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The Influence of Voice Leading on Harmonic Priming

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The present study investigates the potential influence of voice leading on harmonic priming effects. Eight-chord sequences were presented to the participants, who had to perform a fast reaction task on a target chord ending the sequences. The target chord acted either as a tonic chord or as a subdominant chord. On the basis of previous findings, we expected more accurate and faster responses on tonic target chords. The critical new point of this study was to assess whether the size of this priming effect would be affected by good versus bad voice leading. In half of the trials, the writing of the sequences respected the rules of voice leading (normal voice leading), whereas in the other half it did not (parallel voice leading). The critical result was a significant main effect of voice leading on participants' performances (with faster responses for normal voice leading), which did not, however, affect the strength of the harmonic priming effects.

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Western harmony may be conceived of as a set of chords having specific syntax-like functions (harmonic functions) depending on the context in which they occur. In most popular styles, these harmonic functions are thought to be independent of the sounding of the chords, that is, of the chordal disposition. Everyone has probably heard an average, quasi-self-taught guitarist accompanying a song by playing chords without paying attention to how the tones of the successive chords are (or are not) linked. In this rudimentary musical setting, it is usually sufficient for chords to express their syntax-like function, even though false melodic relations exist between the notes of successive chords.

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A counterexample may be found in jazz music. A rapid look at a jazz score may lead to the false belief that in this musical style, harmonic function works independently of the melodic motion created by the tones of successive chords. Indeed, the harmony of the piece is represented by chords, without any specific indication of the chordal disposition. However, it becomes obvious that playing the harmony represented by the chords, without any sense of how to arrange the chords, results in a piece that has little to do with jazz. This suggests that the way in which the tones of successive chords are organized may be a crucial feature of Western music. In the first section of this article, we describe how different music theory frameworks consider these two principles of organization (voice leading and harmony) as important and strongly interrelated factors. We then turn to the psychological implication of each factor and raise the question of a potential influence of voice leading on harmonic processing. The present experiment was designed to test whether good voice leading (i.e., that respects the rules of harmonic treatises) actually enhances the processing of chord sequences.

Western harmony and voice leading are so strongly interdependent that one cannot understand the complexity of this relation without considering the long historical process that fathered the rules of harmonic writing in the tonal system. A brief review of the great historical stages shows that intensifying debates opposing the theoreticians of the past foreshadow the difficulties for contemporary listeners in understanding the psychological relevance of both structures. Voice leading was an essential component in medieval polyphony, and it remained so in Renaissance polyphony. The emergence of tonal harmony, so fiercely debated by theorists (Ceulemans, 1994; Dahlhaus, 1967), was accompanied by a gradual modification of the relationship between counterpoint and harmony. With *Gradus, ad Parnassum*, Fux (1725) attempted a tonal adaptation of the principles of the polyphony of Palestrina. Bach the composer—for want of theoretical writing on the subject—has left us a most authoritative demonstration, surmounting the inevitable conflict between the legacy of counterpoint and the force of tonal harmony.

It is against this backdrop that Rameau (1722), with his revolutionary *Traité de l'harmonie réduite à ses principes naturels,* instituted the fundamental bass and clarified the principle of chord inversion. In *Génération harmonique* (1737), he relied on the harmonic series to support his theories and to explain the perfect major chord. The crucial point remains his attempt to produce chords relation to each other by the progression of the fundamental bass, which forms a virtual line, by the succession of the chords' roots. The harmony thus becomes an active principle whereas in the past it was only a resulting one. It is the far-off origin of the root progression theories. Rameau, the theorist, truly marked the advent of harmonic thought, but his theories—often inadequately known—were to meet with strong opposition. Kirnberger (1771–1779, 1773), inspired by the polyphonic harmony of Bach, accorded the utmost importance to the bass line. He thus partially accepted Rameau's contribution, but he rejected the complete submission of melody to harmony.

