophysics of reading in normal and low vision. *Optometry and Vision Science*, *85*(10), 897. doi:10.1097/OPX.0b013e31818901ef

forScore. (2019). About forScore. Retrieved from https://forscore.co/about-design/

Francis, B. (2005). The Jordy electronic magnification device: opinions, observations, and commentary. *Journal of Visual Impairment and Blindness*, *99*(9), 553–564. doi:10.1177/0145482X0509900907

Furneaux, S., & Land, M. F. (1999). The effects of skill on the eye–hand span during musical sight–reading. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *266*(1436), 2435–2440. doi:10.1098/rspb.1999.0943

Geruschat, D. R., Deremeik, J. T., & Whited, S. S. (1999). Head-mounted displays: are they practical for school-age children?. *Journal of Visual Impairment and Blindness*, *93*(8), 485–497. doi:10.1177/0145482X9909300802

Gilman, E., & Underwood, G. (2003). Restricting the field of view to investigate the perceptual spans of pianists. *Visual Cognition*, *10*(2), 201–232. doi:10.1080/713756679

Goolsby, T. W. (1994). Eye movement in music reading: Effects of reading ability, notational complexity, and encounters. *Music Perception: An Interdisciplinary Journal*, *12*(1), 77–96. doi:10.2307/40285756

Gudmundsdottir, H. R. (2010). Advances in music-reading research. 331 *Music Education Research*, *12*(4), 331–338. doi:10.1080/14613808.2010.504809

Harper, R., Culham, L., & Dickinson, C. (1999). Head mounted video magnification devices for low vision rehabilitation: a comparison with existing technology. *British Journal of Ophthalmology*, *83*(4), 495–500. doi:10.1136/bjo.83.4.495

Hersh, M., & Johnson, M. A. (2010). *Assistive technology for visually impaired and blind people*. London, England: Springer Science & Business Media.

Hesse-Biber, S. N., & Leavy, P. (2010). *The practice of qualitative research*. Thousand Oaks, CA: Sage Publications.

Housley, L., Lynch, T., Ramnath, R., Rogers, P. F., & Ramanathan, J. (2013). *Implementation considerations in enabling visually impaired musicians to read sheet music using a tablet*. Paper presented at the Computer Software and Applications Conference (COMPSAC), 2013 IEEE 37th Annual, Kyoto, Japan.

Jacko, V. A., Choi, J. H., Carballo, A., Charlson, B., & Moore, J. E. (2015). A new synthesis of sound and tactile music code instruction in a pilot online braille music curriculum. *Journal of Visual Impairment and Blindness*, *109*(2), 153–157. doi:10.1177/0145482X1510900212

Labbett, S. (1995). Information on music for people with partial sight. *British Journal of Visual Impairment*, *13*(3), 131. doi:10.1177/026461969501300309

Leoné MusicReader. (2019). MusicReader. Retrieved from https://www.musicreader.net/software.html

Madell, J., & Hébert, S. (2008). Eye movements and music reading: Where do we look next? *Music Perception: An Interdisciplinary Journal*, *26*(2), 157–170. doi:10.1525/mp.2008.26.2.157

Massof, R. W., & Rickman, D. L. (1992). Obstacles encountered in the development of the low vision enhancement system. *Optometry & Vision Science*, *69*(1), 32–41. doi:10.1097/00006324-199201000-00005

Morrice, E., Johnson, A., Marinier, J.-A., & Wittich, W. (2017). Assessment of the Apple iPad as a low-vision reading aid. *Eye*, *31*(6), 865. doi:10.1038/eye.2016.309

Peterson, R. C., Wolffsohn, J. S., Rubinstein, M., & Lowe, J. (2003). Benefits of electronic vision enhancement systems (EVES) for the visually impaired. *American Journal of Ophthalmology*, *136*(6), 1129–1135. doi:10.1016/s0002-9394(03)00567-1

Poupart, J. (1997). *La recherche qualitative: enjeux épistémologiques et méthodologiques*. Quebec, Canada: Gaétan Morin.

Read, G. (1979). *Music notation: a manual of modern practice* (2nd ed.). New York, NY: Taplinger Pub. Co.

Schumann, R. (1996). *Album for the young: Opus 68 for the piano*. San Diego, CA: Kjos.

Smaligo, M. A. (1998). Resources for helping blind music students: A variety of resources is available to help educators teach blind students how to read music and become part of the music classroom. *Music Educators Journal*, *85*(2), 23–45. doi:10.2307/3399168

Tuttle, D. W., & Tuttle, N. R. (2004). *Self-esteem and adjusting with blindness: The process of responding to life's demands*. Springfield, IL: Charles C Thomas Publisher.

Udtaisuk, D. B. (2005). *A theoritical model of piano sight playing components* (PhD). Columbia, MO: University of Missouri, Columbia, Missouri, USA.

Wanet-Defalque, M.-C., & Machabée, L. (2009). *Les déterminants de la non-utilisation des aides techniques: revue de la littérature* (pp. 16). Retrieved from http://www.inlb.qc.ca/wp-content/uploads/2015/01/DeterminantsNon-utilisationAidesTechniques-final.pdf

Whittaker, S. G., Scheiman, M., & Et Sokol-McKay, D. A. (2016). *Low vision rehabilitation: A practical guide for occupational therapists* (2nd ed. ed.). Thorofare, NJ: Slack.

Williams, J. R. (2008). The declaration of Helsinki and public health. *Bulletin of the World Health Organization*, *86*, 650–652. doi:10.2471/blt.08.050955

Wittich, W., Jarry, J., Morrice, E., & Johnson, A. (2018). Effectiveness of the Apple iPad as a Spot-reading Magnifier. *Optometry and Vision Science*, *95*(9), 704. doi:10.1097/OPX.0000000000001269

Wittich, W., Lorenzini, M.-C., Markowitz, S. N., Tolentino, M., Gartner, S. A., Goldstein, J. E., & Dagnelie, G. (2018). The effect of a head-mounted low vision device on visual function. *Optometry and Vision Science*, *95*(9), 774. doi:10.1097/OPX.0000000000001262

Wolffsohn, J. S., & Peterson, R. C. (2003). A review of current knowledge on electronic vision enhancement systems for the visually impaired. *Ophthalmic and Physiological Optics*, *23*(1), 35–42.