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Effect of processing fluency on metamemory for written music in piano players

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Abstract

We examined the effects of processing fluency on metamemory for written music. In Experiment 1, piano players studied short sequences notated in either treble or bass clef by playing them on a silent keyboard with either their left or right hand, creating a congruent (fluent) and an incongruent (dysfluent) condition (hand/clef match or mismatch, respectively). A subsequent recognition test accompanied by confidence ratings (CRs) gauged retrospective metamemory. Items in the congruent conditions were recognized better (a desirable-difficulty effect), but CRs showed that participants were unaware of this memory difference. In Experiment 2, judgments of learning (JOLs) followed each studied sequence to gauge prospective metamemory. JOLs were higher in the congruent condition, although recognition was unaffected. In Experiment 3, whether the music was fingered on the silent keyboard or not did not influence results. These data are discussed within the framework of metacognitive theories that emphasize the importance of processing fluency.

Keywords

Cognition, consciousness, memory, music cognition, metacognition reading

Music is an auditory phenomenon but is often represented via written notation. Most formally trained musicians rely extensively on written notation to learn and perform music (Reitz, 2014). Research on music cognition, however, has been largely limited to the auditory processing of music (Schellenberg, 2016). In this study, we focus on metamemory for music, also an understudied topic, relying on written notation of music without the aid of the accompanying auditory correlates. Presentation modality matters in memory for language, which is also a primarily auditory phenomenon that can be represented visually (Meijs, Hurks, Wassenberg, Feron, & Jolles, 2015). The modality in which music is learned is even a

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more important issue than in language because of the lack of semantic meaning in the case of music (cf. Patel, 2008), which impedes any mediation between the two modalities in the reconstructive process of memory.

Metacognition refers to people's awareness and knowledge of their own cognitive processes (Kornell & Finn, 2016) and is essential for successful self-directed learning across the lifespan (Efklides, 2016). Arguably the most studied domain within metacognition is metamemory, which concerns those processes related specifically to memory (Dunlosky & Tauber, 2014). Within metamemory for music, Peynircioğlu, Brandler, Hohman, and Knutson (2014) found that ease of learning (EOL) decisions and judgments of learning (JOL) given by musicians indicated that they would learn and remember visually studied materials better than their auditorily studied counterparts. However, the true visual nature of such metamemory decisions remained unclear because participants played the materials on a keyboard and thus had auditory feedback while making their decisions. In another study on metamemory for music, Abushanab and Bishara (2013) examined differences between fixed-order practice and random-order practice in piano players. Although random-order practice led to better performance of rehearsed music, participants indicated that they had learned more from the fixed-order practice. This study too allowed for auditory feedback, however. Indeed, to our knowledge, only a handful of articles have been directed at memory for written musical notation per se (Brodsky & Henik, 2003; Finney & Palmer, 2003; Hoppe et al., 2014). Moreover, there have only been a few studies on metamemory for music in any modality (Korenman & Peynircioğlu, 2004; Peynircioğlu, Rabinovitz, & Thompson, 2008; Peynircioğlu, Tekcan, Baxter, Wagner, & Shaffer, 1998). Thus, in the current study, we examined memory for written music and whether processing written notes without auditory feedback would affect metamemory for that learning. Given the lack of semantic mediation in the context of musical materials, a major goal of this research was to determine if at least some of the mechanisms that underlie metamemory with verbal materials would also underlie metamemory for musical materials when the study environment was visual.

A large body of research points to the role of fluency as an important mechanism underlying metamemory judgments (see Rhodes, 2016; Jemstedt, Schwartz, & Jönsson, 2018, for reviews). Fluency refers to the ease of processing when stimuli are being read, heard, or otherwise perceived (Sungkhasettee, Friedman, & Castel, 2011). The experience of fluency increases participants' ratings in many metamemory judgments, including JOLs, EOLs, post-answer confidence ratings (CR), and feeling-of-knowing judgments (Jemstedt et al., 2018; Jia et al., 2016; Susser & Mulligan, 2015). With few exceptions (e.g. Knoll, Otani, Skeel, & Van Horn, 2016), this research focuses mainly on verbal memory, however. Thus, we look at the effects of processing fluency on written-musical sequences to determine if metamemory judgments will be influenced in a similar manner in this context.