Harmonic orientation took a firmer hold as the notion of harmonic degree or *Stufe* became established among several Germanic theorists. Sechter (1853), who favored the movement of a descending fifth in the bass,[1] presented the theory with remarkable coherence. From then on, the motion of the bass line was the focus of attention, without sacrificing the role of voice leading: the influence of four-part chorales was still strongly felt among German composers; Schumann is a fine example. From that time on, composers tended toward increasingly complex harmonies, and works of the final decades of the Romantic century evince a widened conception of tonality. To account for this evolution, Riemann's function theory (1893) is distinct from the seven degrees of the *Stufentheorie*, reduced instead to the three harmonic functions of tonic, dominant, and subdominant. This synthetic vision constituted the final and distant stage in the transformation of Rameau's legacy by the Germanic theorists of the 19th century. The extension of Riemann's concept of harmonic function and the generalization of substitutions seemed to ensure the triumph of harmonic thought.

Yet it would be wrong to claim that musical Europe has been in constant allegiance to Rameau's principles. Paradoxically, the strongest resistance to the logical consequences of the fundamental bass was in Rameau's native country (Bartoli, 2001), and most 19th century French treatises (Catel, 1802, through Dubois, 1921, some of which are still in use today) remained resistant to the teaching of harmonic progressions, which was largely adopted elsewhere. This didactic specificity is all the more strange given that the repertoire of the 19th century shows how much harmony predominates. If the French treatises, with their catalog of prohibitions, seek out purity of realization by emphasizing voice leading, they give few explanations about the effect produced by such voice leading on the comprehension of harmony. Even today, competent teachers devote the greatest attention to voice leading. "Good voicing" places the priority on attending to the upper voice and the bass, but it is also concerned with the elegance of the inner voices. The concern for "purity" of writing appears to be a holdover from the practice of tonal counterpoint, with which all these teachers had first-hand experience, but also and particularly seems to result from the sensitivities of a fine musician to interactions in music that are ultimately irreducible to mere verticality.

Let us move on from the historical example of France in order to observe how theorists in the first half of the 20th century envisaged the

1. This tradition may be traced from Sechter through to Schenker and Schoenberg.

question of the relationship between the two dimensions (vertical and horizontal) of tonal music. The Schenkerian concept, with counterpoint between the two outer voices, restored to counterpoint an importance that the harmonic functionalism of Riemann had removed. Schenker frequently opts for the harmonization of contrapuntal or linear phenomena and is not sparing in his criticism of Rameau. Schenker sought a balance, ultimately placing counterpoint and harmony into a dialectic relationship. Hindemith (1937) demonstrated similar preoccupations in his *Unterweisung in Tonsatz*, in which he subjected contrapuntal as well as chordal writing to an exterior framework, the "superordinate"[2] structure of two voices formed by the bass governing the harmonic progression and the most important melodic voice.

Schoenberg (1911, 1954) the theorist provided an important contribution to the understanding of extended tonality, with the concept of monotonality and his classification of harmonic progressions. History has above all valued Schoenberg's contribution as a composer and his search for complete freedom in voice leading, from that point on liberated from chromatic resolution (Schoenberg, 1928). But when Schoenberg envisaged counterpoint during the earlier periods of dodecaphonic serialism, for which he claimed authorship, his attitude was radically different. Nothing elucidates Schoenberg's ideas more clearly than the text (Schoenberg, 1931) in which he flatly refutes the very concept of "linear counterpoint," ironically speaking about an impossible independence of voices that would evolve with total and mutual indifference. Schoenberg puts the question clearly: how could a listener perceive the resulting combination?[3] Counterpoint cannot be purely linear, just as harmony cannot be reduced to a vertical dimension.

Beyond its theoretical interest, the vigor of the debate highlights the strength of the interactions and the complexity of a question that concerns more particularly the elaboration, choice, and especially control of musical material, when attempting, in strict experimental conditions, to approach the musical repertoire governed by tonal harmony. Finally, taking into account the orientation that prevails in the present study, it was perhaps in an ironic note that Schoenberg, in a premonitory way, introduced in the most relevant fashion the perceptual problem we address here. Thus, we turn again to Schoenberg to understand some of the aspects of harmonic tonality, to which the stimuli used in the following experiment pertain: in *Structural Functions of Harmony*, Schoenberg (1954) emphasizes the decisive role of root progressions and takes into account the *nature* of motion. The Schoenbergian approach to progres-

2. *Übergeordnete Zweistimmigkeit.*

3. This is a pertinent question in a controversial text where Schoenberg criticizes the work of Ernst Kurth (1917), *Grunlagen des linearen Kontrapunkt*, which he admits that he has not read.

sions emphasizes the relations between chords. It develops what Rameau had anticipated and assumes that the motion of the bass is sufficiently informative to characterize the tonal progressions.

