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Successful approaches to mental practice: A case study of four pianists

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ABSTRACT: Musicians often use mental practice for enhancing performance, but individuals may have different preferences and skills in their characteristic, individually successful ways of carrying out such practice. In this study, we focus on the approaches to mental practice of four pianists who, according to the ratings of a panel of expert judges, showed outstanding improvement in their performances following their mental practice of a new piece in at least one of the two conditions: silent reading of the score or reading the score while simultaneously listening to the music. The four pianists' approaches to mental practice were studied through self-reports in post-task interviews that were compared with eye-tracking data gathered during the actual mental practice. In successful mental practice, the pianists relied on their experience and the skills they had practised in audiation, use of recordings, imaginary rehearsal, and structural analysis. The results encourage musicians to explore their characteristic approaches to mental practice, and to deliberately practise and develop versatile mental practice skills in order to apply them flexibly in different musical situations. Eye tracking was found to be a useful tool for validating and supplementing musicians' subjective self-descriptions and for revealing covert mental processes in the context of music reading.

KEY WORDS: aural models, eye tracking, individual differences, mental practice, musical imagery, silent music reading

Learning new pieces from musical scores is a common and often tedious chore for musicians, and it demands a lot of instrumental practice. Mental practice, away from the instrument, can complement regular practice activities. It provides musicians with an opportunity to strengthen their mental representations of the music and its performance, during breaks from physical practice and in situations when an instrument is not at hand. Mental practice, sometimes referred to as mental simulation (van Meer & Theunissen, 2009) or imagery (see Clark, Williamon, & Aksentijevic, 2012; Nordin, Cumming, Vincent, & McGrory, 2006), was defined by Richardson (1967) as “the symbolic rehearsal of a physical activity in the absence of any gross muscular movements” (in Driskell, Copper, & Moran, 1994, p. 481). In some studies of musicians and music making, the term has been understood more broadly, encompassing simulated playing movements (Bernardi, Schories, Jabusch, Colombo, & Altenmüller, 2013; McHugh-Grifa, 2011; Ross, 1985). In a recent survey study by Fine, Wise, Goldemberg, and Bravo (2015), musicians understood mental practice as exclusively related to performance preparation involving, for example, aural, visual, or movement imagery of musical performance (see also Holmes, 2005). Mental practice may be used for developing musical understanding, as well as technical prowess, interpretation and memorisation (Connolly & Williamon, 2004; Fine et al. 2015; Holmes, 2005).

Mental practice can be seen as a form of deliberate practice (Nordin et al., 2006) – a purposeful and effortful structured activity for improving performance (Ericsson, Krampe, & Tesch-Römer, 1993). Mental practice has been found beneficial for both cognitive and physical tasks, but may be especially effective in tasks that include cognitive elements (Driskell et al., 1994; van Meer & Theunissen, 2009). Thus, performing music can be seen as an ideal target for applying mental practice. Existing research in the field of music suggests that mental practice is effective in itself (e.g. Bernardi, De Buglio, Trimarchi, Chielli, & Bricolo, 2013; Bernardi et al., 2013a; Coffman 1990; Ross, 1985; Theiler & Lippman, 1995), but cannot compete in effectiveness with physical practice (Bernardi et al., 2013a; Bernardi et al., 2013b; Coffman, 1990; Highben & Palmer, 2004; Lim & Lippman, 1991), especially in more difficult musical tasks (Cahn, 2008; but see Miksza, Watson, and Calhoun, 2018). However, some *combination* of physical and mental practice may be at least equally effective as the same amount of physical practice (Bernardi et al., 2013a; Coffman, 1990; Lim & Lippman, 1991; Ross, 1985; Rubin-Rabson, 1941; Theiler & Lippman, 1995). This implies that it is possible to reduce physical strain, without hampering learning, by combining mental with physical practice.

Mental practice in music can also be conducted with supportive aural models, that is, while listening to a recording. The findings concerning the efficacy of these two methods are contradictory. Some studies have suggested that mental practice while listening to a recording can improve performance (Fortney, 1992; Theiler & Lippman, 1995), and it might even be superior, for the purposes of memorizing music, to “silent” mental practice (Lim & Lippman, 1991; Theiler & Lippman, 1995). In some studies, however, the superiority of using aural models over silent mental practice was not detected (Bernardi et al., 2013a; Coffman, 1990; Loimusalo & Huovinen, 2016). Not surprisingly, musicians might show individual preferences for one or other of these methods depending, for instance, on their music reading skills or their ability to ‘hear’ music in a score (Loimusalo & Huovinen, 2016, see also Bernardi et al. 2013a).

In their meta-review, van Meer and Theunissen (2009) suggest that individual differences potentially play a role in the effectiveness of mental practice. In music, such differences might be related to musicians' relative tendencies to rely either on their imagery skills or on score analysis (see Fine et al., 2015). For instance, more advanced aural skills have been associated with better performances from memory after mental practice (Bernardi et al., 2013a; Highben & Palmer, 2004), especially with tonal music (Loimusalo & Huovinen, 2018). Furthermore, superior memory for music following mental practice may be supported by habits in memorising music such as regular reliance on formal analysis (Bernardi et al., 2013a; Loimusalo & Huovinen, 2018). Other factors affecting mental practice might be experience of and familiarity with using imagery (see Bernardi et al., 2013b), not least because imagery skills improve through regular practice (Clark & Williamon, 2011). Indeed, greater musical expertise has been shown to involve more frequent use of imagery (Gregg, Clark, & Hall, 2008). This is in line with findings from the fields of sports psychology and dance, in both of which higher levels of expertise have been associated with increased use of imagery (Nordin et al., 2006; Nordin & Cumming, 2006).

Interestingly, differences between individual musicians' choices of mental practice strategy, and the impact of these differences on the results of learning have so far gained little attention. The studies of Bernardi and colleagues represent a notable exception. These found that the strategy of using auditory imagery in mental practice was associated with better performances from memory (Bernardi et al., 2013a), and with enhanced anticipation of movement in subsequent instrumental performance (Bernardi et al., 2013b). In the present study, we address such strategies from a different perspective, selecting cases based on individuals' successful use of mental practice, and using a qualitative approach to tease out the strategies involved. In particular, we will look at the ways in which pianists carry out their mental practice while reading the score in silence ('silent condition') and while simultaneously listening to the music presented in the score ('listening condition'). In order to address individual differences genuinely, we will define the term 'mental practice' as encompassing all strategies for preparing for performance with a score but without an instrument, including movement simulation (see Bernardi et al., 2013a).

Musicians may use mental practice at all stages of practising a piece and, just as in the field of dance (Nordin & Cumming, 2005), such practice may be expected to serve various purposes such as learning by heart, planning the technical aspects of performance, enhancing confidence, or developing artistic refinement (Connolly & Williamon, 2004). In the present study, mental practice was undertaken at an early stage of learning a piece: pianists were asked to practise the music without an instrument having given a first 'performance' while sight-reading from a musical score. We aimed to identify different approaches to mental practice by exploring pianists' self-reported strategies for mental practice in the experiment and by inspecting how they viewed (visually studied) the notation during the time of mental practice, as revealed by eye-tracking methods. We were especially interested in the successful mental practice of pianists with different levels of sight-reading ability. We therefore asked advanced student and young professional pianists to play a piece of music twice: first sight-reading the musical score and then again following a period of mental practice. Four expert judges evaluated audio recordings of each pair of performances. On the basis of these evaluations, we selected four cases demonstrating notable improvement potentially attributable to the pianists' use of mental practice. After this, we examined the pianists' accounts of their mental practice strategies, as described in interviews after the tasks. Because mental practice is necessarily covert and the pianists' self-reports subjective, the latter were compared to, and validated by, video-recordings of participants' eye movements while they were undertaking mental practice.

In music research, eye-tracking methods have primarily been used to study music reading during performance (for reviews, see Madell & Hébert, 2008; Puurtinen, 2018a). Eye tracking has also been used to study silent music reading, but typically in studies modelled on the controlled protocols of psychological research (e.g. Burman & Booth, 2009; Drai-Zerbib & Baccino, 2013; Waters & Underwood, 1998). Musicians' silent study and comprehension of notated music in a more natural setting have only rarely been addressed (see Penttinen, Huovinen, & Ylitalo, 2013). In educational science, the examination of individuals' eye movements during the study of domain-relevant material is viewed as having the potential for developing pedagogical practices in different fields (Jarodzka, Holmqvist, & Gruber, 2017), but to undertake such examination requires an understanding of the benefits and limitations of the method, and thus the experimental use of eye-tracking usually takes place in conjunction with other research methods. Such applications are still quite scarce in research on musicians and music making (Puurtinen, 2018b). The present study therefore served as an exploratory pilot for the use of eye-tracking methods in qualitative research on mental practice. It addressed the following research question: What kinds of mental practice approaches are successful in pianists' encounters with new pieces of music, and how are these mediated by practice condition (silent *vs.* listening)?