In order to manipulate the fluency of musical stimuli, we presented piano players with written musical sequences in either treble (G) clef or bass (F) clef and asked them to play these sequences with their right or left hand. In written piano music, bass clef is usually played with the left hand, whereas treble clef is usually played with the right hand. In the first two experiments, on some trials the expected hand matched the expected clef (congruent conditions) and on other trials, it did not (incongruent conditions). The assumption was that the items in the congruent conditions would be processed more fluently than those in the incongruent conditions. And to the extent that fluency processing affected musical stimuli similarly to verbal materials, the main prediction was that items in congruent conditions would receive higher metamemory judgments. To avoid auditory feedback, we used a silent electronic keyboard in all experiments.

We expected that piano players would learn bass clef sequences better when playing with their right hand and would learn treble clef sequences better when playing with their left hand. That is, we expected the incongruent conditions to be remembered better than the congruent conditions. This ostensibly counterintuitive hypothesis followed from what is known as the desirable difficulty effect in memory—within limits, we are often better at remembering that which was harder to learn initially (Bjork, 2017). That is, in many situations, what is difficult at the time of learning is easier at the time of test (Kornell & Finn, 2016), presumably because of greater effort expended in processing the more difficult items, which translates to greater depth of processing. However, we expected metamemory to follow fluency instead (Jemstedt et al., 2018; Rhodes, 2016; Rhodes & Castel, 2008). As such, metamemory judgments would be higher when the clef and hand matched, thus resulting in a dissociation between memory and metamemory.

An additional question was whether retrospective metamemory judgments such as post-recognition CRs would also be affected by the fluency manipulations and, if so, whether they would differ from prospective metamemory judgments such as JOLs because here the fluency of processing would involve a test item rather than a to-be-learned item. CRs are made after retrieval has occurred, but JOLs are made during study. As such, although the underlying mechanism might be the same, there is a subtle difference in implications in that, in JOLs, fluency is assumed to influence decisions about facility in learning ("I can play it more fluently therefore I have learned it") whereas in CRs, fluency is assumed to influence already actualized memory decisions ("I played it more fluently therefore my memory was accurate"). With verbal materials, processing fluency has been shown to increase retrospective confidence (Kelley & Lindsay, 1993). However, because the current situation involves a more perceptual rather than semantically reconstructed memory, it could be thought to be more veridical, and hence there might not be much room for confidence variations, which might in turn depress any influence of processing fluency (cf. Dunlosky & Tauber, 2014).

Experiment 1

Method

Participants

The participants were 48 Florida International University students (37 women) who received course credit for participating. Twenty-four participants were trained piano players who had been playing for a mean of 9.6 years (range 1–40 years) and 24 participants were musically illiterate controls. All piano players were able to read and play Minuet in G by Petzold (previously attributed to J. S. Bach) with both hands, which served as our reading threshold test. This piece was chosen arbitrarily, but it represents an easy piece that most players learn to play early in their instruction. Each participant was tested individually on a Macintosh computer during a session that lasted approximately half an hour. This and all studies were approved by the appropriate Internal Review Board.

Materials

Superlab 4 software was used to run the experiment and collect the data. The musical phrases were taken from less well-known classical music scores,[1] entered into MuseScore notation software, and then converted into .jpg files. The reading threshold test was administered on a

Generalmusic WK1000 electric piano. Participants used this piano to finger notes, but the sound was off during the experiment. Fingering was added by the experimenters to minimize any fluency fluctuations that could result from use of different fingerings. Appendix A in online supplementary materials shows all the musical sequences used in the experiment.

Design

The experiment had a 2 (clef: treble or bass) x 2 (hand: left or right) repeated measures design. Playing treble clef with the right hand and bass clef with the left hand were collapsed into a separate *congruent* condition, and playing treble clef with the left hand and bass clef with the right hand were collapsed into a separate *incongruent* condition. Sequences in the congruent condition were assumed to be processed more fluently than those in the incongruent condition. Whether a sequence was in a congruent or an incongruent condition was counterbalanced across two groups of participants, and whether a sequence was used as a target or a distractor stimulus during the recognition test was counterbalanced across two more groups of participants. In distractor sequences, the notation was identical except that one randomly chosen note (though never the first one) was one step higher or lower than the original but still made musical sense. A given sequence of music remained in its original clef for all participants, and the sequences were presented in a single list with congruent and incongruent conditions interspersed randomly for each participant.