From this historical review, one notices that concern with elegance and with good voice leading are characteristic of the French academic works, which, however, presented themselves as *Traités d'harmonie*. Although it was not explicitly formulated, the perceptual hypothesis, according to which good voice leading would contribute efficiently to the harmonic result, is perceived retrospectively as a consequence of the singular position of the authors of these didactic works. One may thus legitimately wonder whether the constant attention paid to voice leading has a real influence on harmonic comprehension. This issue, which preoccupies theoreticians today, arises when sequences in which voice leading is respected are compared with sequences in which voice leading is inaccurate.

From a psychological point of view, voice leading and harmony may tap into different cognitive processes. Voice leading relates to stream segregation, that is, to the perceptual organization of musical sounds (Bregman, 1990; Huron, 2001). This process is though to occur early in the processing of auditory information (McAdams & Bigand, 1993). The processing of the harmonic function of a chord is said to come into play at a later stage and to be strongly dependent on the activation of abstract knowledge of Western harmony (Bharucha, 1987; Lerdahl & Jackendoff, 1983; Tillmann, Bharucha, & Bigand, 2000). Let us consider each stage of musical processing in more detail.

Western tonal music is considered to have a horizontal organization, referring to the successive sounds that form melodies, and a vertical organization, referring to the simultaneous sounds that form harmonies (Bregman, 1990). Voice leading is the horizontal organization of music and has as a main purpose the creation of perceptually independent musical lines (Huron, 2001) or in other words, segregation of the melodic lines into different auditory streams (Bregman, 1990). Voice leading optimizes the segregation of different voices by reinforcing the horizontal links between the tones of each melody (sequential integration) and decreasing the fusion between the notes of the different voices (integration of simultaneous components; Bregman, 1990).

Several principles of grouping affect stream segregation (Bregman, 1990). The first is the frequency separation between consecutive notes of a single voice. Strengthening the horizontal links can be viewed as reinforcing the coherence of each melodic line, which depends on the frequency separation between the component tones of each melody. Close pitch proximity in successive notes within a voice (referring to conjunct motion in music) maintains the coherence of the melody. In Western tonal music, conjunct motions are preferred to disjunct motions, which weaken and break the coherence of melodic lines. Given that stream segregation and fusion interact (Bregman, 1990), disjunct motions, contributing to the fusion of the different voices, are avoided in musical writing.

A second important principle that affects stream segregation is tonal fusion. It refers to the tendency for some sound combinations to cohere into a single sound image. Two factors influence tonal fusion, the frequency ratio of the component tones and their spectral content (Bregman, 1990; Huron, 2001). Tonal fusion is more likely to appear when the frequencies of the simultaneously sounding component tones are related by simple integer ratios, as is the case for unisons, octaves, and perfect fifths. These three types of intervals, which most strongly encourage tonal fusion and decrease stream segregation of the different voices, are also avoided in musical writing.

Onset synchrony is another principle of grouping that influences stream segregation. Sounds are more apt to be perceived as components of a single auditory image when they are synchronized in time. Onset synchrony may be compared to a particular amplitude co-modulation (Huron, 2001) and may interact with tonal fusion. Fusion decreases as onset asynchrony increases. Perfect intervals (unisons, octaves and perfect fifths), because of their acoustic properties, create tonal fusion, which is reinforced by onset synchrony. From this interaction, a last principle of grouping that influences stream segregation may be described: parallel motion. Parallel motion refers to the movement of both voices in the same direction while keeping the same numerical intervals (Aldwell & Schachter, 1989). The intervals cited above (unisons, octaves, and perfect fifths), because of their quality, diminish the individuality of voices (each melodic line has a common fate). Working against the goal of voice leading, parallel unisons, octaves, and perfect fifths are avoided in musical writing.

