A Comparative Review of Priming Effects in Language and Music

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Language and music are both two instances of rich and well organised structures processed by the human brain. In both domains, discrete elements are ordered in hierarchical patterns according to certain principles of combination. Experienced listeners in a given linguistic or musical culture show implicit knowledge of structural patterns and organisational principles in a number of ways. This knowledge permits for example to develop expectancies as a function of the previous context and influences the processing of further incoming events (i.e. linguistic or musical). Both semantic and harmonic priming research illustrates that the identification of a target event is facilitated by the prior presentation of a related prime context. In psycholinguistic studies, the semantic priming paradigm has been used in numerous research to study the effect of contexts on word processing: for one word contexts (e.g., Meyer & Schvaneveldt, 1971) and for longer contexts such as sentences or paragraphs (e.g., Stanovich & West, 1979). In music research, a harmonic priming paradigm has been developed more recently for the analyses of single-chord contexts (Bharucha & Stoeckig, 1986, 1987; Tekman & Bharucha, 1992) and of long-chord contexts (Bigand & Pineau, 1997; Bigand, Madurell, Tillmann & Pineau, 1999, Tillmann, Bigand & Pineau, 1998; Tillmann & Bigand, in press) on chord processing.

The present paper reviews a set of semantic and harmonic priming experiments. The harmonic priming studies are presented in parallel to semantic priming studies that had been based on a similar rationale. They are regrouped in four subsections as a function of the used context and its manipulation in the experimental designs: a) local context (one word, one chord), b) global context (sentences, sequences), c) combined local and global contexts and d) normal vs. scrambled global contexts. Overall results showed that the processing of both a word and a chord is facilitated by a locally related context and by a globally related context. However, results in language and music are diverging concerning the combined influence of local and global contexts together and concerning the presentation order of events in the global context (normal versus scrambled order). In contrast to semantic global relatedness effects, an integrative stage of processing seems not to be indispensable to account for global relatedness effects in harmonic priming. In the last section, results and theoretical frameworks are discussed.

Local Context Effects

In psycholinguistic studies, it has been well established that the processing of a target word (*nurse*) is faster and more accurate when it follows a prime word which is semantically related (*doctor*) than a prime word which is semantically unrelated (*bread*) (Meyer & Schvaneveldt, 1971).

In music research, Bharucha and colleagues adapted the priming paradigm to music (Bharucha & Stoeckig, 1986, 1987; Tekman & Bharucha, 1992). Participants heard a prime chord followed by a target chord. The prime and target were either closely related (belong to the same key) or distantly related harmonically. For example, if the prime chord was C major, Bb major would be a related target and F# major an unrelated target. On half of the

trials, the target chord was slightly mistuned, and participants were asked to make a speeded intonation judgement, i.e., to decide as quickly as possible whether the target chord was in tune. The priming effect was shown by (1) a bias to judge targets to be in tune when they were related to the prime, and (2) shorter response times for in-tune targets when they were related to the prime, and for out-of-tune target when they were unrelated to it. Thus, a single chord can generate expectancies for related chords to follow, resulting in greater perceived consonance and faster processing for expected chords.

Global Context Effects

In language and music processing, it is an important issue to understand how priming effects occur in more ecologically valid situations involving larger contexts than one word or chord. Semantic priming effects have been extended to longer contexts such as sentences or discourses. The processing of a target word was facilitated if that word formed a congruent ending for the sentence context than when it formed an incongruent completion (e.g., the cowboy fired the *pistol* vs. the interpreter knew the *pistol*) (Fischler & Bloom, 1980; Stanovich & West, 1979).

Recent studies extended harmonic priming effects to large contexts. Bigand and Pineau (1997) manipulated the global context of eight-chord sequences. Just as in the sentence priming experiments presented above, the expectations for the last chord (the target) were varied by changing the harmonic context created by the first six chords. The last two chords were held constant. In the expected condition, the last chord was a harmonically stable tonic chord, part of an authentic cadence (V-I). In the unexpected condition, the last chord took the form of a less stable fourth harmonic degree following an authentic cadence (I-IV). Participants were faster and more accurate in their intonation judgement of the last chord when it was expected. These results suggest that harmonic priming involves higher level harmonic structures and does not occur only from chord to chord.

