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The influence of musical relatedness on timbre discrimination

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Musical priming research has reported that sensory consonance/dissonance judgements for a target chord were faster when targets were musically related to a musical prime context. The present study extended this context effect to a timbre discrimination task. This new task allowed us to investigate whether musical priming results from congruency effects similar to those reported in other domains. Targets were played with two musical timbres and were either strongly related (i.e., tonic chord) or less related (i.e., subdominant chord) to the prime context. In three experiments, timbre discrimination judgements were always faster for related targets than for less-related targets. This finding establishes that musical relatedness influences the processing of timbres and suggests that this priming effect does not derive from response biases due to congruency effects. Using a timbre discrimination task in musical priming studies offers other methodological advantages and controls, which are discussed in the final section.

For language, objects, and music, it has been established that a prime context influences the processing of a target event. For language, the processing of a target word is facilitated when it is preceded by a semantically related prime word in comparison to an unrelated one (e.g., Meyer & Schvaneveldt, 1971).

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In a similar way, musical target processing is facilitated after a musically related prime context in comparison to an unrelated one (e.g., Bharucha & Stoeckig, 1987; Bigand & Pineau, 1997). In semantic priming research, theoretical frameworks have proposed priming explanations based on either prelexical influences (i.e., perceivers' semantic knowledge stored in memory; Collins & Quillian, 1969) or postlexical influences linked to participants' strategies with experimental task and situation (e.g., Duscherer & Holender, 2003; Klinger, Burton, & Pitts, 2000; Naccache & Dehaene, 2001; Reynvoet, Caessens, & Brysbaert, 2002). In musical priming research up to now, priming data have been interpreted solely in terms of automatic activation of listeners' musical knowledge (e.g., Bharucha, 1987; Tillmann, Bharucha, & Bigand, 2000), but eventual task-specific influences and response strategies have not been investigated yet. Our present study addresses this issue for musical priming with the goal to provide further evidence for listeners' knowledge of musical relations.

In the musical priming paradigm, the experimental factor of interest consists in manipulating the musical relationship between the prime (one chord or a chord sequence) and the target. The target is related or unrelated to the previous context according to the rules of Western tonal music (i.e., YES or NO related). For example, in studies by Bharucha and colleagues (Bharucha & Stoeckig, 1986, 1987; Justus & Bharucha, 2001; Tekman & Bharucha, 1992, 1998; Tillmann & Bharucha, 2002) prime chord and target chord belonged to the same tonality (related condition) or not (unrelated condition). In studies by Bigand and colleagues (Bigand, Madurell,Tillmann, & Pineau, 1999; Bigand & Pineau, 1997; Bigand, Poulin, Tillmann, & D'Adamo, 2003; Tillmann & Bigand, 2001; Tillmann, Bigand, & Pineau, 1998; Tillmann, Janata, Birk, & Bharucha, 2003), target chords ending musical sequences acted as either the most referential event of the tonality (tonic chord) or a less referential event (i.e., subdominant), which still belong to the tonality of the context. In other words, the targets are (YES response) or are not (NO response) the most referential event of the tonality of the context. Participants are never informed about the manipulation of the musical relatedness, but were required to make speeded accuracy judgements on a perceptual feature of the target, notably its sensory consonance/dissonance. For half of the experimental trials, target chords were rendered either out-of-tune (Bharucha & Stoeckig, 1986, 1987; Tekman & Bharucha, 1992, 1998) or dissonant by adding a nondiatonic tone (Bigand et al., 1999; Bigand & Pineau, 1997; Tillmann et al., 1998). In both situations, target chords sound either sensory consonant or dissonant, and participants have to respond as fast and as accurately as possible whether the target was consonant or dissonant (i.e., YES or NO consonant). This experimental setting mirrors the word/nonword lexical decision task used in psycholinguistic research (i.e., YES, it is a word or NO, it is not a word): Participants focus on the orthography of the target word without being required to pay attention to the preceding prime context.