The principles of grouping just described contribute to the perceptual organization of the musical surface. They do not, however, account for the type of functional relationship musical events have in a piece. The musical function of an event depends on its level in both the tonal hierarchy and the event hierarchy (Lerdahl & Jackendoff, 1983).[4] It embodies the hierarchical relations that accrue to an entire tonal system beyond instantiation in a particular piece. Tonal hierarchy refers to a set of rules, specific to the Western tonal system, that can be internalized through passive exposure to Western tonal music (Krumhansl, 1990; Tillmann et al., 2000).

During the past two decades, numerous studies using harmonic priming have attempted to understand how harmonic expectancies generated by a musical context are linked with tonal hierarchy. The rationale of harmonic priming studies comes from research in psycholinguistics about seman-

4. An event hierarchy refers to the hierarchy of specific pitch-time events: a tonal hierarchy is an atemporal schema of Western tonal pitch regularities that is stored in long-term memory.

tic priming. In that domain, lexical decision judgments about words and nonwords are processed faster and more accurately when target words (*doctor*) are preceded by a semantically related word (*nurse*) rather than a semantically unrelated word (*bread*) (Meyer & Schvaneveldt, 1971; see Neely, 1991 for a review). Similarly, Bharucha and Stoeckig (1986, 1987) showed that processing of a target chord was facilitated when the target chord belongs to the same key as the prime chord than when it does not. Studies by Bigand and his collaborators, using larger prime contexts (Bigand & Pineau, 1997; Bigand, Poulin, Tillmann, Madurell, & D'Adamo, 2003; Bigand, Tillmann, Poulin-Charronnat, & Manderlier, in press; Tillmann, Bigand, & Pineau, 1998), have shown that the processing of a target chord depends also on its harmonic function in the previous musical context. For both musicians and nonmusicians, stable tonic chords are better processed than less stable but congruent subdominant chords at the end of eight-chord sequences. The sensitivity of listeners, especially nonmusicians, to the subtle difference between tonic and subdominant chords demonstrates listeners' highly sophisticated knowledge of the Western tonal system. Moreover, Bigand et al. (2003) provided further evidence that harmonic priming effects mostly occurred at a cognitive level of processing and were only weakly influenced by perceptual, bottom-up processes. They demonstrated that the harmonic function of the target chord was more influential than the number of tones shared by the target chord and the previous musical context. This finding, consistent for both musicians and nonmusicians even at very fast tempi, reinforces the hypothesis that music involves high-level cognitive processing.

The manner in which processing of horizontal organization (voice leading) of music and processing of vertical organization (harmonic function of chords) of music combine in listeners' perception remains an open question in experimental psychology. According to music theory treatises, the processing of harmonic functions of chords should be facilitated if the piece obeys the main rules of voice leading. By contrast, a musical piece that systematically violates these rules would obscure the perception of these functions. This assumption seems reasonable if we consider that voice leading creates auditory streams by reinforcing horizontal connections between component chord tones and then makes the perception of each melodic line more salient. By doing so, correct voice leading would enhance the harmonic structure of a piece by facilitating a forward movement toward a cadence at each level of the chord.

It should be emphasized, however, that this assumption remains speculative at this stage of the research and that no piece of evidence has yet been reported in support of this view. More importantly, we may also argue that, by making each melodic line more prominent, correct voice leading weakens the fusion of the component chord tones, which should in turn result in greater difficulty in identifying the harmonic functions of chords. Of course, this assumption is as speculative as the previous one. In the absence of any empirical evidence, it is thus difficult to disentangle both possibilities.

The present study aimed to contribute to this question by contrasting the influence of two types of voice leading on the harmonic priming effect. The first critical manipulation involved the harmonic function of the last chord (target chord) of eight-chord sequences that might act either as a tonic or as a subdominant chord. Previous research has demonstrated that, in a priming study, a target chord was processed faster and more accurately when it acted as a tonic chord in the previous context rather than as a subdominant chord (see Tillmann et al., 2000 for a review). The second critical manipulation involved the voice leading of the sequences (normal vs parallel). In a "normal voice leading" condition (correct voice leading), eight-chord sequences were written while respecting the voice leading principles just described, whereas in a "parallel voice leading" (bad voice leading), eight-chord sequences were created by using systematic parallel voice leading, including parallel octaves and perfect fifths. This type of writing, violating most of the basic voice-leading rules of Western tonal music (avoidance of successive and hidden octaves and fifths,[5] and encouragement in using voice leading by contrary motion), fails to yield forward movement to a cadence at each level of the chord. According to music theory treatises, unlike parallel voice leading, normal voice leading should reinforce the perception and facilitate the processing of harmonic function of chords. In a priming experiment, this influence should result in a stronger priming effect in normal voice leading.