METHOD

Participants

A total of 23 pianists (17 females, 6 males) took part in an experiment. The mean age of the group was 25.17 years (*SD* = 3.59). They reported 15.0 (*SD* = 5.4) years of playing the piano and 4.5 years (*SD* = 2.6) of studying to be professional musicians or music educators. They were all current students at or recent graduates from institutions of higher music education in Finland. The criterion for inclusion in the study was to have accomplished "level D examination or above" in classical piano performance, often required for applying to instrumental training in higher music education in Finland.

Four pianists – Camilla, Tom, Niles, and Susan[1] – were selected as cases for further examination of the data on the basis of the evaluations of a panel of expert judges (four experienced pianists and piano pedagogues) who listened to audio recordings of both pairs of performances given by each of the 23 pianists. The expert judges' ratings indicated that these four pianists had different levels of sight-reading ability, as demonstrated in their first performance. Ratings of change between their first and second performances indicated outstanding improvements potentially attributable to their mental practice, in at least one of the two conditions (silent and listening). For more details of the selection procedure and descriptions of the cases, see *Analysis of performance data* and *Cases* below.

Musical materials

Two short compositions for solo piano were used in the experiment. Both Piece 1 ('Oi mergele, tu jaunoji'; see Figure 3) and Piece 2 ('Pute vejas'; see Figure 4) were taken from the suite *Devynios liaudies melodijos* by the Lithuanian composer Jurgis Gaižauskas (1922-2009). They are similar in length, sharing stylistic features such as modal character and linear texture, although small adjustments were made to ensure that the main features of the pieces were

[1] All pseudonyms.

comparable.[2] The original dynamic markings were removed from the scores to match the inexpressive MIDI performance prepared for the experiment, and for obtaining differences between pianists' expressive interpretations.

Procedure

The experiment was carried out in accordance with the ethical standards of Declaration of Helsinki (1964). Participants were tested individually in a laboratory in the presence of the third author. First, they read a participant information sheet detailing how data would be used and stating that participants would remain anonymous in scientific reports, and completed a consent form. They were shown the experimental setup and asked to carry out a short sight-reading task, playing an electric piano (Roland FP-7) while reading the notated music from a computer screen that was placed behind the keyboard. After this, the main experiment took place.

Following a 10 s familiarization phase in which the participant viewed the musical score without touching the instrument, he or she gave a first performance while sight-reading one of the two pieces, then undertook mental practice in one of the two conditions (silent *vs.* listening) and performed the piece again. The task was then repeated with the other piece in the other condition. Order effects were controlled for by rotating the order in which the two pieces were played and the two mental practice conditions between pianists according to participant ID and the date and time at which they played.

Instructions were provided in writing on the same computer screen on which the music was presented. At the beginning of the experiment, the pianist was instructed to perform the piece while sight reading, "not minding mistakes and doing the best you can." A suggested tempo (the tempo of the recording used in the listening condition) was given with four metronome clicks (Piece 1: 67 bpm, Piece 2: 72 bpm), after which the metronome was silenced. When the pianist had given the sight-read performance, he or she was instructed "to practise the piece quietly in your mind" without touching the instrument. The music appeared on the screen for 2 min 55 s, corresponding to the duration of three consecutive MIDI performances that were played in the listening but not the silent condition. Then the pianist was asked to perform the piece for the second time, this time with no metronome prompt.

During the experiment, the eye movements of the 23 pianists were recorded using a Tobii T60 XL Eye Tracker, manufactured by Tobii AB, 2009, with a recording frequency of 60 Hz, and infra-red cameras embedded into the computer screen. In order to allow as comfortable playing positions as possible, no chin or head rests were used, and a 65-70 cm distance between the pianist's eyes and the screen was accepted although it slightly exceeded the recommendation of the eye-tracker manufacturer (Tobii T60 XL Eye Tracker User Manual, Revision 2, 2010). A five-point calibration procedure was performed at the beginning of the recording session. All performances were recorded using Logic Pro X software version 10.2.0 (© Apple Inc., 2004-2015). The experimental setup is illustrated in Figure 1.

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[2] In Piece 1 we removed the middle voice in the left hand at bars 5-7 and 9-10 to make the piece more similar to Piece 2 in terms of its texture. In Piece 2 we changed the bass clef to a treble clef in the left hand at bars 16-20 to make the notation more similar to that of Piece 1.

Figure 1. Experimental setup.

After the session, the first author conducted semi-structured interviews with each participant, with the scores of the two pieces at hand. The interviews lasted 30 to 40 minutes, and were recorded using a digital audio recorder and a video camera. The main purpose of the interviews was to shed light on the pianists' mental practice strategies in both conditions, and on their experiences of giving the performances. The interview began with the question "What did you do during the mental practice?" and continued with 'content-empty' follow-up questions (Petitmengin, 2006) to help the pianists report their mental practice in more detail. The interviewer asked the pianists specifically if they had been able to imagine the music in the silent condition. Follow-up questions concerned both the content and vividness of imagery. The participants were asked "how the performances felt"; follow-up questions focused on details of the experiences reported. They were also asked if they had conceived of an interpretative idea or strategy for the second performance of each piece, and if so, when. The final interview question asked if the pianist used mental practice in his or her regular practice, and if so, how.

Case selection

Analysis of performance data

The expert judges rated the quality of each sight-reading performance on a scale from 1 (low) to 5 (very high). After each such judgment, they heard the same pianist's second performance of the piece, and used two 7-point scales ranging from –3 to 3 (0 represented no change) to rate the change between the performances in terms of a) "technical fluency" and b) "quality of expressive interpretation."

To estimate the reliability of the ratings, the first author counted errors in pitch (incorrect notes, extra notes, and missing notes), and rhythm (number of beats with rhythmic errors) in the performances. Significant negative correlations were found between mean ratings for sight reading and errors in pitch ($r = -.828$, $p < .001$) and rhythm ($r = -.461$, $p < .001$). The ratings of quality of sight-reading performance were therefore deemed reliable and thus usable in subsequent analyses. Mean ratings for change between the two performances in terms of technical fluency were significantly correlated with change in the percentage of pitch errors in relation to all notes in both the silent ($r = -.503$, $p = .014$) and listening conditions ($r = -.529$, $p = .009$). There were no significant correlations between mean ratings of change in expressivity and pitch errors, suggesting that these could be independent of each other (silent condition: $r = -.158$, $p = .470$; listening condition: $r = -.196$, $p = .371$).

Cases

Four pianists with different levels of sight-reading ability, according to the expert ratings, but who showed outstanding improvement in technical fluency and expressive interpretation following mental practice in one or both conditions were selected as cases, and their eye-movement and interview data were subjected to further analysis. Figure 2 shows their sight-reading and mean change ratings for each piece in each condition.

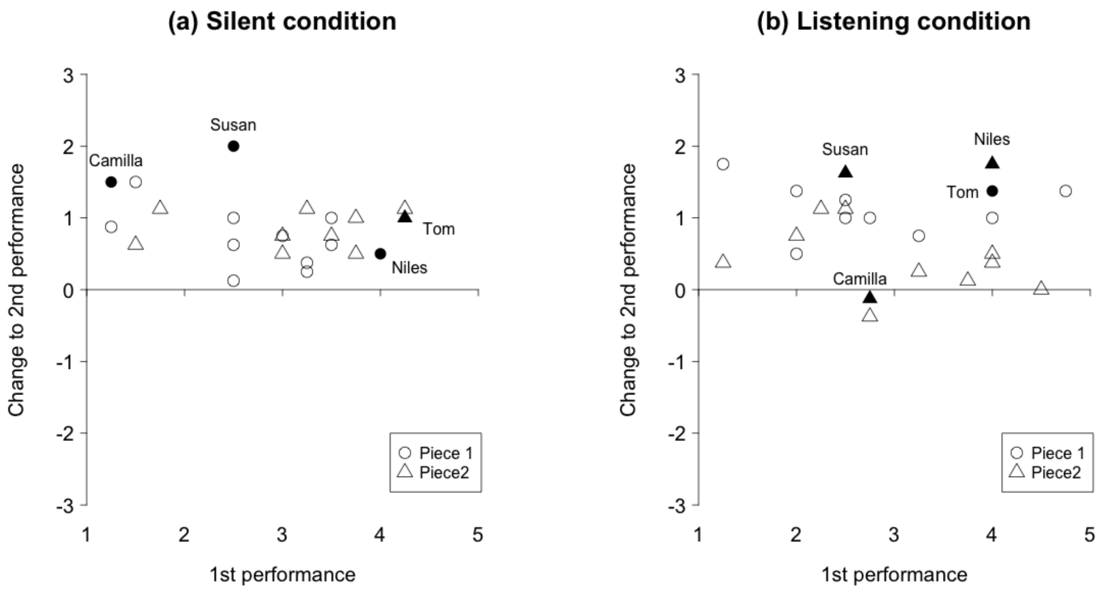

Figure 2. The four cases in relation to the group of 23 pianists. The horizontal axis shows ratings of performance while sight reading, and the vertical axis shows mean ratings of change between the 1st and 2nd performances.