In psycholinguistic research, semantic priming has been explained not only by the automatic activation of perceivers' semantic knowledge, but congruency effects and response competition models have been proposed (Duscherer & Holender, 2003; Holender, 1992; Klinger et al., 2000). In priming studies using the lexical decision task, the congruency concerns the detected relation between words (i.e., YES, they are related vs. NO they are not related) and the requested (binary) response (i.e., YES, it is a word vs. NO, it is not a word). A congruency relation speeds up positive lexical responses for related trials (i.e., YES a word and YES related) and slows down positive responses for unrelated trials (i.e., YES a word, but NO unrelated). The decision biases linked to congruency detections in binary responses might thus enhance semantic priming effects based on other components (e.g., prelexical ones like automatic spreading activation). More generally, when the prime context varies on the same dimension as the dimension of the experimental task, the prime influences the target judgement. Klinger et al. (2000) reported that lexical relationships between prime and target (i.e., word vs. nonword) influence lexical decision judgements, but not affective judgements—while affective relationships between prime and target (i.e., positive vs. negative) influence affective judgements, but not lexical decision judgements.

Congruency effects result from an overlap between the response types in the experimental task and the contextual manipulation between prime and target. They may thus occur in the music domain as well. Most of musical priming research has used the sensory consonance task, which might confound true priming effects (accounted in terms of activation of musical knowledge) and congruency effects. Indeed, a striking observation is that priming effects are most of the time modulated by the target type. In-tune (consonant) targets are processed faster and more accurately when they are related to the prime context. This priming effect tends, however, to be less pronounced for the out-of-tune (dissonant) targets. More troublesome, in some experiments opposing related to unrelated primes (e.g., Bharucha & Stoeckig, 1987; Tillmann et al., 1998) priming effects for out-of-tune (dissonant) targets are even reversed, leading to crossover interactions between target type and musical relatedness. In these cases, the prime's influence is reflected in a response bias (i.e., a tendency to judge chords to be in-tune when musically related to the prime and out-of-tune when unrelated) and in an increased sensitivity to the chord's intonation (i.e., shorter response times for in-tune targets when related and for out-of-tune targets when unrelated). This interactive effect observed between target type and musical relatedness suggests that musical priming effects may result from congruency effects similar to those described in semantic priming studies (e.g., Duscherer & Holender, 2003; Holender, 1992). In the speeded consonance task, a related, consonant target is a congruent trial and a consonant, unrelated target is an incongruent trial. In the congruent trial, responses to consonant targets (i.e., YES, a well-sounding chord) are speeded up since they are related to the context (i.e., also evoking a YES response). In an incongruent trial, however, the requested YES-response to the consonant target is slowed down since the target is unrelated to the context (i.e., evoking a NO-response). For musical priming with the speeded consonance task, this congruency effect might be enhanced by the nature of the to-be-given judgement and the experimental manipulation, which both concern the same acoustical dimension. The musical unrelatedness creates a contextual dissonance, which might either reinforce the dissonance of the target (congruent trial) or enter in conflict with the consonance of the target (incongruent trial). That is to say, responses are faster for targets that are sensorially and contextually consonant (or dissonant) and slower for targets that are sensorially consonant, but contextually dissonant (and vice versa). A similar concern applies for finer musical manipulations since less-related targets with less important functions evoke a feeling of incompleteness and the listener's desire for the music to continue. The feeling of incompletion (or remaining "dissonance") might be either in agreement or in conflict with the task-relevant feature of consonant or dissonant targets. These conflicting or agreeing indications might thus create response biases for the requested intonation judgements. In sum, the traditional interpretation of musical priming data in terms of an automatic activation of musical knowledge can be challenged by an interpretation in terms of congruency effects.