Global harmonic priming was extended to wider harmonic contexts (Bigand et al., 1999). The global context was manipulated in 14 chord sequences at three levels, while holding constant the chord prior to the target (local context). The function of the target chord was changed by transposition. In the highly expected condition, the whole sequence is played in the same key, and the target chord is part of an authentic cadence (V-I) that closes the overall structure. In the unexpected condition, the sequence is played in the dominant key and the target chord is the fourth harmonic degree following an authentic cadence (I-IV). These two conditions replicated those of Bigand and Pineau (1997) with longer chord sequences. In the middle expected condition, the first half is harmonically identical to the first half of the highly expected condition and the second half to that of the unexpected condition. Although the chords of the second half are strictly identical, the target chord in the middle expected condition is no longer the fourth harmonic degree following an authentic cadence. In this context it may be analysed as part of the authentic cadence (V-I) that returns to the main key. The results provide evidence that musical expectations derive from various levels of hierarchical structure. Strongest facilitation was observed for highly expected targets, as the target chord was expected at both high and intermediate levels. Facilitation was reduced when it was expected at the higher level only (i.e. middle expected condition). The weakest priming effect was observed when the target chord was not strongly expected at both high and intermediate levels.

Global and Local Context Effects

In psycholinguistics, Hess, Foss and Caroll (1995) manipulated both global and local contexts prior to the target word. The relationship between the target and the general topic

of the discourse ("global context") was crossed with the relationship between the critical word and the sentence prior to it ("local context"). For example the target word *poem* was considered as related to both local and global contexts when it occurs in a sentence like "the English major wrote the *poem*", and when the overall topic of the discourse, in which the sentence occurs, is about an English major who fall in love. It was no more related to the global context when the sentence occurs in a story about a computer science major being in the hurry to finish writing a program.[1] The main outcome of Hess et al.'s (1995) experiments was that the facilitation of a target word depended on whether the global context was related to the target, regardless of the local context. According to the authors, this result provides evidence that "the locus of context effects is primarily outside of the lexicon, in processes that determine semantic relationships among incoming words" (Hess, et al., 1995: 63).

In music research, Tillmann, Bigand & Pineau (1998) performed crude changes in harmonic relationships and varied the target's relatedness at both global and local levels in harmonic sequences. For example, in a C major key, the target chord was globally and locally related (GRLR) when it was a tonic chord (C) and was preceded by a dominant chord (G). It was globally related but locally unrelated (GRLU) when the preceding dominant chord was played one semitone higher (G#). In this case, the target and the preceding chord do not belong to the same key. The target was globally unrelated but locally related (GULR) when only the first six chords of the sequences were transposed one semitone above (i.e., in the C# major key). Here the key of the first six chords is weakly related to the keys of the target chord and its preceding chord (i.e., C and G major keys). Finally, the target chord was both globally and locally unrelated (GULU) when the first seven chords were transposed one semitone above (in the C# major key). The performance of participants demonstrated a strong effect of both global and local context. Target chords were processed more accurately and quickly when they were locally or globally related to the previous context. Facilitation decreased for targets that were only locally or only globally related, and was the lowest for locally and globally unrelated targets. Furthermore, the effect of global context tended to be more pronounced at a fast tempo.

Global Context Effect in Normal and Scrambled Contexts

The global relatedness effect in long contexts was further studied by comparing target words in sentences to target words in lists or scrambled sentences. A change in the temporal order of words in a sentence strongly decreased the strength of the related priming effect (Masson, 1986; O'Seaghdha, 1989; Simpson, Peterson, Casteel & Brugges, 1989). In Simpson et al. (1989), sentences were presented visually either in a normal form (The auto accident drew a large crowd of *people*) or in scrambled form (Accident of large the drew auto crowd a *people*). Normal sentences showed facilitation for related targets and inhibition for unrelated targets, but there was no effect of relatedness for scrambled stimuli. The findings highlight the role of syntactic connectedness and suggest that contextual facilitation depends on the ease of integration of new words with the current text-level representation.