Camilla, aged 24, was rated as having relatively low sight-reading ability. She was selected because her improvement in the silent condition was the second largest of the 23 pianists, while her performance was rated as having deteriorated in the listening condition. Camilla had 20 years of experience playing classical piano and five years of training in higher musical education. She reported spending ten hours each week playing and/or singing music and 12 hours undertaking activities involving musical notation, including playing from notated scores, reading music in silence, writing music, and teaching.

Tom, aged 27, received the highest mean ratings for sight-reading (4.125) among the 23 pianists. He was selected because of relatively high ratings for improvement between the performances before and after mental practice, especially in the silent condition, where his scores were among the four highest. Tom had 20 years of experience playing classical piano and three and a half years of training in higher musical education. He reported spending six hours each week playing and/or singing music and three hours undertaking activities involving notation.

Niles, aged 23 years, was rated as having high sight-reading ability. He was selected because he made the most improvement following mental practice in the listening condition but was among the four who made the least improvement in the silent condition. Niles had 17 years of experience playing classical piano and two and a half years of training in higher musical education. He reported spending 40 hours each week playing and/or singing music and 20 hours undertaking activities involving notation.

Susan, aged 27 years, was rated as having below-average sight-reading ability. She was selected because her second performances were rated as greatly improved – among the top three – following mental practice in both conditions. Susan had 20 years of experience playing classical piano and seven years of training in higher musical education. She reported spending three hours each week playing and/or singing music and one hour undertaking activities involving notation.

Data analysis

Eye-movement data

Eye-movement data obtained from the four pianists recorded during the two periods of mental practice, each lasting 2 min 55 s, were examined qualitatively by the third author. The recordings were first viewed in video format, and then systematically segmented into episodes no shorter than 1 s using the visualisation tool of the Tobii Pro Studio 3.4.7 software. Fixations – the short moments when gaze remains somewhat still and targets a specific location (see Holmqvist et al., 2011) – were defined according to the Tobii Fixation filter, with a velocity threshold of 35 pixels/window and a distance threshold of 35 pixels.

An analytical procedure following the 'visual inspection' type of scan-path analysis described by Holmqvist and colleagues (2011, pp. 256-259) was chosen for the following reasons. Scan-path data are often and preferably analysed quantitatively (*ibid*.), but this was not appropriate for a qualitative study examining only four cases. Rather, the purpose of recording eye movements was to compare data from the recordings with post-task interview responses relating to specific moments during mental practice.

Chin rests were not used in the experimental setup because participants were encouraged to sit comfortably while playing, reading and listening. For this reason they may have moved a little while the eye-movement recordings were being made even though they had been instructed to sit still. This could have affected the accuracy with which their eye positions were tracked. For example, the eye tracker could 'lose' the position of the eye for a second or there could be errors in calibration ('data offset'). Such events made it impossible for us to use the Tobii Pro Studio software to analyse the data, because it would not have been possible to compensate manually for missing data and offsets. We were able to do this, however, using qualitative coding.

The starting point for the scan-path analysis was the observation that the movements of participants' eyes as they read the music ('viewing process') represented different degrees of linearity. We developed a segmentation routine through a process of constant comparison enabling us to label each of the episodes into which we had divided the eye-movement recordings as a continuous instance of one type of viewing process (instructions for coding can be found in the appendix):

1) *linear reading* – reading two or more consecutive bars in order, with two or more fixations for each bar
2) *linear skimming* – fixating on three or more consecutive or near-consecutive bars in order, with 1-2 relatively short fixations for each bar
3) *non-linear skimming* – reading not more than two consecutive bars in order; typically fixating briefly on different bars
4) *selective stopping* – time spent on 1 to 3 bars but in a way that could not be categorized as one of the viewing processes listed above
5) *missing data* – episodes in which no fixations targeted the music on the screen.

Each viewing episode was indexed by bar number, unless it was categorized as non-linear skimming, in which case it was categorized by page number(s) 1 and/or 2. This procedure, illustrated in Figures 3 and 4, enabled each pianist's reading of the score while undertaking mental practice in the two conditions to be described in detail.

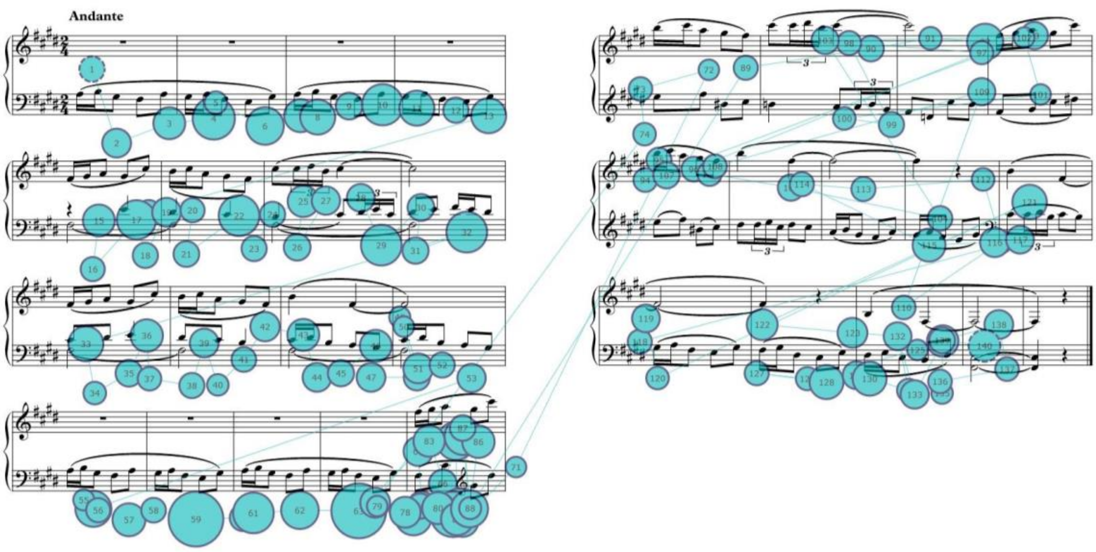

Figure 3. A still picture corresponding to the first 54 seconds of Tom's eye movements in the listening condition (Piece 1), as visualised by the Tobii Pro Studio software. The numbers give the order of fixations, the size of the bubbles indicates their relative duration, and the lines between the bubbles indicate transitions between fixations. Tom stopped at bar 17 then skim-read to catch up with the music that had continued to play. On the second, third and fourth systems of page 1 the data are slightly offset, as seen in how streams of fixations have landed between and below the systems.

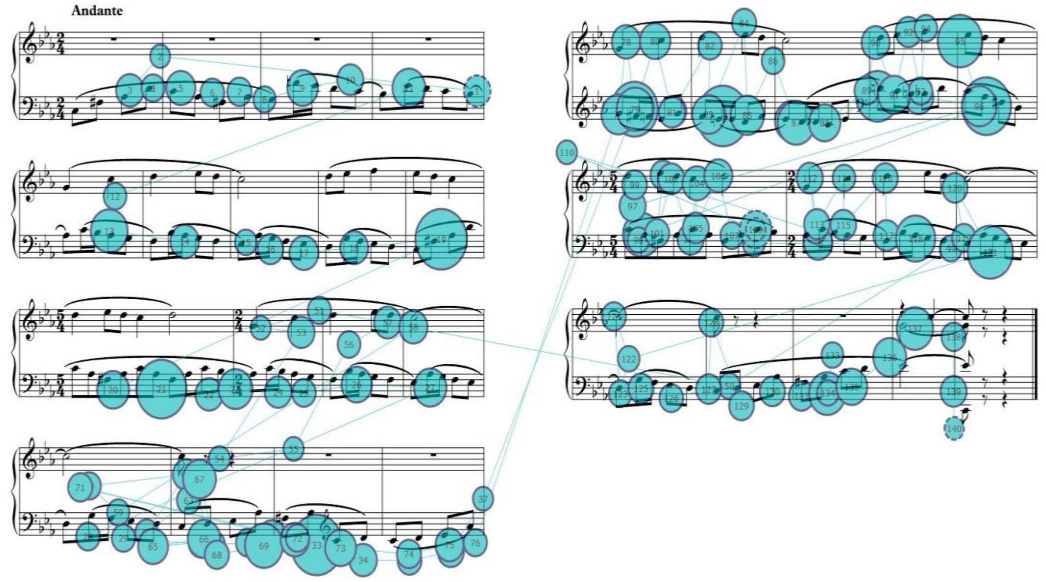

Figure 4. A still picture of Susan's eye movements while listening to the second of the three playbacks in the listening condition (Piece 2), as visualised by the Tobii Pro Studio software. Sometimes she read the left hand only, or focused on difficult bars, as shown by the selective stopping at bars 14 and 15, and repeated readings of bars 14–22.