The present study attempts to replicate musical priming effects with an experimental procedure that aimed to reduce eventual response biases linked to congruency effects. A new priming task based on musical timbre discrimination was defined. This experimental situation contained only musically *legal* events (i.e., no mistuned or dissonant events), for which the choice of YES or NO responses was not required. Participants had to decide whether the target was played by one of two musical timbres (named TimbreA and TimbreB). Furthermore, combining the priming paradigm with a task based on timbre processing allowed us to investigate whether musical relatedness influences the processing of the harmonic spectrum of a sound (i.e., one of the acoustic characteristics distinguishing musical timbres). Up to now, musical priming research has mainly used the sensory consonance task, which demonstrated the prime contexts' influence on the processing of acoustical roughness, but not of other features of musical chords.

EXPERIMENT 1

In Experiment 1, the prime context was played with a musical timbre A and the target with either TimbreA or TimbreB. The participants' task was to indicate whether the target was played by TimbreA or TimbreB. On the basis of previous priming data, we expected facilitated processing for related over less-related targets played by both timbres. This variant of the timbre discrimination task allowed us to include one condition of the previously used sensory consonance task: TimbreA trials (i.e., with the target being played with the same timbre as the context) were physically identical to consonant trials of the sensory consonance task (i.e., with the entire context containing consonant chords only). Additionally, TimbreA trials were the closest to classical listening situations of music, creating a continuously sounding sequence without acoustic alterations for the target.

Method

Participants. Twenty-nine students of the University of Lyon participated in Experiment 1. Number of years of musical training, as measured by years of instrumental instruction, ranged from 0 to 14, with a mean of 2.8 ($SD = 3.6$) and a median of 2.

Material. The material of Bigand et al. (2003) was used, it was constructed as follows: 12 different six-chord sequences (in each of the 12 major keys) were completed with two endings (seventh and eighth chords) resulting in 24 eight-chord sequences. In the related context, the two final chords had the function of a dominant followed by a tonic, in the less-related context they functioned as a tonic followed by a subdominant. For both contexts, the eighth chord defined the target and never occurred in the prime context (among the first seven chords). The stimuli were created in MIDI with Digital Performer 3.01 Software (Mark of the Unicorn) and played with timbres from a Yamaha S03 synthesiser. The prime context was played with an acoustic piano timbre (XG002), and the target with either the piano timbre or a harp timbre (XG047). The harp timbre was mainly chosen because its attack time was comparable to that of the piano, and this feature allowed avoiding rhythmic changes between context and target (i.e., keeping constant the sequence's isochrony up to the last chord). Each of the prime chords sounded for 620 ms, the target for 2000 ms and the interchord interval was set to 0. The stimuli were recorded with SoundEdit16 Software (MacroMedia) and the experiment was run on PsyScope Software (Cohen, MacWhinney, Flatt & Provost, 1993).

Procedure. The experiment contained two phases. In the first phase, participants were trained to differentiate between the timbres with 24 single chords and four chord sequences. In this timbre discrimination task, participants were asked to judge as quickly and accurately as possible whether the isolated chord (or the last chord of the sequence) was played by TimbreA or TimbreB by pressing one of two keys. TimbreA referred to the acoustic piano and TimbreB to the harp. TimbreA was defined as sounding rather "bright" and TimbreB as rather "dull". Example chords for each timbre were presented at the beginning. For the chord sequences, participants were informed that the first seven chords were also played by TimbreA. In the experimental phase, participants judged the timbre of the target with chord sequences only. Presenting the 24 experimental sequences (12 related, 12 less related) with both timbres resulted in 48 trials that were presented in random order for each participant. In both phases, an incorrect response was accompanied by an alerting feedback signal and a correct response stopped the sounding of the target. The target was followed by a 250 ms noise mask, and the next trial started when participants pressed a third key.

