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CHAPTER 32

Sight-reading

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Introduction

Anyone who wants to perform the works of traditional Western music, and approach other musical styles using a similar performance practice, will most likely have to master music notation. Many musical cultures rely on a system of symbols to store and teach complex musical styles that are not, or only partly, grounded in improvisation. While the beginning music reader has to overcome the same problems as all readers do when learning to read other texts, namely going from a tedious matching of symbols to sounds to meaning, the expert reader has automatized the process of encoding and transforming the signs into embodied action.

For our purposes, we will call sight-reading the execution—vocal or instrumental—of longer stretches of non- or under-rehearsed music at an acceptable pace and with adequate expression. Some people also label this 'playing by sight' or 'prima vista'. Another related set of activities might be called music or note reading: for example, the following of a score with the aim of studying a piece while the music is playing, or the studying of a new piece of music away from the instrument prior to physically practising it. Both activities may even be accompanied by the sounding out of some notes on an instrument. However, the characteristic goal of sight-reading is the authentic performance, or as Mozart once phrased it, 'to play the piece . . . so as to make believe that it had been composed by the one who plays it' (letter from 1778 cited in Crofton and Fraser 1985, p. 111). Similar to improvisation, sight-reading requires the instant adaptation to new constraints, which places it among those that motor scientists refer to as open skills (as opposed to closed skills that require reproduction of well-rehearsed motions, such as swimming, figure skating or playing a well-rehearsed piece of music). Today, studio musicians and accompanists must be able to sight-read, and many orchestra musicians have done it on a regular basis for centuries. It is this kind of un- or under-rehearsed performance that we are concerned with because it forms a well-defined and discrete skill comparable to that of playing by ear or improvising.

When and under what conditions does sight-reading emerge as a skill in a culture? Music archaeology tells us about some forms of notation from ancient Egypt and Greece and other cultures which have developed coding systems for music that mainly serve mnemonic purposes (e.g. Bent *et al.* 2008). The Western model of notation started to develop in the ninth century in order to code multivoice vocal and later instrumental music. In a musical culture (regardless of geographical place and historical time) in which music is solely improvised, sight-reading is not necessary, yet music reading skills may still be used for learning to play an instrument (e.g. in India). When composers and performers assume specialized roles and performers are expected to perform a fixed repertoire, then sight-reading may be required to limit rehearsal times or if the repertoire changes frequently (e.g. in the Baroque era). While the nineteenth century still saw renowned performers play other composers' pieces from the score, canonization of the repertoire, the developing art of interpretation, and rising audience expectations has since then led to a performance practice based on memorized performance by solo performers of the piano and violin. Our modern performance traditions have come to favour polished performances and relegated sight-reading to a useful craft, generally not worthy of public notice or competition (we know only of the Karl Bergemann sight-reading competition, Hanover, Germany).

Obviously, most orchestral, chamber, and studio musicians play from the score and so do many performers of contemporary art music. There are a few known solo pianists who have used scores even for standard repertoire. It is unclear whether musicians perform better with or without the score, but the audience is likely to expect memorized performances. Also, using the score requires page-turning or the presence of a music stand which may be disturbing for the audience and the performer and might detract from the sounding music. A music stand may obstruct the view and hinder gestural freedom and the positive influence of expression that is conveyed through the body (cf. Lehmann *et al.* 2007, pp. 173–174).

In marked contrast to the public neglect and low prestige of sight-reading among performers stands the steady interest of music psychologists and pedagogues in this skill (for reviews see Sloboda 1984; Lehmann and McArthur 2002; Lehmann *et al.* 2007, Chapter 6). Starting with the early music psychology experiments of the 1920s (published in Jacobsen 1941) and the development of sight-reading tests (Watkins 1942, and the Watkins–Farnum Performance Scale), all aspects of skills relating to sight-reading attracted renewed interest in the 1970s (e.g. Sloboda 1974, 1976, 1977) and have continued to do so (cf. Lehmann and Ericsson 1993, 1996; Kopiez and Lee 2006, 2008 for the acquisition of sight-reading skills) up until recent psychophysiological studies (e.g. Schon and Besson 2005; Yumoto *et al.* 2005). It is important for research that we measure individuals' ability to perform at first sight under standardized conditions. Optimally, those conditions should mirror real-life conditions encountered by expert sight-readers (Lehmann and Ericsson 1993).