Interview data

Interview data were analysed, to identify participants' strategies for mental practice, using qualitative content analysis (Elo & Kyngäs, 2008; Hsieh & Shannon, 2005) and comparisons with the eye-movement data. The interviews were transcribed verbatim and subjected to a four-stage analysis of their content. First, transcripts were read and participants' responses were clustered into six general themes: sight-reading performance, silent condition, listening condition, second performance, self-described characteristics, and regular mental practice. Second, each participant's account of what they had done or tried to do at different stages of their mental practice was coded into condensed descriptions of mental practice in the silent and listening conditions. Third, these codes were compared, and condensed descriptions with similar contents were subsumed into the same category of mental practice strategies (for example 'structural analysis'). Where appropriate, condensed descriptions in the same category were labelled more specifically according to their content (for example, structural analysis can include simple, thematic, modal-harmonic, and comparative analysis). Fourth, the interviews were re-read and the coding scheme was stabilised by evaluating the suitability of each description to its category of mental practice strategies. Following this content analysis, relevant aspects of each pianist's coded mental practice strategies were verified by comparing them to the viewing processes inferred from the eye-movement data. Finally, the strategies described by each of the four pianists and their observed viewing processes were condensed interpretatively into the individual approaches to mental practice that are described in the following four narratives.

RESULTS

Before discussing individual approaches to mental practice, we provide an overview of their components. The following categories of strategies were identified from the content analysis:

audiation, *imaginary rehearsal* (including movement simulation and various kinds of imagery – visual, motor, tactile, and spatial), *structural analysis* (simple, thematic, modal-harmonic, comparative), *focus on learning to play the right notes, search for relevant information, local problem solving*, and *disorientation*. The eye-movement analysis, in turn, yielded an overview concerning the prevalence of different types viewing processes during mental practice (see Table 1). While all four pianists spent the largest percentage of their mental practice time on linear reading, there was nevertheless a considerable range, from less than half the time (Niles and Susan in the silent condition) to almost all the time (Camilla in the listening condition).

Table 1. Types of viewing processes: Percentages of mental practice time

	Camilla		*Tom*		*Niles*		*Susan*	
Condition	*Silent*	*Listening*	*Silent*	*Listening*	*Silent*	*Listening*	*Silent*	*Listening*
Piece	*1*	*2*	*2*	*1*	*1*	*2*	*1*	*2*
Linear reading	89.02	95.40	55.17	54.86	48.00	84.48	47.70	88.64
Linear skimming	0.58	0.00	0.57	2.29	6.29	0.57	3.45	3.98
Non-linear skimm.	2.89	1.72	11.49	9.14	15.43	8.05	10.34	1.70
Selective stopping	7.51	2.87	32.76	32.00	20.57	5.17	38.51	5.68
Missing data	0.00	0.00	0.00	1.71	9.71	1.72	0.00	0.00

Camilla: Coping approach

Camilla's improvement following silent mental practice was outstanding, but the change in her scores from the first to the second performance was rated negative in the listening condition. In line with her relatively low scores in sight-reading (see Figure 2), she described her first performance of Piece 2 as a "struggle for survival… note, note, note." In Piece 1, she reported "being somehow really lost while playing. I nearly was not able to catch the time signature." Her mental practice thus demonstrated a *coping approach*, in which she used practical strategies to learn to play the right notes and cope better in the upcoming performance. For example, in the silent condition, she described her "energy mainly going to making out the pitches." Diagrams mapping Camilla's coded viewing processes during the mental practice periods reveal an emphasis on linear reading (see Figure 5), and, as we will see, the statements she made in her interview indicated that while she was doing this, she was using imaginary rehearsal with visual, motor, and tactile imagery.

Camilla's mental practice strategies also included simple music analysis. Recalling her strategies in the silent condition, she said, "First, I was thinking: 'Now, let's get some clarity to this time signature.'" While studying the key signature she imagined the keyboard: "I was thinking in my mind: 'yes, these black keys are involved.' And then, I started to play it through in my mind, bar by bar, to the end." The coded eye-movements shown in Figure 5 suggest that, at the beginning of mental practice in the silent condition, Camilla's initial focus on time and key signatures consisted of only five seconds of selective stopping at bar 1. She went on to report rehearsing the piece in her mind "pretty much in the same tempo I was playing it the second time – quite slowly." The eye-movement data confirm that she did indeed take as long as 116 seconds to read through the piece.

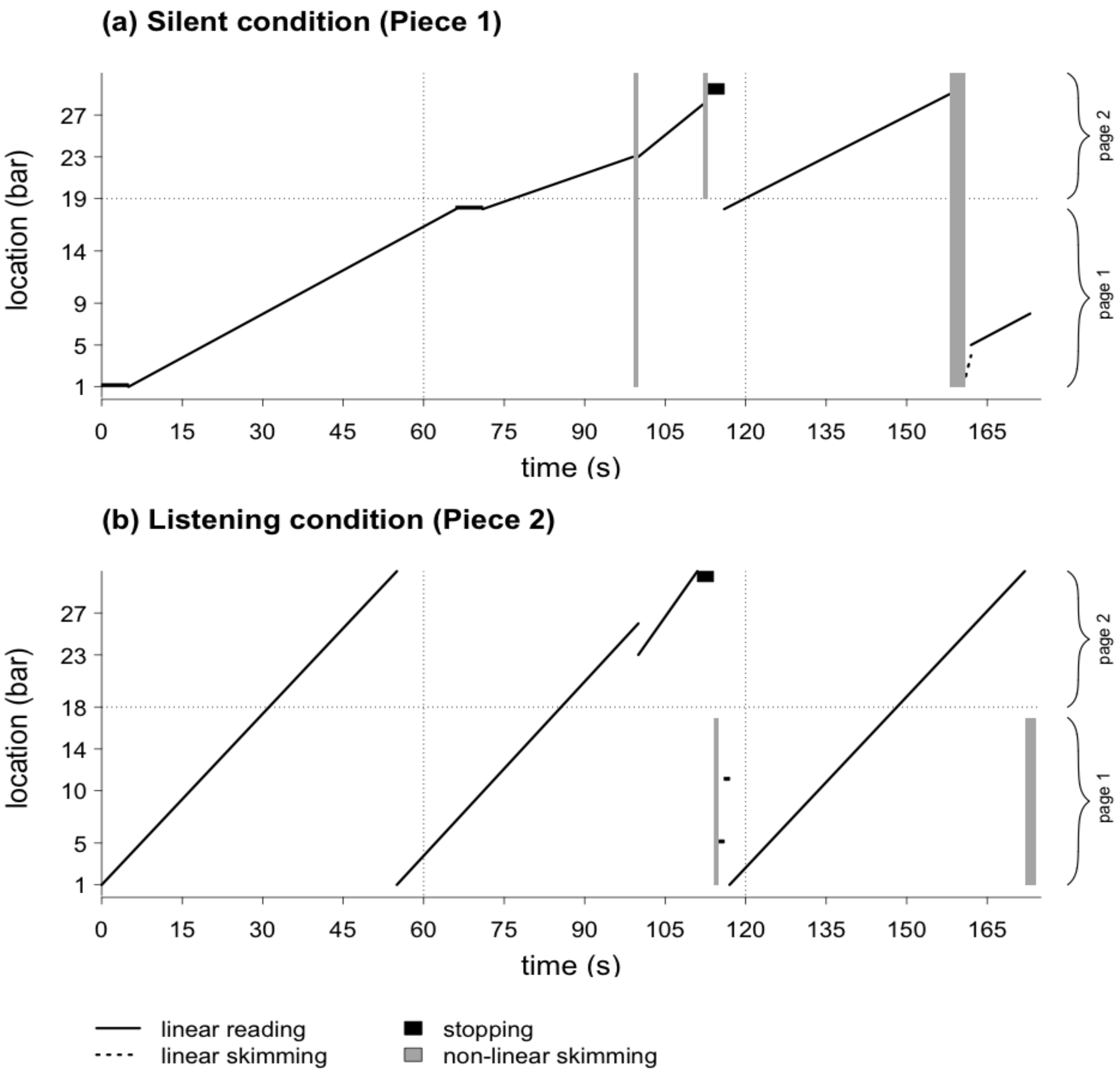

Figure 5. Camilla's viewing processes in the silent and listening conditions, showing long episodes of linear reading as coded from the eye-movement recordings. The bar numbers indicated on the vertical axis correspond to the first bars on successive systems in the score.