Results

Percentages of correct responses and response times of correct responses were analysed by two 2×2 ANOVAs with musical relatedness (related/less related) and target timbre (TimbreA/TimbreB) as within-subject factors. Performance in the timbre discrimination task (Table 1) was overall high, but tended to be better for TimbreB than for TimbreA, $F(1, 28) = 3.83$, $p = .06$. There were no significant effects for accuracy. For correct response times (Figure 1), the main effect of musical relatedness was significant, $F(1, 28) = 13.62$, $p < .001$, and interacted with target timbre, $F(1, 28) = 7.53$, $p < .05$. Response times were faster for related targets than for less-related targets. This difference was significant for TimbreA, $F(1, 28) = 11.93$, $p < .01$, and only marginally significant for TimbreB, $F(1, 28) = 3.80$, $p = .06$. Overall, response times were faster for TimbreB than for TimbreA, $F(1, 28) = 36.41$, $p < .0001$. An ANOVA with chord sequences as random variable confirmed the main effect of musical relatedness, $F_2(1, 11) = 23.07$, $p < .001$, the main effect of target timbre, $F_2(1, 11) = 134.40$, $p < .0001$, and their interaction, $F_2(1, 11) = 9.93$, $p < .01$.

TABLE 1
Percentages of correct responses for targets played by TimbreA and TimbreB in related and less-related contexts in Experiments 1, 2a, and 2b

	Experiment 1		*Experiment 2a*		*Experiment 2b*	
	TimbreA	*TimbreB*	*TimbreA*	*TimbreB*	*TimbreA*	*TimbreB*
Related	86.5	90.2	85.7	84.1	94.7	93.0
	(2.2)	(2.1)	(2.4)	(2.0)	(1.5)	(1.9)
Less related	87.6	91.7	90.2	84.4	96.7	95.3
	(2.1)	(1.8)	(2.3)	(3.8)	(1.8)	(1.7)

TimbreA and TimbreB refer to the response options for participants in the timbre discrimination task. They were played by different instruments in the three experiments (see Method sections). Standard errors are in parentheses.

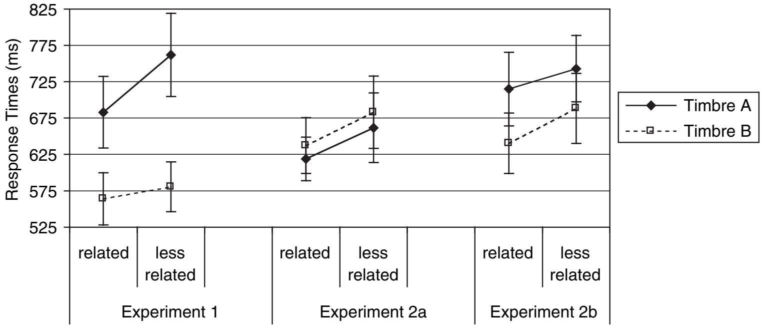

Figure 1. Correct response times for targets played by TimbreA and TimbreB in related and less-related contexts in Experiments 1, 2a, and 2b. Note that TimbreA and TimbreB refer to the response options for participants in the timbre discrimination task and that they were played by different instruments depending on the experiment (see Method sections).

Discussion

Experiment 1 replicated the musical priming effect with a timbre discrimination task: Target processing was facilitated after related prime contexts in comparison to less-related prime contexts. However, once again an interaction between target type and musical relatedness was observed, with a stronger context effect when the target was played with the same timbre as the prime context (TimbreA) than when the timbre changed (TimbreB). This interaction between target type and musical relatedness cannot be explained by the automatic activation of listener's tonal knowledge. As a consequence, it suggests the influence of other processes in this experimental setting. In light of the discussed congruency effects, it might indeed be argued that this version of the timbre discrimination task has become a deviant detection task for participants (i.e., contrasting the responses YES "same timbre" and NO "different timbre"). In terms of congruency detection, the positive answer for TimbreA (YES, same timbre) would be congruent with the related context, but incongruent with the less-related context (NO, not well-ending), leading to longer response times for the less-related context and thus enhancing the observed relatedness effect. In sum, priming and congruency effects were likely to combine in Experiment 1, leading to an interaction between target type and musical relatedness. An alternative interpretation of this interaction focuses on the used timbres: Playing the target with the same timbre as the context created a continuous, coherent sequence, while changing the timbre of the target created a disruption in the acoustical surface. The stronger priming effect for TimbreA (no timbre change) than for TimbreB (timbre change between context and target) suggests that the timbral continuity and the more continuously sounding sequence strengthened the influence of musical relatedness on chord processing.