In this chapter we will briefly look at how notation is perceived and then move on to the structure of sight-reading while taking into account the real-time conditions under which it takes place. This will include a discussion of perceptual and problem-solving issues. Finally we will outline the course of skill acquisition with its characteristic differences between novices and experts, and present a model of sight-reading performance.

Perception of music notation and sight-reading

To begin, we have to understand how the eye operates when we try to acquire information in everyday life. Contrary to what most people believe, the eye does not function like a movie camera. Rather, its operation can be likened to that of a flashlight in the dark being turned on and off at short intervals. Roughly four to five times a second the eye moves around the visual field in discrete jumps (saccades) with short resting points (fixations). The saccades take about 15–50 msecs, the fixations about 150–200 msecs. At this point it becomes clear that a conscious attending to every eighth note in a piece at MM = 120 would be almost impossible. During each fixation, the external image is projected on the retina at the back of the eye. Wile the retina is comparably large, we are able to receive a sharp image only from a narrow part in the middle. This round central part is called the fovea centralis, and whatever surrounds it will produce the somewhat blurry parafoveal image. Hence, the field of vision that will be perceived in great clarity only averages 0.5–2°, which corresponds to the size of an inch at a reading distance of about 30 inches (75 cm), or the area covered by a pointed-up thumb with extended arm. The parafoveal vision includes 10° of the field of vision (e.g. Rayner and Pollatsek 1989). The role of preview benefits and parafoveal-on-foveal effects are currently a hot topic in word-reading research. It is from such individual snapshots that our brain fashions what we experience as a large and steady picture of the outside world. Unfortunately, the eye movements cannot be allocated wilfully but are in fact guided by preconscious processes and drawn by outside stimuli. For example, movements and boundaries in the visual field attract attention, just as do human faces, but our cognition also guides the eye movements. For example, when a car disappears behind another we are likely to scan the plausible location of its reappearance, and we search the face of a person for cues to his or her mood. Today, we know that information gathered from one or several fixations is integrated in meaningful units or chunks of information which are the basis for further processing. Since the location and duration of fixations is indicative of the processing underlying music reading, eye movements offer important insights into the workings of the musical mind. To explain the structure of sight-reading, we have to account for how much and which information is retrieved from the page and how it is assembled into meaningful units that are sequentially programmed and executed.

The problem in surveying the results of eye movement in sight-reading is that the research methodologies are not standardized with regard to complexity of stimulus, tempo of performance, and so forth. Unlike in text-reading research where many studies appear within a few years using the same paradigm, the time lag between publications on sight-reading is large and findings are often difficult to integrate. By and large, the earliest studies (Jacobsen 1941) established what subsequent studies have confirmed, namely that eye movement patterns are dependent on the level of expertise: beginners had many fixations, long pauses during fixations, and unsystematic reading of note combinations; intermediate musicians had about as many fixations as there were notes, and they read chords in systematic fashion from bottom to top; experts showed fewer fixations than notes and also systematic reading of chords (from top to bottom). Saccades can point forward in reading direction but also backwards (regressively)—for example to the current point of performance. This is most likely done to double-check things that have been read already or result from attention being detracted to performance errors (not a very efficient strategy). With increasing experience, the sight-reader experiences a reduction in the number of regressive fixations. Kinsler and Carpenter (1995), who strangely claimed that 'a thorough search of the literature failed to find any account whatsoever of the eye movements used to read music' (p. 12), studied eye movements during performance of notated rhythms. Their results showed that slower tempi lead to more and shorter fixations. One problem in research with self-selected performance tempo is that slower tempi necessarily result in more fixations. Lannert and Ullman (1945) found a 0.45 correlation between tempo and accuracy, and we can never be sure if participants have traded off faster tempi for more fixations and thus ensure a more accurate performance. Equal speeds can only be achieved by using a pacing-voice methodology (Lehmann and Ericsson 1993).