Procedure

Participants were tested individually in a session that lasted approximately half an hour. After taking a survey on their musical background and proficiency, they were given the sheet music for Minuet in G by Petzold and asked to play it. All 24 participants included in the analyses as piano players were able to play it without error, thus verifying that they had the required level of competence to participate. There was one major difference between how piano players and musically illiterate participants were treated during the experiment. Piano players were required to play the musical sequences on the keyboard, whereas musically illiterate controls did not play but simply looked at the sheet music. Thus, piano players were actively engaging their motor systems, whereas the musically illiterate controls were not (cf. Schiavio & Timmers, 2016). The experiment was identical for the two groups in all other respects.

Four practice trials occurred before the main experiment. The practice trials were identical in procedure to that of the actual experiment. A two-measure sequence of music was presented to participants for 15 s. Piano players were also required to play it using the hand indicated above the line of notation. After the 15 s of practice, participants engaged in a brief distractor task. The distractor task was designed to prevent rehearsal of notes or fingerings, and participants spent 15 s reading as many letters and numbers as they could from a list of 30 numbers and letters. The numbers were 1, 2, 3, 4, or 5, intended to interfere with any possible mental rehearsal of fingerings shown above the notes, and the letters were A, B, C, D, E, F, or G, intended to interfere with any attempted rehearsal of the names of the notes during the distraction period, and the numbers were presented in a random order after each study item. Following the distractor task, participants were given an old/new (free-choice) recognition test. On half the trials, the musical sequence was the same as the one they had just studied (and the correct response was "old") and on the other half of the trials, it was the lure item for that sequence (and the correct response was "new"). Following recognition responses, participants gave CRs on a 1 to 3 scale, with 1 indicating low confidence and 3 indicating high confidence.

Table 1. Memory performance (proportion recognized) in Experiment 1 as a function of hand played (right, left) and clef indicated (treble, bass). Note that musically illiterate controls did not actually play.

Piano players			
	Right	Left	*M*
Treble	.79	.85	.82
Bass	.91	.81	.86
M	.85	.83	
Musically illiterate controls			
Treble	.78	.79	.79
Bass	.80	.75	.78
M	.79	.77	

Results

In all tables below, congruent trials refer to the means of the treble/right and bass/left conditions, and incongruent trials refer to the means of the treble/left and bass/right conditions.

Recognition results

The results are presented in Table 1. Participants' false alarm rates were minimal in all conditions (less than 5%), and thus only the correct recognitions of targets (hits) are presented. The main question of interest was recognition in the congruent and incongruent conditions, which would indicate the effect of fluency on memory. Recognition in the congruent condition (treble/right combined with bass/left; 80%) was significantly less than that in the incongruent condition (treble/left combined with bass/right; 88%), $t(23) = 2.91$, $p < .05$. Thus, a desirable difficulty effect emerged because less fluently processed items were recognized better.

More detailed analyses showed that there was no effect of hand, $F < 1$. Music played by the right and left hands were remembered equally well. However, there was a main effect of clef, $F(1, 23) = 5.44$, $p < .05$, $MSE = .04$, partial $\eta^2 = .19$, in that bass clef sequences were easier to recognize than treble clef sequences. There was also an interaction, $F(1, 23) = 8.45$, $p < .05$, $MSE = .16$, partial $\eta^2 = .27$. Post-hoc tests showed that this interaction reflected the observation that bass clef sequences played with the right hand were particularly memorable (91%). Thus, the influence of incongruence reported above was mainly because of the bass clef/right hand combination. For the musically illiterate controls, as expected, there was no effect of either hand or clef, nor was there an interaction.

CRs

These results are presented in Table 2. Congruent conditions were not different from incongruent conditions, $t < 1$. The more detailed analyses showed that, for piano players, there was no main effect of hand, $F < 1$. There was an effect of clef, $F(1, 23) = 13.61$, $p < .05$, $MSE = .33$, partial $\eta^2 = .37$, indicating that participants were more confident about their responses to the bass-clef sequences. There was no interaction of hand and clef, $F < 1$. This pattern was also seen in the musically illiterate participants, $F(1, 23) = 8.51$, $p < .05$, $MSE = .61$, partial $\eta^2 = .27$.