The recordings of Camilla's eye movements in both conditions are characterised by long episodes of linear reading, confirming her own descriptions of linear progression. Some exceptions can be attributed to the complex appearance of particular passages. For example, she commented on the strategies she used in the listening condition, "Perhaps, if there was a more difficult passage, I may have looked at it longer for a while, but I was proceeding with the music all the time." She described rehearsing, in the silent condition, "first through in a steady tempo, then stopping to look at the notes which my eye didn't immediately identify." According to the eye-movement recordings, selective stopping occurred only at bars 18 (5 seconds) and 29-30 (3 seconds) during the first read-through. It may be that these episodes came to her mind during the interview, giving her the erroneous impression that more such episodes must have taken place.

Camilla described her use of multimodal (visual, motor, and tactile) imagery while rehearsing, and she apparently relied in the present study, also, on relatively unintentional movement simulation. The vividness and detailed nature of her multimodal imagery is illustrated by her description of her regular mental practice:

> I kind of visualise the keyboard in my head: how my hands are moving on it. […] Visual [imagery of a performance] is usually pretty important for me, but also the fact that I am constantly pressing [the keys, imaginatively] – I try to remember how they [i.e. the fingers] feel on the keyboard when arriving on a black key, for example.

By contrast, Camilla described aural imagery in her silent practice as being "rather sketchy," which may also have led her to think that she has a greater need for movement simulation "to get a sensory image." Camilla seemed to be familiar with multimodal and detailed mental practice, which for her has an "important role at the final stage while practising for a concert." In her regular "really hard, but extremely effective" mental practice she described trying to "recall the name of the note, what it looks like in the score, what it looks like on the keyboard, which finger – trying to remember it note by note, precisely."

Her worsened performance in the listening condition (see Figure 2) may be due to her selecting too fast a tempo after listening to the recording. She reported first performing the piece slower, because "I think it suited [the piece] better." However, after listening to the recording, she "performed it pretty fast, but then, it came to nothing. I couldn't perform it that fast."

In sum, Camilla's approach to mental practice showed a *coping approach*. The goal of her practice was to learn to play the correct notes. She used a linear reading style to rehearse in imagination, focusing briefly on passages that looked complex. Her imagery, note-by-note, seemed vivid, but she described her audiation in the silent condition as sketchy. In the silent condition, which permitted slow and detailed practice, she was able to use this general approach to improve her performance. The tempo of the recording in the listening condition may have been too fast for her, rendering the presence of an auditive model detrimental to her subsequent performance of the piece.

Tom: Problem-solving approach

Tom improved his performance following mental practice in both conditions, but more so in the listening condition. His sight reading was rated high, and he seemed to find the pieces relatively easy to play. Tom described his sight-read performance of Piece 1 by saying "it was ok" and, commenting on Piece 2, "the voices were found quite easily." He nevertheless reported a "problem in the left hand with those large intervals [indicating bars 17-18]" in Piece 1, motivating him to think "what would be the solution?" Tom's approach to mental practice could be characterised as *problem solving,* whereby local problems observed during sight-reading were solved by analysis in combination with visual and motor imagery. In comparison to Camilla's note-centered approach, Tom's imagery seemed more holistic and fluent:

> I was trying to visualise it. […] It's not like "middle finger there and index finger there" – or that, too, but [also] sort of the whole movement combining all the sounds together. […] I can close my eyes and see they keys. But it's always combined with the sensation.

Tom's determination to solve specific problems became apparent in the listening condition: Despite the recorded music continuing to play, Tom focused on bars 17 and 18, "a passage that I rehearsed in my mind a lot in the meantime to get it right." Part of the eye-movement recordings are shown in Figure 3. This shows Tom's first accumulation of fixations in bar 17; the schematic summary of the whole eye-movement process in Figure 6b reveals several similar episodes of *selective stopping* in the same area. Tom recounted analysing the problem and reflecting on different solutions, finally choosing to divide the hands in a different way from that shown in the notated score – a strategy that seemed characteristic of his usual practice: “Sometimes it is consciously done, and sometimes it happens that I quite spontaneously divide it, even if it were just a single voice”. Tom described his problem solving in the listening condition:

> First, I was probably thinking of fingerings, whether it could be played with the left hand, but then I thought: “Those notes are located within an octave, the right hand is not jumping as much, so it [the texture] could be divided.”

In the listening condition, Tom did not allow himself to read the whole piece through with the recording: his viewing processes consisted mainly of linear reading for just over half the time, stopping for just under a third of the time, and non-linear skimming (see Figure 6b). The following extract from his interview illustrates this combination of viewing processes with his ability to concentrate on local details despite the recorded music continuing to play:

> At times, I found myself stopping [at one passage in the score], and after that waking up: “A-ha, it’s playing here now.” And then, I might search for the current passage [in the score], and maybe again glance at it for a while. […] When I stopped, I wasn’t thinking about the sounding music. I was pretty well able to concentrate on the visual score and what I was trying to resolve there.

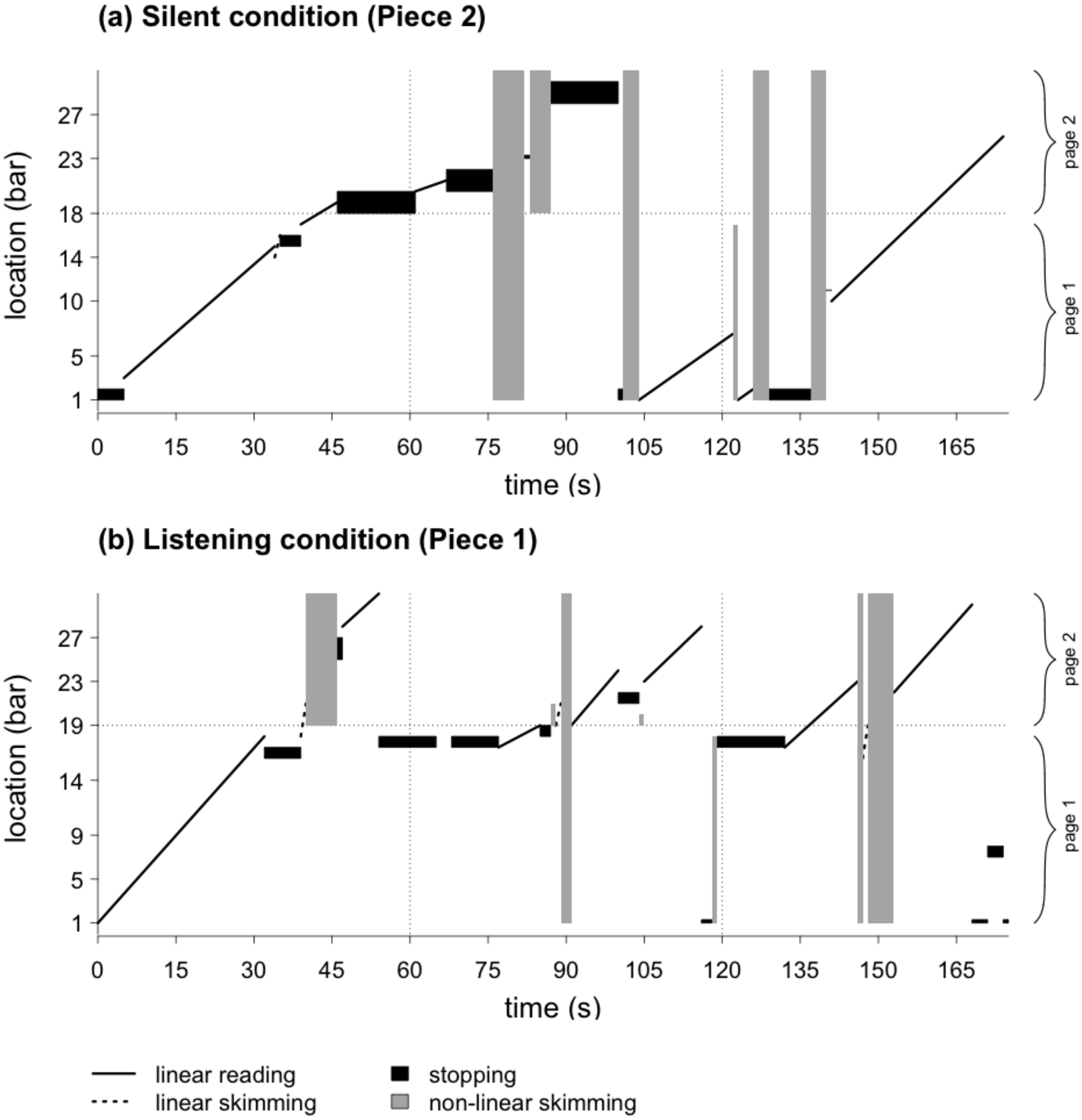

Figure 6. Tom's viewing processes as coded from the eye-movement recordings, similar in the two conditions: mostly linear reading, selective stopping, and non-linear skimming.