That notational input has an influence on the eye movements was mentioned previously (cf. systematic vertical reading of chords). Notational variants (e. g., eighth notes with or without connecting bars) resulted in person-specific eye movements, and eighth notes (with connecting bars) tended to be looked at in pairs while quarter notes were attended to individually (Kinsler and Carpenter 1995). Truitt *et al.* (1997, also Goolsby 1994) questioned why fixations often landed between notes, and we suggest that readers tend to construct intervals rather than reading every note. Weaver (1943) found that polyphonically structured music was read in horizontal zigzagging patterns that tended to follow melodic lines in the different voices, whereas homophonic music resulted in zigzagging up and down motions. However, a critical look at his stimuli unveils that notation and structure were hopelessly confounded, e.g. no attemept was made to notate polyphonic stimuli in alternative (more homophonic looking) ways. none of the stimuli was polyphonic, yet it notated as if homophonically structured. Regardless of the shortcomings, we can say that experience and structure of input modify viewing patterns.

Once the information has been retrieved during one or several fixations, it is stored and assembled in meaningful units in anticipation of the motor performance. Here also it was found that experience allowed for larger temporal range of planning (Drake and Palmer 2000). The extent and nature of the buffering of information is part of the memory system to be discussed in the next section.

Memory processes

The amount of information stored temporarily from a particular sequence of fixations or during a certain timespan can be assessed by experiments that allow sight-readers only limited visual access to the score by either very brief (tachistoscopic) display, by limiting the period of time during which the score is visible, or by using a computer that follows the fixations with a 'moving window' technique that permits variable preview. By this we can measure aspects of memory, namely the perceptual and the eye–hand span. The perceptual span denotes the distance between the current point of performance and the farthest distance the person is looking ahead. Using a moving window technique, Truitt *et al.* (1997) found that a preview of two beats leads to a slower tempo, larger variability in note durations, and errors. Subjects performed better with previews between two and four beats or, ideally, with previews to the end of the next bar. Furneaux and Land (1999) found the number of notes to be about four for experts and two for novices. Unlike Truitt *et al.* (1997) who found the time between fixation and performance to stand at 0.5 secs, Furneaux and Land (1999) documented between 0.7–1.3 seconds, dependent on the tempo. Similar results have been found in studies on typewriting (Gentner 1988). This narrow preview is at odds with the phenomenological experience of sight-readers who claim a much larger preview. With multiple fixations that can go anywhere in the piece, musicians construct motor programmes that rely on more than mere visual input of the foveal area (see below for further details). This leads to the larger eye–hand spans that can be measured when withdrawing the notation unexpectedly (Sloboda 1977). Sloboda found that meaningful musico-structural units influenced the length of the eye–hand span. For example, a larger distance from the next phrase boundary tended to stretch the eye–hand span; a shorter caused it to shrink. Hiding a longer piece of music at arbitrary points might still allow for cumulative effects of the previously sight-read material, whereas the method of briefly displaying disjointed snippets of information for several hundred milliseconds does not. We know that the reading context influences patterns of fixation (Bekkering and Neggers 2002). If we consider that repeated trials lead to better sight-reading accuracy and that better sight-readers have a better recall for material after a single trial (Lehmann and Ericsson 1993), we have to consider the effects of long-term working memory typically found among experts (Ericsson and Kintsch 1995). This privileged access to long-term memory allows expert readers to store briefly presented material in long-term memory without extensive rehearsal.