In addition, it was likely that the influence of voice leading on the processing of harmonic structures would depend on the extent of the musical training of the participants. According to Bigand, Parncutt, and Lerdahl (1996), nonmusicians were notably more sensitive to voice leading than were musicians, who presumably were better able to infer the harmonic function of chords irrespective of the voice leading. Accordingly, parallel voice leading was expected to have a more detrimental influence on the processing of chord functions in nonmusicians than in musicians.

Method

PARTICIPANTS

Forty-six volunteer students participated in the experiment. Twenty-six students came from an introductory course in psychology at the University of Burgundy (referred to henceforth as *nonmusicians*). The mean number of years they had studied music was 0.65. The 20 other participants were students at the musical conservatory of Dijon (referred to henceforth as *musicians*), who had been qualified as candidates for the final diploma of

5. Hidden octaves or perfect fifth refers to the fact that a leap in the same direction by outer voices to the interval of a perfect octave or a perfect fifth is present and marked with lines.

the conservatory. They had received formal musical training and learned a musical instrument. The mean number of years they had studied music was 12.18. All participants received course credit or were paid $7 for their participation.

MATERIALS

The present experiment was run with the same musical sequences as used by Bigand et al. (2003). Twenty-four eight-chord sequences were used, 12 ending on a tonic chord and 12 ending on a subdominant chord. (See Figure 1 for one example of these sequences.) For example, a sequence in the key of C major ended either with the chords G and C (the tonic chord) or with the chords C and F (the subdominant chord). The same chords C and F defined the tonic ending of a chord sequence in the key of F major, and the chords G and C defined the subdominant ending of a chord sequence in the key of G major. In order to neutralize local harmonic priming effects, the last two chords were always one step apart in the circle of fifths, creating a local authentic cadence (V-I). The first seven chords of the sequences were played at a tempo of 96 quarter notes per minute (625 ms per chord). The eighth chord of the sequence (target chord) lasted 2000 ms.

In addition to manipulating the harmonic function of the target, the voice leading of the sequences was varied. In the "normal voice leading" condition, the 24 eight-chord sequences just described were written by adhering to a number of voice-leading rules. In the "parallel-voice-leading" condition, the 24 eight-chord sequences were written with a parallel motion that did not respect the voice-leading rules, especially by using parallel octaves and perfect fifths. The manipulation of voice leading resulted in 48 chord sequences. These 48 sequences were split into two sets of 24 chord sequences (Set 1 and Set 2). For half of the participants, Set 1 was presented with targets and Set 2 was presented with foils. That is to say, sequence of Set 1 ended on a consonant chord and those of Set 2 on a dissonant chord. The dissonance was created by adding a tone that was in half of the cases a semitone above the tonic and in the other half a semitone above the fifth of the target chord (e.g., either the tone C♯ or G♯ was added to the C-major chord consisting of the tones C-E-G). The goal of this manipulation was to make detection of the dissonance more difficult (especially for the musicians). This added tone was rendered less salient by decreasing its amplitude by 4 dB (37.5%). For the other half of the participants, the attribution of chord type (target/foil) to the two sequence sets was reversed (with Set 1 ending now on a foil, and Set 2 on consonant targets). Each participant thus heard 24 sequences ending on a target and 24 sequences ending on a foil. All these sequences were presented in random order. They were played in different keys so that each of the 12 major keys randomly occurred four times during the experiment.

APPARATUS

All stimuli were played with sampled Expander piano sounds produced by an ETM10 Yamaha Sound Expander. The Yamaha sampler was controlled by the MIDI interface of a Macintosh computer running Performer software. The sound stimuli were captured by SoundEditPro software at CD quality (16 bits and 44 kHz). The experiment was run on Psyscope software (Cohen, MacWhinney, Flatt, & Provost, 1993), and the sequences were presented over headphones.