In order to remove these potential influences other than knowledge-based influences, the timbre discrimination task was instantiated in two different ways in Experiments 2a and 2b. Both timbres of the targets were now different from the timbres of the prime context. In Experiment 2a, the prime context was played with one musical timbre and the target with one of two other timbres. Consequently, both targets represented a timbral change with the context. In Experiment 2b, the prime context was played by a set of different timbres and this timbral variety avoided a disruption specific to the transition between the last prime chord and the target. Moreover, changing the timbre for each chord of the context added a supplementary control that none of the target timbres could be more similar to the timbre of the prime context. With these new variants, the timbre discrimination task could no longer be transposed into a binary judgement on the target (i.e., YES or NO responses), which could interfere with the influence of the manipulated musical relatedness. We expected facilitated processing for the related tonic chord and, more specifically, we now expected parallel context effects for targets played by TimbreA and TimbreB.

EXPERIMENT 2A

Method

Participants. Twenty-three students of the University of Lyon participated in Experiment 2a. Number of years of musical training, as measured by years of instrumental instruction, ranged from 0 to 14, with a mean of 2.2 ($SD = 3.4$) and a median of 0.

Material. The material of Experiment 1 was used, with the exception that targets were played either by the harp timbre or by an electric piano timbre (XG006), which had attack times comparable to that of the acoustic piano (i.e., the timbre of the prime context). The sequences were recorded as described in Experiment 1 and the experiment was run using PsyScope software (Cohen et al., 1993).

Procedure. The two phases proceeded as described in Experiment 1, except that TimbreA referred to the electric piano and TimbreB to the harp. Participants received the same instructions as in Experiment 1, except that for chord sequences participants were informed that the first seven chords were played by a piano-like sound.

Results

Percentages of correct responses and response times of correct responses were analysed by two 2×2 ANOVAs with musical relatedness (related/less related) and target timbre (TimbreA/TimbreB) as within-subject factors. Performance was high overall (Table 1), with performance for TimbreA being slightly better than for TimbreB, but the main effect of target timbre did not reach significance, $F(1, 22) = 2.89$, $p = .10$. For accuracy, no effects were significant. Analyses of correct responses times (Figure 1) revealed only a significant main effect of musical relatedness, $F(1, 22) = 5.8$, $p < .05$; with faster response times for related than for less-related targets. An ANOVA with chord sequences as random variable confirmed this main effect of musical relatedness, $F_2(1, 11) = 8.6$, $p < .05$. This version of the timbre discrimination task, in which both target timbres were deviant from the prime timbre, replicated the musical priming effect. Chord processing was facilitated when the target was related to the prime context and the observed relatedness effect was as strong for TimbreA as for TimbreB.

EXPERIMENT 2B

Method

Participants. Twenty-five students of the University of Lyon participated in Experiment 2b. Number of years of musical training, as measured by years of instrumental instruction, ranged from 0 to 13, with a mean of 2.4 ($SD = 2.9$) and a median of 2.