Inner hearing

Some authors have claimed that inner hearing and audiation processes may be important in sight-reading, and independent tests of audiation, imagery, and pattern matching are positively associated with sight-reading ability (e.g. Kornicke 1995; Waters *et al.* 1998; Kopiez and Lee 2006). These processes would suggest that the mental representation of music notation involves the building of melodic and other expectancies by the performer. Recent electrophysiological studies have confirmed this point. In studies in which listeners followed a visually presented score that was accompanied by the corresponding sounds, discrepancies between the printed score and auditory events resulted in a recorded mismatch negativity about 150 msec after the dissociation in the vicinity of Heschl's gyrus, where auditory pitch detection is located (Schon and Besson 2005; Yumoto *et al.* 2005). This means that performers are likely able to know if their sounds match the score or not. Whether or not auditory images are used for planning of movements may depend on the musician. For example, Banton (1995) found that sight-reading without auditory feedback led to only slightly more mistakes than normal feedback; however, omitting visual access to the keys resulted in markedly poorer performance. A classic experiment by Allport *et al.* (1972) revealed that pianists could repeat words that were presented while sight-reading at the piano, which suggests that auditory feedback is not necessary. However, it may be used to create expectations.

Sight-reading as problem-solving

We already mentioned that not all notes can be focused on and that problem-solving processes will have to complement the incomplete visual input. In fact, everyday experiences teach us that some pieces are able to be sight-read more easily than others, which suggests that those processes may be more or less easily accomplished. Ortmann in 1934 (cited in Clifton 1986) showed with brief presentation times of stimuli, 400 msec and 2 sec, respectively, that diatonically organized music, smaller intervals, and sequences that were congruent with tonal expectations were more easily read than others. This suggests—and this conclusion is backed by much research in other domains—that we tend to form meaningful units that are influenced by our previous knowledge, and hence, expectations. Kinsler and Carpenter (1995) found that repeated renditions of the same piece were accompanied by a reduced amount of ocular movements. Presumably, larger chunks were formed, more previous knowledge was brought to the task, and the visual input functioned as a retrieval cue to a known motor programme (just like playing well-rehearsed music from notation).

What happens when our expectations are not met by the printed score? In a clever study (Sloboda 1976), pianists performed a classically sounding piece of music in which several notes had been altered by a half or whole step to violate tonal expectations. These violations were either introduced in the beginning, middle or the end of a phrase, and they were evenly distributed across the left- and right-hand part. Participants were asked to play exactly what was written. As the researcher expected, many of the artificial alterations were erroneously corrected to sound tonal again, middle positions being more likely corrected, and a repeated trial led to even more such corrections. These alterations may be termed proof-reader's errors. Sloboda (1974) asked music experts to judge mistakes made by sight-readers with regard to their musical adequacy. In keeping with our expectations, the errors were plausible alternatives to or reductions of the written music. Expectations are powerful: one can ask pianists to fill in blanks in an unfamiliar piece while sight-reading it, and they will generate successful inferences (i.e. improvise) based solely on the context of the piece, their stored knowledge, and current expectations (Lehmann and Ericsson 1996). Fine *et al.* (2006) showed that singers also made more mistakes when sight-reading tonally modified Bach chorals compared to unmodified ones and that they were also hindered by modified notes in other voices' parts.

Sight-reading is more than pressing the right notes at the right time; it also involves adding musical expression. Although no specific studies have been done so far, we suggest that expression is added algorithmically according to a likely grammar of musical expression (e.g. Friberg *et al.* 2006). Most interestingly, merely counting up the number of correct notes in a sight-reading task correlates highly with expert ratings of the same performance (Lehmann and Ericsson 1993), suggesting that better sight-readers integrate musical expression and correct notes on the fly. This may be due to a larger temporal range of planning. Only when the performer knows what is ahead can meaningful musical expression be added (e.g. slowing at the end of a phrase).