PROCEDURE

The experimental procedure was split into two phases. In the first phase, participants were trained to differentiate between consonant and dissonant chords with 16 chords played randomly in isolation. They were informed by a feedback sound signal when their response was incorrect. In the second phase, participants performed a speeded accuracy consonant/dissonant judgment for the last chord of each sequence by pushing the "consonant" or the "dissonant" keys of the keyboard. A feedback signal sounded following incorrect responses. After each chord sequence, an interfering sequence of randomly selected pure tones was played in order to avoid a potential memory effect from the preceding sequence.

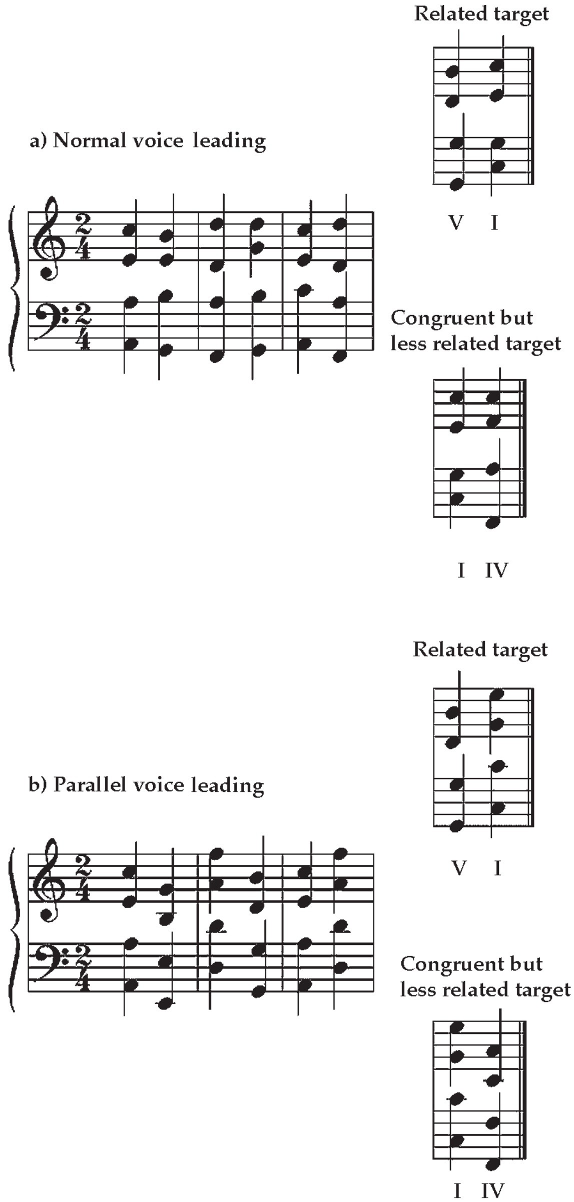

Fig. 1. One example of chord sequences used in the present experiment. Roman numeral I represents tonic targets; IV, subdominant targets; V, the dominant chord.

DESIGN

Crossing harmonic function of the target (tonic vs subdominant) and voice leading (normal voice leading vs parallel voice leading) resulted in four experimental cells, each instantiated by 12 musical chord sequences The harmonic function of the target chord (tonic vs subdominant) and the voice leading (normal vs subdominant) defined the within-subject variables. The musical expertise (musicians vs nonmusicians) defined the intersubject variable. None of these variables was blocked.

Results

Percentages of correct responses are displayed in Figure 2 and were analyzed with a 2 (Musical Expertise) × 2 (Harmonic Function) × 2 (Voice Leading) analysis of variance.[6] There was a significant main effect of voice leading, $F(1,44) = 8.01$, $p < .01$, $MSE = 180.70$, and this effect was modulated by the extent of musical training $F(1,44) = 6.87$, $p < .05$, $MSE = 180.70$. Correct responses were significantly more numerous for normal voice leading than for parallel voice leading conditions for nonmusicians (respectively, 90.06% vs 79.17%, $F(1,44) = 17.09$, $p < .001$, $MSE = 180.70$) but not for musicians (respectively, 97.50% vs 97.08%, $F < 1$). Finally, correct responses were more numerous for musicians than for nonmusicians, $F(1,44) = 18.26$, $p < .001$, $MSE = 397.87$. No other effects were significant.