Material. Sequences of Experiment 1 were used, but with the first seven chords played by different timbres. To increase sound complexity and variety, each of the prime chords was played by two timbres: The first timbre defined the attack of the sound and the second timbre the sustained portion of the sound (e.g., the attack of an acoustic piano was followed by the sustained part of a trumpet sound). Different associations were used on the basis of 10 timbres: organ, guitar, piano, harpsichord, trumpet, oboe, muted trumpet, clarinet, flute, and koto (a Japanese chord instrument). To create the set of experimental sequences, the sound combinations were attributed differently to the prime chords. An example of the used prime contexts contained the following chaining of timbre combinations for the seven chords: organ/trumpet, guitar/oboe, piano/muted trumpet, koto/trumpet, piano/clarinet, koto/flute, guitar/oboe. For the timbre discrimination task, the target was played by either an electric piano sound or a harpsichord sound. In contrast to prime timbres, target timbres were not based on sound combinations, but were unmodified instrument sounds, which had not occurred as such in the prime context. The banks of sound samples were chosen from Miroslav Vitous Symphonic Orchestra samples (monophonic instruments) and Wizoo (polyphonic instruments). The sequences were created with the software Cubase 5.1 (Steinberg) and a Halion sampler

(Steinberg). Sound examples are available at http://olfac.univ-lyon1.fr/unite/equipe-02/tillmann/sound_examples.html. The experiment was run on PsyScope Software (Cohen et al., 1993).

Procedure. The two phases proceeded as described in Experiment 1, except that 48 single chords were presented in the training phase and that participants were informed that the first seven chords of the sequences were played by different combination of instruments. For the task, TimbreA referred to the electric piano and TimbreB to the harpsichord. No verbal labels were proposed.

Results

Percentages of correct responses and response times of correct responses were analysed by two 2×2 ANOVAs with musical relatedness (related/less related) and target timbre (TimbreA/TimbreB) as within-subject factors. Performance (Table 1) was similarly high for both timbres, and no effects were significant. Analyses of correct response times (Figure 1) showed a significant main effect of musical relatedness: Response times were faster for related targets than for less-related targets, $F(1, 24) = 9.56, p < .01$. Additionally, response times were faster for TimbreB than for TimbreA, $F(1, 24) = 29.71, p < .001$. The two factors did not interact ($F < 1$). An ANOVA with chord sequences as random variable confirmed the main effects of musical relatedness, $F_2(1, 11) = 5.1, p < .05$, and target timbre, $F_2(1, 11) = 17.04$, $p < .01$. Experiment 2b extended previously observed priming effects to musical sequences played by different instruments. As for Experiment 2a, the relatedness effect did not interact with the target timbre. The faster response times for TimbreB might be linked to the slightly sharper attack of the harpsichord timbre in comparison to the electric piano timbre (i.e., TimbreA). This observation shows the sensitivity of response times to acoustic features of target events, but most importantly for the present study, this speed difference did not interact with the priming effect.

Discussion of Experiments 2a and 2b

In Experiments 2a and 2b, both target timbres were different from the timbres of the prime context. In terms of timbral continuity of the overall sequence, both timbres were thus deviant from the context. These versions of the timbre discrimination task replicated the musical priming effect: Chord processing was facilitated when the target was related to the prime context in comparison to when it was less related. In addition, the strength of the relatedness effect was similar for the two target timbres suggesting that congruency effects did not interfere with the effect of musical context. Experiment 2 adds evidence that musical priming effects can be observed despite the timbral change between prime context and target. This observation suggests that musical priming may occur between events of different auditory streams. Indeed, changing the harmonic spectrum of a sound contributes to segregate this event from a current auditory stream (Bregman, 1990). Perceiving the target chord as belonging to a different stream than the prime context still results in priming, even if the observed facilitation is reduced in comparison to the coherent, continuous sequences in Experiment 1 (i.e., context and target being played by the same TimbreA). This observation is also valid for Experiment 2b, with timbres being changed for each chord of the prime context. Despite these changes in the acoustical surface, listeners seem to process automatically the prime sequence as a whole. They extracted the tonality underlying the prime sequence and developed expectations for further incoming events. These expectations then influenced the processing of the target event as a function of its relatedness to the prime's tonality. The variations in the acoustical surface (Experiment 2b) did not diminish the musical relatedness effect on target processing in comparison to a smooth continuous prime context (Experiment 2a).[1] In contrast to these musical priming data, studies in language perception have reported that extracting the meaning of a message (i.e., a written or a spoken word) is more difficult with changing letter representation or voices across items. For speech perception, word recognition is influenced by talker variability with lower performance for multiple-talker lists than for single-talker lists (Bradlow & Pisoni, 1999; Ryalls & Pisoni, 1997). In reading, naming performance is slowed down for low-frequency words written with different typography (e.g., AlTeRnAtInG CaSe; Besner, 1989), even if the word superiority effect persists (McClelland, 1976).