In essence, problem-solving or reconstructive processes during sight-reading are considerable if we consider how few fixations are available and how much material needs to be covered. Obviously, those processes function more effectively in better sight-readers. While plausible expectations are constantly being constructed and will usually facilitate performance, in rare instances they may lead the sight-reader astray and cause errors that unveil the underlying mediating processes.

Acquiring the skill

Sight-reading is such a specialized skill that it is futile to look for specific inborn traits that may cause individual differences in sight-reading skill. Among musicians observable individual differences in sight-reading ability are great and need to be explicated. Several variables have attracted the interest of researchers: all sorts of training variables, intelligence, other musical skills, musical ability, general indicators of memory, and reading performance.

The most promising predictors so far have been training variables. Kornicke (1995) and Banton (1995) found that higher self-rated experience as an accompanist or more regular sight-reading practice was related to more accurate sight-reading in the authors' studies. In Kornicke's study, a cumulative index of experience from several scales correlated reliably ($r = 0.4$) with sight-reading achievement. In a regression analysis the best predictor was the estimated number of pieces sight-read. Lehmann and Ericsson

(1996) assessed first, the size of repertoire that pianists possessed to accompany soloists and ensembles and second, accumulated duration of accompanying experience. Both indicators accounted independently for individual differences in sight-reading: a larger accompanying repertoire and more accompanying experience led to better sight-reading performance under standardized conditions. One could conclude from this that experience with the representative situation (real-time demands, short or no preparation time, etc.) as well as the knowledge base acquired through the performance of many pieces facilitates future performance. In general, among the participants of the study the experience as accompanist started a few years after the onset of piano training. They reported playing progressively more difficult accompanying piano parts, commensurate with their parallel increase in pianistic skills. Counter to many musicians' intuitions, this explains nicely why positive correlations are found between general instrumental skills and sight-reading at pre-professional levels (McPherson 1995, 2005).

A similar study on the acquisition of sight-reading skills included different levels of musical complexity (Kopiez and Lee 2006, 2008). In their experiment, subjects sight-read pieces of five levels of difficulty. Sight-reading performance was assessed along with indicators of psychomotor speed (tapping speed, trill speed), elementary cognitive skills (reaction time, speed of information processing [number connection test]), general cognitive skills (tests of short-term and working memory and general mental capacity), and expertise-related indicators (inner hearing, practice times for piano alone and accompanying, starting ages). The best single predictors for the overall score across all five levels of difficulty were trill speed between the third and fourth fingers, sight-reading experience up to age 15, scores on the number connection test, and inner hearing (Kopiez and Lee 2008). While those results emphasize the impact of experience and efficient perceptual encoding, they also suggest that pianistic abilities play a role. The authors also analysed their results separately for the individual levels of complexity (Kopiez and Lee 2006, see Figure 32.1) and showed convincingly that performance at different levels of difficulty was mediated by different combinations of predictors. Hence, those factors that contribute to better performance at lower levels of difficulty may not be the same as those which mediate superior performance at higher levels.

Many educational studies and reviews have offered suggestions on how to improve sight-reading (e.g. Lehmann and McArthur 2002, pp. 147–148; McPherson 2005) and insightful teachers have developed graded material to train sight-reading systematically. However, some advice might be more useful than other: for example, training eye movements by rolling your eyes or similar exercises are certainly futile—you would simply get better at rolling your eyes. Rather, young performers should get accustomed to playing their instrument without constantly looking at it (e.g. piano) to free up their vision to look at the score while still finding their way on the instrument. Performing under real-time conditions also precludes stuttering, i.e. stopping at every mistake and correcting it, but rather 'faking' one's way through the score, i.e. trying to infer plausible content. This can only be done if the student has ample experience with a certain style of music and can build up suitable expectations about how the music might continue. It is here also that knowledge of music theory can be applied. One has to acknowledge that a stable and deliberate interpretation may not be possible at first sight but that attending to dynamic and articulatory signs along with applying simple rules of expression (e.g. creating phrase arches of tempo and loudness) will generate a musically sounding first impression.