Tom described his reading in the silent condition as "just squinting it through, in a few passages thinking of what fingers to use" and "taking just passages here and there." Again, he reported problem-solving strategies such as pondering enharmonic spellings, and thinking of a suitable hand position (possibly reflected in the eye-movement data as selective stopping at bars 1-2 [total 14 seconds], bars 15-16 [4 seconds] and bars 28-30 [13 seconds]):

> There is this passage with an F#, and yet, there is an Ab. […] it is a third, but still enharmonically a second […] In a way, I was thinking of it as a chord: which [hand] position to take there?

As indicated by his coded viewing process in the silent condition, Tom began by proceeding slowly through the whole piece, stopping repeatedly (see Figure 6a). Not being able to hear the music may have caused Tom to feel disorientated. He "wasn't able to get a clear [aural] image just by looking at the score" and he therefore experienced his strategic options as more limited:

> I was looking more at the score. In a way, there was one thing less to do. […] When there was music, you were able to listen to it and concentrate on that, but now, when it was removed, I think that my sight took a bigger role.

With regard to his customary use of mental practice, Tom reported that "in the early stage of learning the piece [he] usually assists [the learning] with recordings," but also "just looks at the score," thus demonstrating familiarity with both types of mental practice. He "did not really plan dynamics" during his mental practice in the present study. Rather, his interpretation of the music seemed to come about while he was performing. In the listening condition the "mechanical performance of the machine may have encouraged playing more musically the second time."

In sum, Tom's approach to mental practice can be described as *problem-solving*. In both conditions, he spent nearly a third of his practice time in selective stopping, and he described solving local problems by analysis in conjunction with imaginary rehearsal. Tom claimed that he had weak audiation skills, and thus he focused more on score-related aspects in the silent condition. However, his prior familiarity with both types of mental practice, his problem-solving approach, and focus on musical interpretation during the second performances may have contributed to the improvements in his performances in both conditions.

Niles: Analytic modelling approach

Niles' sight-reading was rated high, and he experienced sight-reading as "pretty easy." According to our panellists, Niles greatly improved his performance in the listening condition, but his improvement scores in the silent condition were among the lowest in our original group of participants (see Figure 2). In the listening condition, he appeared to be in his comfort zone: he mentioned his experience of using recordings to speed up his learning, and his skill in doing so ("I am always learning to play that way […] I'm pretty good at learning by ear"). Apart from a proclivity for learning from aural models, Niles showed a tendency to analyse, and his approach to mental practice could indeed be characterised as *analytic modelling*. Niles himself described analytical thinking as being for him a "pretty characteristic approach to basically everything." In the silent condition, for instance, he "tried to do some kind of modal harmonic analysis – if it could be parsed through that." Learning by ear seemed to be a process of memorisation, mediated by analytical observations whereby the music "is probably [stored] as harmonic sketches":

> I mean, in a way one knows the relation between the [heard] melody and the root of the chord – say, if it begins on a sixth. And then, one just thinks of how it is related to the harmony.

During the listening condition, Niles reported listening and "following the score with my eyes" – a statement supported by the recordings of his eye-movements (see Figure 7b), which revealed lengthy episodes (54, 48, and 28 seconds) of linear viewing processes. During these episodes, Niles was listening and analysing in two ways. First, he recalled having analytically reflected on his previous performance and having made mental notes of particular passages that would be relevant for the next performance:

> I heard: "Oh, yes: I played that incorrectly […] Oh yes, that's what it was: the bar following this one was where I failed" – and on this basis, I tried to commit to memory, so that I

would make sure to read it more carefully while playing.

Second, Niles' listening involved some thematic analysis: "In the left hand there were these sequences. Then, there goes this chorale type of melody in the right hand […] And then, the five-four time signature was a kind of return to the main theme." The last time he listened to the piece, however, Niles seemed to have lost his motivation for what was an easy piece for him, and expressed disorientation: "I started to think of other things […], it wasn't offering me anything any more."

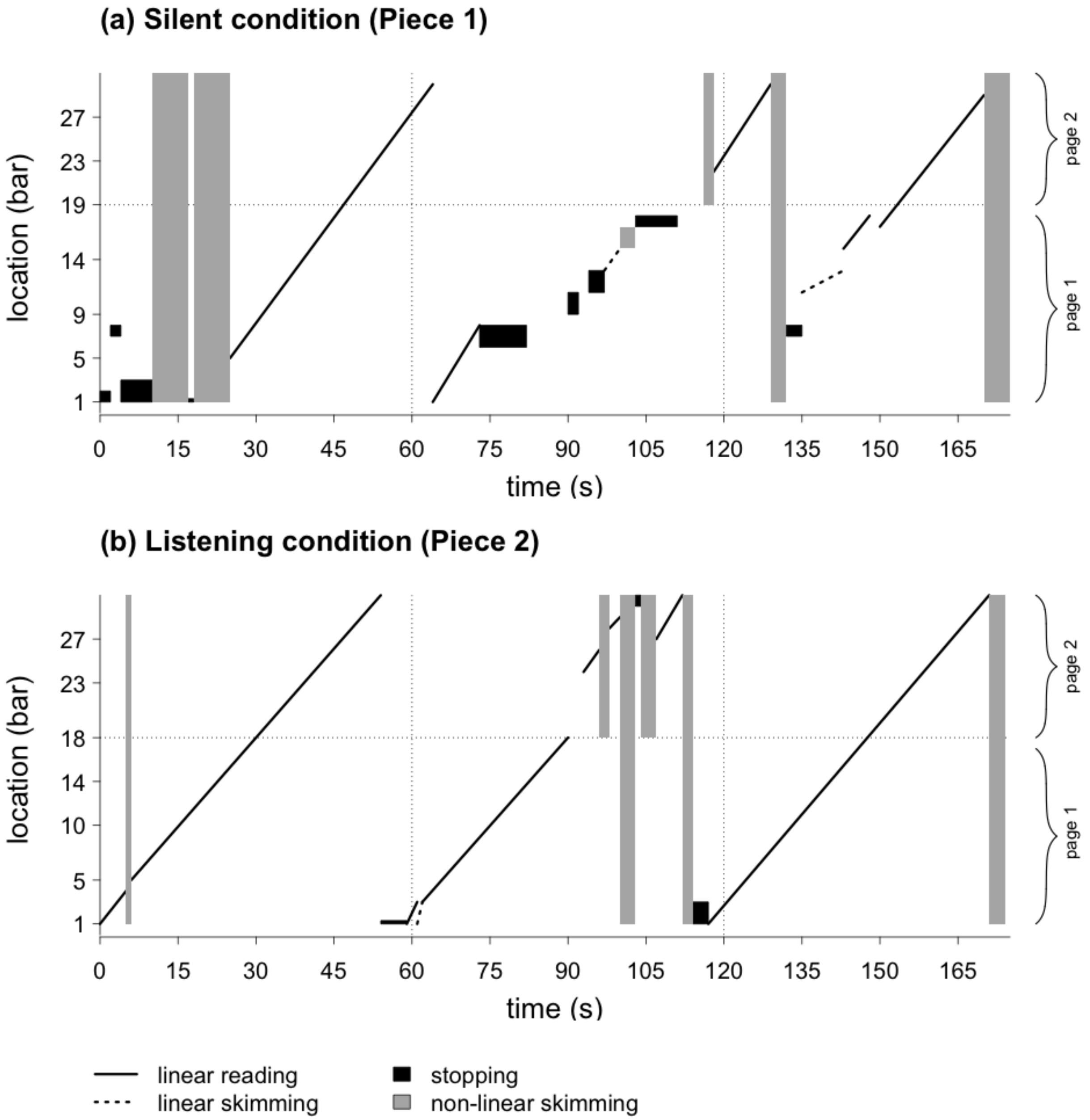

Figure 7. Niles' viewing processes in the silent and listening conditions showing disorientation at the beginning of the silent condition, and linear following of the music that was playing in the listening condition.

Niles' preference for aural models also became apparent in the silent condition: There, he confessed that hearing the music "would have been essential for me." He also expressed confusion and inexperience: "I think it may have confused me. These are not among my characteristic approaches, just to be looking at it there." Part of this disorientation may have been related to Niles' self-evaluation of being "poor at imagining the aural part of it." This could explain his viewing processes at the beginning of the silent condition (See Figure 7a). Niles seems to have found it difficult to get started; for the first 24 seconds, he appeared to lack a clear idea of what to do, resorting mostly to non-linear skimming of both pages. From then on, however, he continued to read through the piece linearly from bar 5.

In the silent condition, Niles, like Tom, selected difficult passages for more detailed study. One example was at the page turn, "where the left-hand kind of jumps there: that was a passage I really went through in my mind multiple times" (see the 8-second stop at bars 17-18 in Figure 7a). He described relying on problem-solving strategies that he would not normally have used, such as planning fingerings. Apart from "imagining how the keys would feel like" he also reported "thinking through a bigger motor machinery" – rehearsing in imagination in a way that might not have been very helpful: "I was thinking about how the weight of the elbow and upper arm shifts when the hand moves." In Niles' own opinion, his visual imagery skills were perhaps undeveloped; he stated "not being visual at all in that sense."