GENERAL DISCUSSION

The present study introduced a new priming task based on timbre discrimination to study musical relatedness effects in chord sequences. The change in task had several methodological and theoretical implications. First, the fact that the timbre discrimination task replicates the musical priming effect obtained up to now with the sensory consonance task demonstrates that musical relatedness influences the processing of sensory qualities of chords other than acoustical roughness. Taken in combination with other recent data showing that musical priming also affects the

[1] A meta-analysis combining Experiments 2a and 2b was run with relatedness and target timbre as within-subject factor and context type (same timbre/different timbres) as between-subjects factor. This analysis confirmed the main effects of relatedness, $F(1, 46) = 14.27$, $p < .001$, and of target timbre, $F(1, 46) = 16.03$, $p < .001$. The factor context type interacted only with target timbre, $F(1, 46) = 4.57$, but not with relatedness ($F < 1$), indicating that the difference between related and less-related targets was not influenced by the different realisations of the prime context.

semantic processing of words in sung music (Poulin-Charronnat, Bigand, Madurell, & Peereman, 2005b), the present study contributes to generalise the effect of musical relatedness to a large set of processing steps in chord perception. More specifically, the timbre discrimination data suggests that spectral processing is one of the perceptual processes influenced by musical relatedness and thus leads to faster response times in the experimental task. Future psychoacoustic experiments have to specify the influence of musical expectations on perceptual processes involved in chord processing (e.g., detection threshold, pitch height encoding, spectral processing).

The critical point of our study was to provide evidence that musical priming effects cannot be reduced to the sole influence of congruency effects. Up to now, most of musical priming studies have used sensory consonance judgements that involve a YES or NO response (the chord is consonant or not), and these response possibilities were likely to overlap with the factor of interest (YES or NO musical relatedness between prime and target). Interpretation of the data in terms of congruency effects was notably based on the previously reported interactions between target type and musical relatedness (e.g., Bharucha & Stoeckig, 1987). The use of a timbre discrimination task presents the advantage to avoid YES or NO responses, notably when the timbres of the targets differ from the timbre of the prime context. The critical point of our finding was that the effect of musical relatedness was of comparable strength for both target timbres in Experiments 2a and 2b. Using two different timbres for the targets aims to discourage an eventual reinterpretation of the experimental task as a binary choice (YES vs. NO) and led to context effects of similar strengths for both targets.[2] This outcome for musical priming can be compared to semantic priming effects of comparable strength when target responses are not associated to YES or NO responses. Duscherer and Holender (2003) reported congruency effects in tasks with binary responses (i.e., is the target word a food item, yes or no?), but reported parallel priming effects for what they referred to as "neutrally valenced responses" (i.e., is the target word a food item or a manufactured item?). Duscherer and Holender investigated the influence of congruency effects in semantic priming with different tasks. Our study investigated the influence of congruency effects in music with different variants of the timbre discrimination task. The following restriction is specific for music: Even if congruency effects

[2] The choice of the target timbres (i.e., their respective similarity and their similarity to the prime timbre) seems to be crucial for the task and the observed data pattern. When one of the two target timbres is more different from the prime timbre than the other, a deviant detection situation similar to that in Experiment 1 might emerge, which then would lead to a stronger priming effect for the target with the timbre more similar to the prime timbre. In Experiments 2a and 2b, no significant interactions between harmonic relatedness and target timbres were observed; this outcome suggests that in these versions of the timbre discrimination task participants did not adapt a specific strategy, which would have led them to choose one timbre as the referent (YES) and the other timbre as the deviant (NO).

might boost the relatedness effect for TimbreA targets in Experiment 1, the stronger relatedness effect might also be due to the fact that sequences ending on TimbreA targets represent the most continuous chord sequences and are the closest to a natural listening situation of music.