Summary

Sight-reading provides a complex problem-solving situation with an intricate interplay of bottom-up mechanisms (driven by the input stimulus of the score and auditory feedback) and top-down processes (driven by expectations and cognitions). It is conceivable that limitations on the general playing of an instrument or a lack of technical proficiency exist that may consequentially impact the ability to sight-read: One can never sight-read beyond the level of rehearsed performance, but how close to it one sight-reads seems to be very much a matter of training. Sight-reading ability at lower skill levels may partly emerge from general instrumental skill

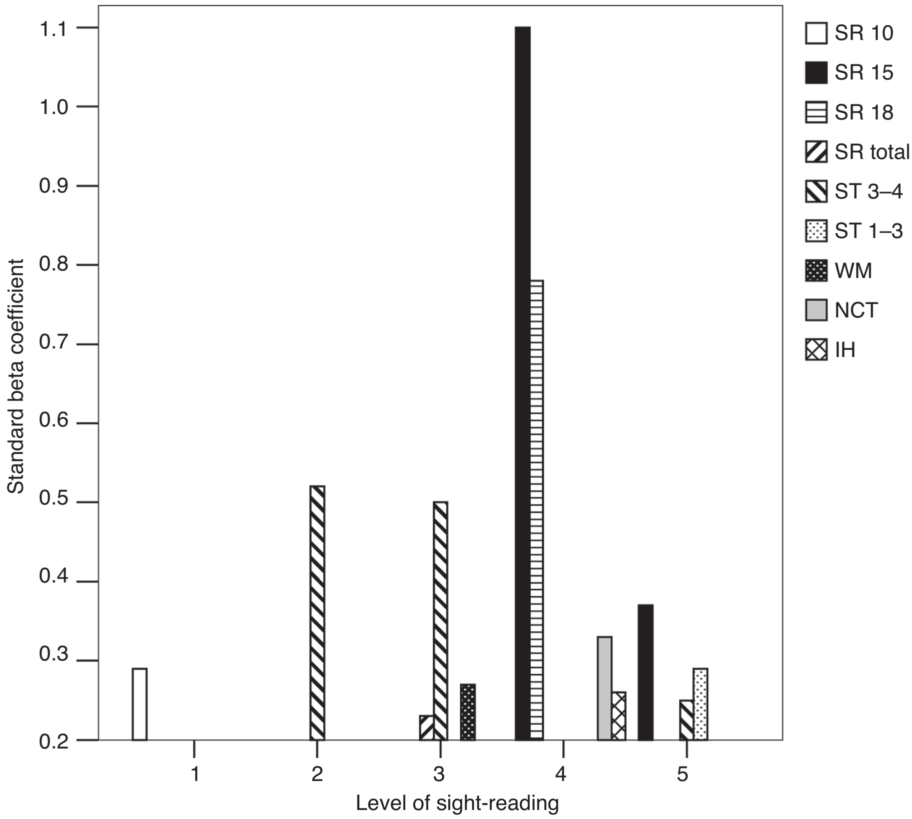

Fig. 32.1 Significant predictors of sight-reading performance, separate for five levels of stimulus difficulty 1=easy, 5=difficult (data from Kopiez and Lee 2006). Predictors: SR, sight-reading experience up to age 10, 15, 18 or total up to the time of the experiment; ST, speed trilling between fingers 1–3 or 3–4 of right hand; WM, working memory in a number task; NCT, speeded number connection test; IH, inner hearing using an embedded melody paradigm.

increase whereas expert sight-reading necessitates extensive deliberate efforts to improve performance. By engaging in many hours of related experience, for example as an accompanist (in the case of pianists), sight-readers develop particular cognitive adaptations, such as efficient encoding, building of expectations and plausible inferencing, and memory skills. These help them cope with the real-time demands of reconstructing on the fly the score along with a preliminary expressive interpretation.

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