Table 2. Retrospective confidence ratings (CR—on a scale of 1–3) in Experiment 1 as a function of hand played (right, left) and clef indicated (treble, bass).

Piano players			
	Right	Left	*M*
Treble	2.64	2.67	2.66
Bass	2.75	2.79	
M	2.71	2.73	
Musically illiterate controls			
	Right	Left	*M*
Treble	2.45	2.48	2.47
Bass	2.67	2.65	2.66
M	2.56	2.57	

Summary and discussion

The recognition results were consistent with some of our hypotheses, but not with others. Recognition memory benefited from desirable difficulty (Bjork, 2017), and performance was higher in the incongruent conditions. Because participants may have had expectations that treble clef is easier to play with the right hand and bass clef is easier to play with the left hand (cf. Mueller & Dunlosky, 2017), or because they were processing these items more fluently and thus deemed them easier to learn (cf. Jemstedt et al., 2018), it is likely that they may have paid more attention to items in the incongruent conditions, which in turn led to better memory. Whether they indeed deemed the congruent items easier to learn was explored directly in the next experiment.

We also observed a general advantage for bass sequences. Because we took our sequences from published music, the bass sequences may have been less complex (or more repetitive, as we were trying for "typical" left-hand music) both visually and musically and thus more likely to be recognized. This was supported by the fact that the musically illiterate participants also showed this effect, even though, not surprisingly, their overall recognition was lower than that of the piano players. Because they could not read music, the fact that they recognized the bass sequences better suggests that the bass sequences were visually simpler.

We expected that, unlike recognition performance, confidence would be higher for music in the congruent conditions. Interestingly, CRs for both piano players and musically illiterate participants showed a boost for sequences written in bass clef, just as in recognition. However, there were indeed some differences between the CR and recognition data. Recognition was higher in the incongruent conditions but CRs were not, consistent with a view that metamemory may be based on factors other than those factors that influence memory and represent a higher-level process (Peynircioğlu & Tatz, 2018; Rhodes, 2016).

Experiment 2

In Experiment 2, we replicated the basic design used in Experiment 1, but to examine whether participants considered congruent items to be indeed easier to learn, we looked at JOLs made after each item was studied, in advance of the recognition test. In addition, the primary goal was to examine if the prospective judgments of JOL for musical sequences were affected in a way similar to the retrospective judgments of CR, or if JOLs would follow the mechanism more commonly seen in the verbal domain and show the typical illusion based on processing fluency (Rhodes & Castel, 2008). Because JOLs are made before the recognition test, they should not be influenced by how people perform during test. Thus, JOLs may reflect the influence of processing fluency associated with learning a sequence directly rather than the indirect way that CRs might have done during the test itself. Other minor differences from the previous experiment included changing the CR scale to 1–6 from 1–3 and making the distractor task more difficult by having participants transpose their responses. Finally, this experiment was done only with piano players.

Method

Participants

The participants were 24 American University students (15 women) who received course credit or $15 for participating. They had been playing the piano a mean of 11.1 years (range 3–20 years), and, as in Experiment 1, passed the screening test by being able to play the Petzold Minuet.

Materials, design and procedure

The materials were identical to those of Experiment 1. The design and procedure were similar except for the following differences. Most critically, participants were given a JOL task after each studied item in which they made a judgment on a 1–6 scale with 1 being *not likely to recognize* and 6 being *definitely able to recognize*. They had 5 s to enter their JOL on the computer keyboard. Other differences included the use of a different piano keyboard (Korg X5D Music Synthesizer) and the CR scale was changed to a 1–6 scale, thereby allowing participants a greater range of responses. To help reduce recognition performance levels, the distractor task was made more difficult. Participants again saw a string of mixed letters (A through F) and numbers (1 to 5). But this time they were asked to transpose the elements in the distractor string by one unit. For instance, if they saw the letter A, they would be required to say B, and if they saw the number 2, they would be required to say 3—and simultaneously press buttons to categorize the numbers and letters (the up arrow was pressed by the right index finger to indicate numbers and the down arrow was pressed by the right index finger to indicate letters). Participants were tested individually on a Dell desktop computer running Windows 8 during a session that lasted approximately half an hour.