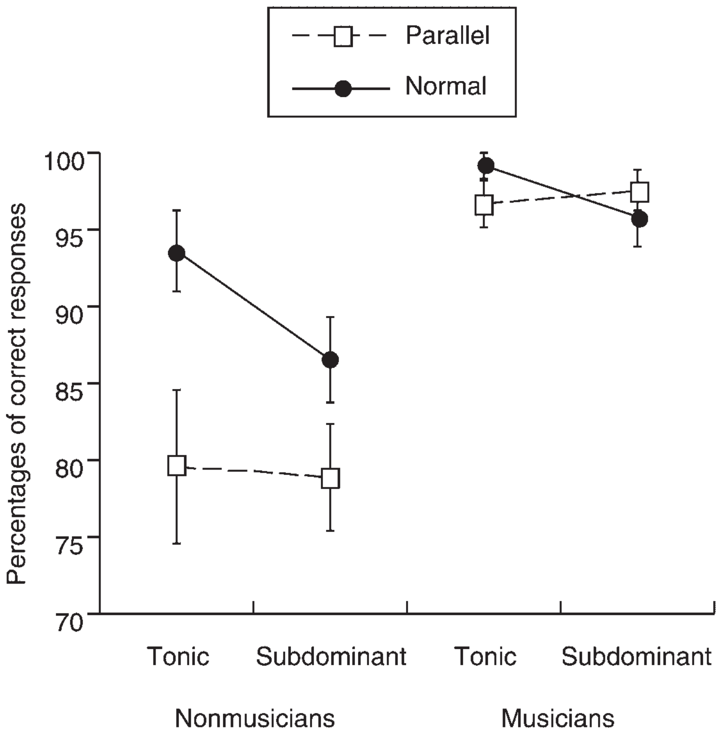

Fig. 2. Percentages of correct responses for both groups of participants, for normal and parallel voice leading and for tonic and subdominant targets.

6. As dissonant chords did not correspond to lawful musical events in Western tonal music, no straightforward prediction could be made for the foil trials. Foil trials were used as fillers, and only data from the target trials are presented below (see Bigand et al., 2003).

Response times for correct responses are displayed in Figure 3. Correct responses were significantly faster for normal voice leading than for parallel voice leading, $F(1,44) = 59.94$, $p < .001$, $MSE = 11562.30$, and this effect was stronger for nonmusicians (966.57 ms for normal vs 1123.92 ms for parallel) than for musicians (653.63ms for normal vs 743.96 ms for parallel), as shown by a significant Musical Expertise × Voice Leading interaction, $F(1,44) = 4.40$, $p < .05$, $MSE = 11562.30$.[7] Correct responses were significantly faster for tonic chords than for subdominant chords, $F(1,44) = 58.88$, $p < .001$, $MSE = 11305.60$, and this effect was stronger for nonmusicians (967.81 ms for tonic vs 1122.69 ms for subdominant) than for musicians (654.87 ms for tonic vs 742.66 ms for subdominant), as shown by a significant Musical Expertise × Harmonic Function interaction, $F(1,44) = 4.50$, $p < .05$, $MSE = 11305.60$. Finally, response times for correct responses were significantly faster in musicians than in nonmusicians, $F(1,44) = 22.41$, $p < .001$, $MSE = 242214.60$. No other effects were significant.