In sum, Niles' preference for listening analytically to recordings and his disorientation as the result of not being able to hear the music in the silent condition can be described as an *analytic modelling* approach to mental practice. Given the panellists' ratings, this approach seems to have served him better in the listening condition than in the silent condition. Although the interview data suggest that Niles has an analytical mind and a good aural memory, they also suggest weak audiation skills. He said he felt disorientated because the piece in the listening condition was easy, as well as because he was unfamiliar with silent practice. The combination of his inexperience, weak audiation skills and poor imagery may have resulted in silent practice that was somewhat unstructured and ineffective, perhaps because – as the result of his preference for listening – he had not practised the skills required for silent mental practice.

Susan: Holistic-structural approach

Susan's sight-reading was rated moderately low, and she described performing Piece 1 for the first time, at sight, as "quite difficult", reporting "analysing harmonies" and "making notes for myself of the passages with most difficulties." According to the expert ratings, there were remarkable improvements in her performances in both conditions, suggesting that her mental practice was effective, overall. We have chosen to characterise her approach to mental practice as *holistic-structural*. Susan explicitly emphasised the importance of "grasping larger wholes," described using structural, thematic, and comparative score analysis, and reported distinguishing relevant from irrelevant information in order to speed up her learning. For example, when identifying a repeating pattern, she might reason thus: "Okay, that's the pattern. When I learn that one, I know them all."

In addition to structural analysis, Susan was rehearsing in imagination using movement simulation and spatial imagery, which she called "checking the distances between the notes with my fingers." This was "supported by audiation," in which Susan reported having advanced skills. She described hearing music from the score "in harmonies and through pitch intervals." Hence, in the listening condition, she would have preferred to "hear it in my mind"

– an ability she believed to develop through additional musical activities such as "transcribing." However, her mental practice was governed "not so much by the senses, but almost by mathematical thinking." She reported in general analysing "relationships between things":

> It includes a lot of comparison: What is similar here, what is different? In which direction are these [elements] going? […] Observing the relationships. Are there repeating patterns? […] What themes are there?

In the listening condition, Susan reported first "following it [i.e. the music] pretty carefully." Figure 8b shows that her first reading episode consisted of 54 seconds of linear reading. The second time she heard the piece, she tried to "forget it and concentrate on the shapes and the repeating patterns I had observed." Susan's claim that she tried to ignore the recording is supported by the viewing processes revealed by the recordings of her eye movements: during the following 30 seconds, 40% of her reading included skimming and stopping. This kind of practice seemed to be motivated by focusing on what she deemed relevant during the three-minute practice session: "If it plays a passage that is clear to me, I don't want to pay attention to that, but rather to the difficult ones."

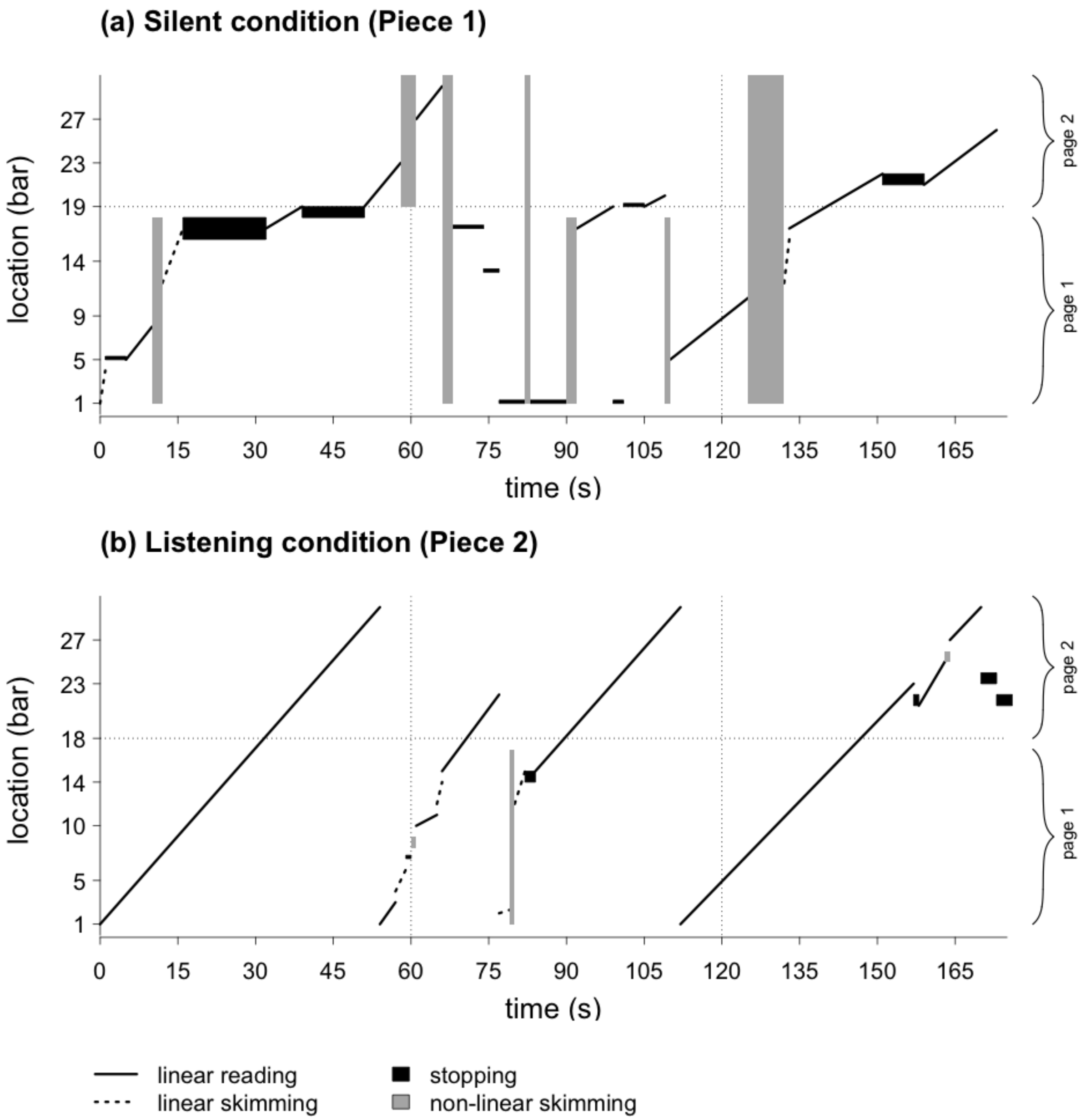

Figure 8. Susan's viewing processes in the silent and listening conditions. In the silent condition, searching and focusing on "relevant" passages and the use of comparative analysis can be seen as selective stopping, linear and non-linear skimming. In the listening condition, Susan followed the music at first, but then tried to ignore it.

In the silent condition, Susan's mental practice again included "analysing the piece a bit. It helps me if I'm able to grasp broader lines. Then I'm able to anticipate what will happen next." In addition, she described searching for and focusing on what is relevant: "That's difficult, that's difficult, and then concentrate on those." Her approach also involved imaginary rehearsal using movement simulation and spatial imagery:

> I looked at some passages to see how playing them would feel in [my] fingers. […] Kind of checking the fingerings. What might be natural? Or, if there are large leaps, how far do they go?

The eye-movement data confirm Susan's descriptions concerning her practice strategies: during the first silent read-through, she jumped over certain passages, skimming linearly through easy passages with only one voice, but stopping at other locations. After this, she continued consecutively skimming and stopping, which may reflect her comparative method of analysis: “for example, when I found this one repeating pattern, I started to search if it could be found somewhere else in the piece.” This kind of comparison might be identified in the recording of her eye movements as consecutive stopping at identical bars (around 75 seconds, Figure 8a; comparing bars 13 and 1 in Piece 1, see Figure 3). Similarly, later in her silent practice, after reading linearly through the first occurrence of the melodic theme (bars 5-11), Susan seems to have searched through the whole score, then read linearly through the second occurrence of the theme (bars 17-22; see Figures 3 [Piece 1] and 8a). Particularly in the silent condition, the improvement in Susan’s expressivity was scored high but, like Tom, she hardly seemed to address expressive aspects in her mental practice. In her own opinion, “after the piece had been structured [in mind], [and] when I was playing it, the interpretation came out naturally.”

In sum, Susan’s *holistic-structural approach* reflected her regular ways of analysing music to enhance her learning: finding and making comparisons between relevant pieces of structural information so as to gain a holistic understanding of the composition. According to the panellists’ ratings, the improvement in Susan’s expressivity was also convincing. Instead of resulting from an explicit concern with expressivity during mental practice, this may be because she understood the piece better following mental practice. Susan seemed to be able to adapt to both conditions while applying the same holistic-structural approach to her mental practice. In the listening condition, she described making use of the aural model to perceive the musical structure holistically while emphasising her focus on relevant information. In the silent condition, her non-linear search processes reveal an interest in structural parallelisms, but she was also able to make use of her apparently advanced audiation skills.