Results and discussion

Recognition

The results are presented in Table 3. Recognition in the congruent condition (77%) was not significantly different from that in the incongruent condition (75%). There was again no effect of hand, $F = 1.3$. However, unlike Experiment 1, there was also no main effect of clef, $F = 1.1$, and no interaction, $F < 1$.

Judgments of learning

The results are presented in Table 4. The main question of interest in this experiment was the difference between JOLs in the congruent and incongruent conditions, which would indicate the effect of fluency. JOLs in the congruent condition (4.24) were significantly higher than those in the incongruent condition (3.93), $t(23) = 4.06$, $p < .05$. Thus, more fluently processed items were rated as having been learned better. More detailed analyses as in Experiment

Table 3. Memory performance (proportion recognized) in Experiment 2 as a function of hand (right, left) and clef (treble, bass).

	Right	Left	*M*
Treble	.73	.75	.74
Bass	.74	.81	.77
M	.74	.78	

Table 4. Judgments of learning (JOLs—on a scale of 1–6) in Experiment 2 as a function of hand played (right, left) and clef indicated (treble, bass).

	Right	Left	*M*
Treble	4.24	3.91	4.08
Bass	3.95	4.24	4.10
M	4.10	4.08	

1 indicated no main effect of clef or hand, $Fs < 1$. But, there was an interaction, $F(1, 23) = 16.4$, $p < .05$, $MSE = 2.28$, partial $\eta^2 = .42$. Thus, unlike the CRs in Experiment 1 and as described below, JOLs appeared to be influenced by processing fluency.

CRs

The results are presented in Table 5. With respect to the main question of fluency, there was no effect of congruence. As in Experiment 1, there was no main effect of hand, $F < 1$, but a significant effect of clef, $F(1, 23) = 26.5$, $p < .05$, $MSE = .21$, partial $\eta^2 = .54$. Participants were more confident in their responses to bass-clef sequences. But unlike in Experiment 1, there was also an interaction, $F(1, 23) = 6.8$, $p < .05$, $MSE = 0.8$, partial $\eta^2 = .29$. Post-hoc tests showed that the interaction was driven by the strong confidence for bass-clef sequences played with the left hand in one of the two congruent conditions.

Experiment 3

In Experiments 1 and 2, we tested if metacognitive judgments (CRs, JOLs) would be affected by changes in fluency. To create relative dysfluency, in addition to simply reading the music, we required piano players to play treble clef music with their left hand and bass clef music with their right hand. One caveat was that in Experiment 1, although we had musically illiterate participants to control for the effects of being able to read and thus process the stimuli in a musical sense rather than use visual patterns in making recognition decisions, we did not have a control for whether actual fingering of the sequences affected the results of our piano players beyond simply reading the sequences (cf. Schiavio & Timmer, 2016). Experiment 2 also did not control for the possible influence of the additional motor component in eliciting the results. Thus, an alternative explanation was that participants were responding not to perceived difficulty but to some other aspect of their own motor responses while playing the music silently. In Experiment 3, we had the same piano players simply read the music or read and also finger it on a keyboard. This allowed us to test directly whether invoking motor learning had any additional impact over engaging in silent visual encoding of the musical sequences.

Table 5. Retrospective confidence ratings (CR—on a scale of 1–6) in Experiment 2 as a function of hand played (right, left) and clef indicated (treble, bass).

	Right	Left	*M*
Treble	4.60	4.42	4.51
Bass	4.71	4.90	4.81
M	4.66	4.66	

Table 6. Memory performance (proportion recognized) in Experiment 3 as a function of encoding mode (played, read) and clef indicated (treble, bass).

	Played	Read	*M*
Treble	.85	.80	.83
Bass	.88	.88	.88
M	.87	.84	

Method

Participants

The participants were 24 American University students (14 women) who received course credit or $15 for participating. They had been playing the piano for a mean of 10.7 years (range 4–16 years and passed the same screening test as in the previous two experiments.