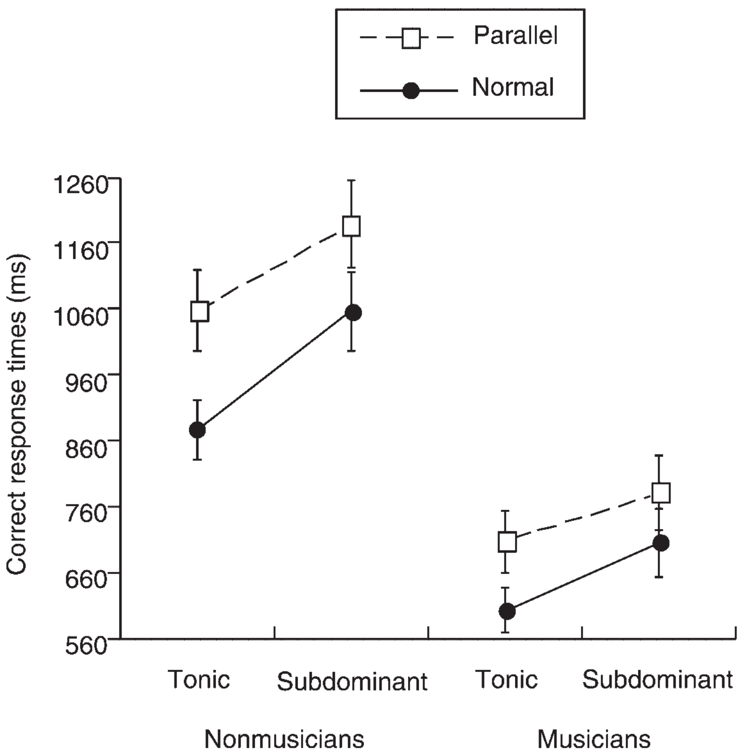

Fig. 3. Correct response times for both groups of participants, for normal and parallel voice leading and for tonic and subdominant targets.

7. A further contrast analysis showed that the effect of voice leading was significant for the musicians, $F(1,44) = 14.09$, $p < .001$, $MSE = 11562.30$.

Discussion

The present findings replicate harmonic priming effects already reported in previous studies for both musicians and nonmusicians (Bigand & Pineau, 1997; Bigand et al., 2003; Bigand et al., in press; Tillmann et al., 1998). All of these studies demonstrate that the processing of a target chord depends on its harmonic function in the musical context. A previous musical context primes the processing of a target chord that acts as a stable musical event in the context: tonic target chords are better processed than subdominant target chords.

The first new point of this study was to demonstrate a main effect of voice leading on the accuracy and the speed of consonant/dissonant judgments. Nonmusicians made more errors and the reaction times of both musicians and nonmusicians were longer for parallel voice leading than for normal voice leading. This finding confirms the importance of voice leading, as suggested by music theory and psychology of music. Voice leading that reinforces auditory streaming results in a greater ease of processing for both tonic and subdominant targets. Interestingly, the data made clear that this effect of voice leading was more pronounced in nonmusicians, which is consistent with previous findings reported with a different experimental task (Bigand et al., 1996). One possible explanation of this overall positive contribution of voice leading is that continuous melodic lines between the four voices of the chord enhance the attentional tracking of the sequence, and the perceptual anticipation of each tone is likely to occur in the next chords. By increasing the segregation of the melodic line, normal voice leading improves perception of an added dissonant tone in a dissonant target, which results in faster and more accurate consonant/dissonant judgments.

Given the main effect of both harmonic context and voice leading on the processing of the target chord, the critical point of the present study was to assess how both factors combined in listeners. Music theory assumes that voice leading and harmony interact with each other (Aldwell & Schachter, 1989). Good voice leading is assumed to reinforce the segregation of melodic lines and to facilitate the forward movement toward cadences. As a consequence, normal voice leading was expected to improve the perception of the harmonic function of chords, which should result, in harmonic priming studies, in stronger priming effects in normal than in parallel voice-leading conditions. The present study did not support this assumption, and harmonic priming effects were shown to be similar in both normal and parallel voice leading, suggesting that the perception of the harmonic function of the last chord did not strongly depend on the type of voice leading used. That is to say, a tonic chord acts as a more stable event than a subdominant chord, even when the voice leading violates all of the most basic rules of the Western harmonic treatises. The surprising large priming effects observed in the parallel voice-leading condition may also suggest that parallel voice leading continues to contain some clues to harmonic understanding. These clues should notably be found in the contour of the bass line (which often progress in fifth-to-fifth intervals) and in the fact that all chords stand in root position.

Finally, our last outcome concerns the contribution of harmonic function and voice leading to the processing of chords as a function of musical expertise. Our findings confirm the sensitivity of nonmusicians to subtle harmonic differences, as already noted in previous studies (Bigand & Pineau, 1997; Bigand et al., 2003; Bigand et al., in press; Tillmann et al., 1998). It provides new evidence showing that nonmusicians are more sensitive than musicians to voice leading in long musical contexts (see Bigand et al., 1996 for short contexts). Alternatively, musicians are likely to be more competent than nonmusicians in the extraction of the harmonic function of chords, and despite incorrect voice leading, musicians may continue to have fairly fluent harmonic perception.

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