DISCUSSION

The present study explored skilled pianists’ approaches to mental practice. Data obtained from four pianists, representing different levels of sight-reading performance and showing considerable improvement following mental practice in one or both of two conditions, were selected for further analysis. The two conditions were 1) studying a score silently and 2) studying a score while simultaneously listening to the music presented in the score. In the course of interviews, the pianists provided descriptions of their mental practice. Analysis of information from these descriptions was combined with analysis of recordings of the pianists’ eye movements while undertaking mental practice, from which their viewing processes were inferred. These methods complemented each other, offering a basis for examining covert mental operations and enabling us to verify, at least to some extent, the accuracy of the pianists’ self-reports.

Each of the four pianists used a unique approach to mental practice. As suggested by Fine et al. (2015), they seemed to have their own characteristic ways of emphasising either imagery practice or score analysis (see also Hultberg, 2008; Imreh & Crawford, 2002). Camilla and Tom were more practice-oriented, but while Camilla rehearsed by playing the music through in her mind in order to learn to play the right notes, Tom combined analytical thinking and imaginary rehearsal to solve local problems. By contrast, Susan and Niles took more interest in structural analysis, which they conducted in different ways.

Our research question concerned the identification of successful approaches to mental practice. Although the four pianists had different levels of sight-reading ability, they all were engaged in either imaginary rehearsal or structural analysis in ways with which they were *familiar* and *skilled*. In the silent condition, Camilla succeeded by using her customary practice of slow-paced and detailed imaginary rehearsal. Niles reported that he was especially skilled at learning by ear, and was indeed more successful in the listening condition. Tom and Susan, in turn, were successful in both mental practice conditions. Tom had experience of silent reading and using recordings to learn music; he demonstrated problem-solving strategies and the fluent imaginary rehearsal. Susan also used familiar strategies for learning new works: searching for relevant information and applying comparative structural analysis. Less successful approaches to mental practice may be the result of less experience and fewer skills in applying appropriate strategies. Niles, for example, felt lost in the unfamiliar silent condition and lacked the imagery skills that could have helped him. The extent to which mental practice is effective is thus related not only to familiarity with the task (see van Meer & Theunissen, 2009) but also to familiarity with the mental practice undertaken (see also Bernardi et al., 2013b; McHugh-Grifa, 2011). This suggests that relevant skills can only be developed if strategies for mental practice are deliberately learned and rehearsed.

Expertise is generally associated with more refined use of varied strategies (Hallam, 2001), and thus expert musicians may be better at developing the skills required for mental practice. Musical sophistication has also been found to be reflected in visual processing and the accuracy of information gathered while reading music silently (Penttinen et al., 2013). Of our four cases, Susan was perhaps the pianist with the greatest musical expertise, as suggested by her years of studying the piano. She adapted to both mental practice conditions in the present study, reporting the use of both structural analysis and imaginary rehearsal. Of the four pianists, Susan's ability to imagine the sound of the music independently of recording being played at the same time seemed most advanced.

Not all the improvements in performance that were observed can be attributed to participants' use of mental practice. Camilla's performance worsened in the listening condition, perhaps – in part – because she chose to play at too fast a tempo after listening to the recording. She was at more of an advantage in the silent condition because her coping approach to mental practice involved imagining the music slowly, a useful strategy for less expert musicians (see Wright, Wakefield, & Smith, 2014). The connection between the tempi at which a piece is practised mentally and subsequently played illustrates the relationship between thought and action: thinking of music at an unsuitable tempo can be detrimental to performance. Timing in mental practice should therefore be considered in relation both to the musicians' performance levels and the purpose of their mental practice (see Wright et al., 2014).

On the basis of our findings we make the following recommendations for mental practice. First, musicians should develop their imagery skills and hone, in particular, their abilities to undertake structural analysis and audiation. Even though they may consider score analysis to be a less useful practice activity than imaginary rehearsal (Fine et al., 2015), the improvements made by Susan and Niles demonstrate that it can enhance performance away from the instrument (see Bernardi et al., 2013a). With regard to audiation, often induced during silent reading of music (Brodsky, Kessler, Rubinstein, Ginsborg, & Henik, 2008), the ability to evoke a *correct* inner aural representation from a score varies across musicians. Aural skills make a difference not only to learning outcomes (Bernardi et al., 2013a; Highben & Palmer, 2004; Loimusalo & Huovinen, 2018), but also to the activities carried out during mental practice: Tom and Camilla seemed to compensate for their lack of audiation by using other strategies. If Niles had had better audiation skills he would not have felt so lost; he would have been able to use his aural memory without needing an external model.

Improvements in expressivity were observed even though participants did not focus on expressivity while undertaking mental practice. Such improvements may have arisen from participants' efforts to increase their structural and aural understanding of the piece, or from gaining technical confidence through imaginary rehearsal. Perhaps this was in part related to the design of our study, in which mental practice was undertaken after the first sight-read performance, that is, at an early stage of learning. If one is to play music expressively, one should arguably know it first. It is more likely to be important to use expressive, emotional and metaphorical imagery (see Holmes, 2005; Nordin & Cumming, 2005) in the later stages of preparing for performance.

Approaches to mental practice could be studied in future at different stages of practice, and in relation to performance on different instruments (as in Holmes, 2005). Also, video recordings could be used to assess the use of movement simulation. One limitation of the present study is that, because we were interested in individual differences, we did not control the tempi of the performances that were evaluated.

Our study demonstrates that musicians engage in mental practice in different ways, and that individual musicians' approaches to mental practice involve a complex combination of their performance needs, skills, habits, preferences and motivation. Thus, simply recommending students to undertake mental practice fails to address the content and usefulness of its components. Practice habits sculpt a musician (Klickstein, 2009), so those responsible for developing and delivering instrumental music education should, rather, advise students to explore and deliberately practise different ways of carrying out mental practice. The huge influence of contextual factors and individual musicians' skills and tendencies precludes the provision of any simple guidelines to success, but it is likely that the deliberate practice of strategies for mental practice would result in better self-regulation, self-awareness, practice efficacy and imagery abilities (see Clark & Williamon, 2011). In our view, it would be best to teach effective approaches to mental practice in such a way as to recognise musicians' own strengths, but also expanding their understanding of strategic possibilities. The larger their toolkit, and the more experience they have of appropriate, individually-relevant strategies for mental practice, the more choice and metacognitive knowledge musicians will have for effective practice away from the instrument.

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APPENDIX: INSTRUCTIONS FOR CODING THE EYE-MOVEMENT EPISODES

Linear reading	In the visualisation tool, two or more successive fixations for one musical bar.
	Reading of two or more successive bars (one after another)
	May contain relatively fast re-reading of previously read bars within the same "linear reading" sequence when these do not contain excessive time spent on re-reading: difference between selective stopping is an interpretation of the whole sequence.
	May contain individual fixations to other parts of the score: the 1-s sequences allow minor inaccuracies - important to interpret that the sequence overall appears to keep within a selected temporal framework (reading at a certain paste allows individual fixations without confounding the whole sequence)
	The sequence may contain individual bars that only have 1 fixation each, when fixations are relatively long; in such cases, the whole sequence in taken into consideration when deciding between selective stopping and linear reading.
Linear skimming	In the visualisation tool, no, one or two relatively short fixations for one musical bar: difference between linear reading is an interpretation of the whole sequence.
	Fixating on three or more successive or near-successive bars: this to clarify that the sequence is linear and non-linear scanning.
	Can contain skipping of bars while reading.
Non-linear skimming	In the visualisation tool, no, one, two or three fixations for one musical bar.
	Reading not more than two successive bars; typically fixating briefly on bars here and there.
Selective stopping	Time spent on *one, two or three musical bars* that does not fit in the above-mentioned categories (i.e. scanning and then stopping at one bar with three or more fixations, but not reading linearly two or more successive bars so that also the second bar gets more than one fixation.
	Typically consists of repeated reading of selected bar(s) during linear reading, or stops on certain parts of the score during non-linear or linear scanning.
	May contain individual fixations to other parts of the score: the 1-s sequences allow minor inaccuracies - important to interpret that the sequence overall appears to keep within a selected temporal framework (reading at a certain paste allows individual fixations without confounding the whole sequence).
	NOTE: when linear reading starts after a stop, linear reading is considered to start from the leftmost part of the visual area (i.e. leftmost fixation on the leftmost bar). When reading repeatedly bars 17-18 and then continuing linearly, the linear reading starts at the leftmost fixation on bar 17
	NOTE: when stopping after linear reading, the stop is considered to start after the rightmost fixation to the area in question (i.e. from first regression)
Missing data	Sequences lasting 1 second or more in which eye movements were not recorded.