Materials, design, and procedure

The materials were identical to those of the previous two experiments. The design was similar except that instead of the "hand" factor, we had a "study type" factor. Thus, it was a 2 (clef: treble or bass) x 2 (study type: read or play) repeated measures design. The procedure was identical to that of Experiment 1 with two exceptions. First, participants played half of the music sequences on a silent keyboard, but simply read the other half; the to-be-read and to-be-played items were intermixed randomly in a single list. Second, all sequences were played with the expected hand (and therefore, we did not have a fluency manipulation in this study). As in Experiment 2, JOLs and CRs were also obtained, and each participant was tested individually on a Dell desktop computer running Windows 8 during a session that lasted approximately half an hour.

Results and conclusion

The results are presented in Tables 6, 7, and 8. In terms of our main question, there were no effects of playing versus reading in terms of recognition, $F < 1$, JOLs, $F = 1.22$, or CRs, $F < 1$. Thus, the results were collapsed for other analyses. Similar to the results of Experiment 2, there were no effects of clef on either recognition, $F = 2.19$, or JOLs, $F < 1$, but unlike in Experiment 2, there were no effects on CR, $F = 1.21$, either. There were no interactions between playing vs. reading and clef for any measures, all Fs < 1. It appeared that, for present purposes, the motor activity engaged in fingering the sequences did not produce a difference compared to just reading the sequences. Thus, any differences in these measures in Experiments 1 and 2 can be attributed to fluency (of reading or playing) rather than some other effect elicited by motor activity.

Table 7. Judgments of learning (JOLs—on a scale of 1–6) in Experiment 3 as a function of encoding mode (played, read) and clef indicated (treble, bass).

	Played	Read	*M*
Treble	4.61	4.56	4.59
Bass	4.49	4.72	4.61
M	4.55	4.65	

Table 8. Retrospective confidence ratings (CR—on a scale of 1–6) in Experiment 3 as a function of encoding mode (played, read) and clef indicated (treble, bass).

	Played	Read	*M*
Treble	4.70	4.64	4.67
Bass	4.91	4.74	4.83
M	4.81	4.69	

General discussion

We were interested in the effects of processing fluency on memory and metamemory for written musical sequences. To study this, we presented participants with short musical sequences written in either treble or bass clef. Piano players were instructed to play the sequence on a silent piano keyboard with either their left or right hand. This allowed us to manipulate fluency by matching or mismatching hand with clef. Because the treble clef is usually played with the right hand on the piano and the bass clef is usually played by the left hand, we anticipated that congruent sequences (right hand/treble clef and left hand/bass clef) would be processed more fluently when reading the music than incongruent sequences (left hand/treble clef and right hand/bass clef). This hypothesis was supported by the JOLs in Experiment 2 in which congruent sequences were given higher JOLs than incongruent sequences, showing that, just as with verbal materials, processing fluency can influence metamemory judgments, as well.

For CRs, we did not find a similar fluency pattern. Instead, there was a bias to give the judgments pertaining to bass-clef sequences higher confidence. This pattern in CRs may have occurred because participants had direct feedback from their recognition experience, allowing fluency effects at encoding to be discounted (e.g. Dunlosky & Tauber, 2014). Higher confidence for bass-clef sequences was consistent with the better recognition shown for bass-clef sequences in Experiment 1, but not in Experiments 2 and 3. Indeed, with respect to recognition, too, we obtained inconsistent results across experiments. In Experiment 1, a "desirable-difficulty" effect was observed, that is, recognition was higher in incongruent conditions than congruent ones, but this was not seen in Experiment 2 and 3.

In Experiment 3, we ruled out that the observed effects were influenced by differences between motor learning and reading (Schiavio & Timmer, 2016), as the additional motor component affected neither recognition performance nor either of the metamemory judgments. Thus, despite the importance of kinaesthetic considerations in music processing in general (Miller, 2016), they did not seem to matter in the current study. We should note that any motor representation can indeed affect music processing (Leman, Maes, Nijs, & Van Dyck, 2018), and what the fingers, hands, and arms do during playing can act as additional memory or metamemory cues. The focus of the present study, however, was specifically on the effects of visual fluency, and within this realm of relatively short sequences and limited study time, motor processing did not seem to have an additional effect. It would be interesting to pursue kinaesthetic fluency itself as a future direction along with how cues from the three different modalities (auditory, visual, kinaesthetic) might be integrated to help memory and metamemory processes.