Extending the priming data to a timbre discrimination task adds new evidence for the cognitive component of musical priming (Bigand et al., 2003; Bigand, Tillmann, Poulin-Charronnat, & Manderlier, 2005; Poulin-Charronnat, Bigand, & Madurell, 2005a; Tillmann et al., 2003). First, the musical priming effect persisted even when possible influences of congruency have been controlled with the timbre task variations. Second, the data suggest that priming effects are not overrun by perceptual processes like auditory streaming and that the harmonic structures of a musical sequence (i.e., tonality and chord functions) are automatically processed despite constantly changing timbres (Experiment 2b). Observing musical priming effects despite the acoustical discontinuities points to the implication of higher level processes in abstraction of the acoustical surface of the sound. This finding contributes to highlight the strength of cognitive processes in harmonic perception in Western listeners, even in listeners who have not received explicit musical training.

The study furthers our understanding of listeners' perception of musical structures and notably the formation of musical expectations. For music perception, expectations do not only influence speed and efficiency of processing, but have been attributed a role for musical expressivity and emotion (Meyer, 1956). Musical priming provides an experimental tool to investigate the role of expectations in music perception (Justus & Bharucha, 2001; Tillmann & Bigand, 2005). It might be argued that listening to perceptual changes in timbre as in our experiments is unusual in real music. First, it is important to note that Experiment 1 also used continuously sounding sequences that excluded timbre changes. Second, timbral changes as used in Experiment 2b can be linked to techniques used in contemporary music. The prime context with the changing timbres created a Klangfarben-harmony. In music, the term Klangfarbenmelodie was initially coined by Schoenberg (1911) as a composition style employing different instruments to melodies or to single pitch sequences. The same technique was applied to orchestrations by Marco Stroppa (1998). The distribution of tones (or chords) among several instruments involves breaking up musical lines and adds greater colour and texture. Our present data suggest that listeners can take advantage of the expressiveness and the colourful richness of the instrumentation while still being able to understand the tonal structures.

The use of a speeded timbre discrimination task provides further methodological control for musical priming studies. The timbral change between prime and target acts like a surface marker indicating without ambiguity "when" participants have to respond. The timbre discrimination task thus demonstrates the influence of musical expectations (i.e., "what" event should come next) on chord processing while controlling for temporal expectations caused by the context's musical structure (i.e., more or less reinforcing the indication of the sequence's ending and thus "when" the target will occur). Our data corroborates recent findings ruling out the interpretation that processing differences between related and less-related contexts were solely due to ambiguities about when in time the target will occur (Tillmann & Bigand, 2004).[3] They support the interpretation that differences in musical relatedness and tonal function influence target chord processing. Finally, the timbral surface marker of the target further allows adapting the musical priming paradigm to the investigation of musical expectations developed on both pitch and time dimensions in Western tonal music (Jones & Boltz, 1989). Listeners develop expectations for "what" type of event might come next and also "when" in time this event should occur. Musical priming using the timbre discrimination task allows investigating these musical expectations not only with subjective judgements and memory tasks, but also their influence on processing speed (Tillmann & Lebrun-Guillaud, in press).

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[3] This criticism had been based on the hypothesis that the musical structure of the prime context might create an ambiguity about "when" to respond that is stronger in contexts ending on less-related targets than in contexts ending on strongly related targets. As a consequence of this ambiguity, response times would be longer for the less-related context.

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