We would like to return to the finding that congruence between hand and clef was not critical in influencing participants' confidence levels in their recognition responses and thus processing fluency did not appear to influence CRs. Instead, participants were more confident in recognizing bass-clef sequences, regardless of hand. Because this effect was also found with musically illiterate participants, it suggests that the higher CRs for bass clef sequences were a function of the simpler visual patterns of the bass-clef sequences, at least in Experiment 1. This visual simplicity may then be considered to be a fluency effect, but it is a visual fluency effect rather than one based on the fluency of processing the music in its written form. Because CRs are retrospective judgments, made after the memory decision, they often differ from judgments made prospectively before memory is tested (Jemstedt et al., 2018). In particular, participants have access to the output of their memory system. Thus, retrieval fluency, rather than the fluency at encoding, may have a stronger effect, drowning out the effects of congruence or encoding fluency (e.g. Dunlosky & Tauber, 2014; Undorf, Söllner, & Bröder, 2018). Jemstedt et al. discuss the concept of the cue landscape. The cues that are accessible to the metacognition system change across learning and retrieval processes. Although processing fluency may be critical for ease-of-learning judgments and JOLs, other information (e.g. feedback from memory performance, ease of retrieval) may matter more for CRs. This can account for why the congruence between hand and clef mattered for JOLs, but not for CRs. The reason that the same findings were not obtained in Experiments 2 and 3 may be the inclusion of the JOL ratings during the study phase, which may have in turn led the participants to no longer consider fluency as a factor while making the post-recognition judgments.

With respect to the recognition data, we expected better memory when sequences were not played with the typical hand because of what we know about desirable difficulty—material that is initially difficult is often easier to remember later than material processed more easily (Bjork, 1994; 2017). Although this was exactly the pattern found in Experiment 1, it did not replicate in Experiment 2. One possible explanation for this difference is the fact that participants made JOLs before proceeding to recognition in Experiment 2 but not Experiment 1. This may have served as an extra study session, erasing some of the advantages of the incongruent condition. In addition, giving JOLs have been shown to sometimes change the learning process itself (Mitchum, Kelley, & Fox, 2016). Thus, it may be that in this case, too, making the JOLs sufficiently altered the participants' learning and thus obscured a desirable difficulty effect. Alternatively, JOLs may have prompted participants to engage in control strategies that increased their focus on all items and therefore the desirable difficulty effect may have washed out (Tauber, Dunlosky, & Rawson, 2015).

In summary, one major finding was that JOLs for written musical sequences were influenced by processing fluency. When participants played incongruent sequences (those normally played with their left hand with their right hand and vice versa), lower JOLs were observed than when they played congruent sequences, probably because the mismatch interfered with the fluent processing of those sequences. We also found that piano players judged sequences written in the bass clef to be more memorable even when they were not (Experiment 2), possibly because bass clef piano music presents simpler visual patterns. These effects occurred even though the piano players did not hear what they were playing. Thus, this music-driven effect was found in the absence of auditory stimuli. The written musical notation was sufficient to activate musical representations for the participants. Very few studies have looked at silent musical reading (but see Reitz, 2014). Indeed, it is interesting both theoretically and practically to know how literate musicians process written musical notation in the absence of sound. This preliminary investigation into the study of written-music processing suggests that at least with respect to metamemory, silent reading of music also activates musical representations and possibly motor plans as well.

The psychological issues addressed in this paper have direct analogs for both optimizing music pedagogy and performance. In education, learning to read music notation is important for any beginning musician, but learning to memorize sequences of music is also essential to musicians. Indeed, any student wishing to gain admittance to a top conservatory must memorize many hours of music. Similarly, for professionals, music reading is a necessity, but top performances often mean memorizing music so that the sheet music is not a distraction. Thus, looking at the role of reading and memorization in music is critical. One caveat was that the short, single-line sequences that were used in our study did not reflect real-world situations. A future direction may be to use longer, and therefore more realistic, sequences requiring the learning of both lines. Nonetheless, within this realm, understanding the role of metamemory is essential because people use such decisions as JOLs and CRs as an index of whether something has been sufficiently learned and rely on these judgments to control future memory strategies (e.g. Bjork, 1994; Dunlosky & Tauber, 2014).

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Supplemental material

Supplemental material for this article is available online.

Notes

1 The music was adapted from those available at http://www.allpianoscores.com site.

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