In music, a recent study focused on the influence of structural coherence on global harmonic relatedness effects (Tillmann & Bigand, in press). Chord sequences with either a related or an unrelated target were presented in a normal version and in a scrambled version. Two strengths of scrambling were defined: permuting chords two by two and four by four. Scrambling the order of chords violates several harmonic transitions usual in Western music and decreases the coherence of the sequences. Nonmusicians and musicians were sensitive to these structural manipulations: Scrambled sequences were judged as less coherent than normal sequences. Recognition memory was affected by the scrambled sequences which

[1] If the story was about a computer science major who fall in love, the target word "poem" was said globally related, but locally unrelated when it occurs in the sentence: "the computer science major wrote the *poem*".

seemed to favour a bias to reject an excerpt as having occurred in the unstructured sequence. The principal aim of the study was to investigate if scrambling the temporal order of chords influences the facilitated processing of a related target chord in contrast to an unrelated target chord. The harmonic priming data pointed out that the processing of the related target chord was facilitated in both the normal and scrambled sequences, even when a stronger scrambling was used and when subjects had to attend attentively to the sequences due to a secondary recognition task. Scrambling chords in a sequence left nearly unaffected the facilitation due to global relatedness. Participants thus perceived changes in the structural organisation of the normal and scrambled sequences, but this change had no reliable impact on the priming effects. The fact that a sequence is more or less conform to a coherent overall structure, may be of perceptual importance, but seems to tap into other cognitive processes that those underlying the processing of a chord.

Discussion: Spreading Activation versus Integration?

Semantic and harmonic priming data pointed out that a preceding context influences the processing of further incoming events. Both semantic and harmonic priming effects had been extended from a single event to larger contexts (i.e., sentence, chord sequence). In psycholinguistic, two potential sources of priming were distinguished for sentences and discourses. One source is located inside the mental lexicon (i.e., intralexical priming): priming rests on a fast and automatic activation that spreads via the long-term connections between semantically related items (Forster, 1979; Duffy, Henderson & Morris, 1989; Neely, 1991). The sentence context is assumed to contain at least a single word that is semantically associated to the target word. Activation spreading from this context word activates the semantically related target and facilitates its processing. Spreading activation may also result from combination of words that do not prime individually. A second source of priming arises from the processes that integrate local structures within a coherent whole (Sharkey & Sharkey, 1987; Hess et al., 1995). Facilitation occurs for target words that are easily integrated into the ongoing discourse representation (discourse priming).

The discourse-based model was strongly supported by the finding that priming effects do occur across intervening material, even when it is semantically unrelated to the prime (Foss, 1982, Foss & Ross, 1983; Hess, et al., 1995). According to Hess et al. (1995), an intralexical spreading activation model predicts that the processing of the target word would be facilitated when it is semantically related to the local context, regardless of the global context. On the opposite, a strong version of a discourse-based model would predict a greater facilitation for the target word when semantically related to the global topic of the discourse regardless of the local context. Results of their study were interpreted as evidence for a priming source other than activation inside a mental lexicon. The spreading activation account was further challenged by studies that compared target words in normal and scrambled sentences. A change in the temporal order of words in a sentence strongly decreased the strength of the related priming effect (Masson, 1986; O'Seaghdha, 1989; Simpson et al., 1989). If context effects arise from activation spreading among words, such a manipulation of the prime's structure should not affect the processing of the target word. The results demonstrated that "the intralexical spreading activation by itself is a rather poor candidate to account for sentence context effects" (Simpson et al., 1989: 95). Processes that integrate local structures within a coherent whole thus represents a second source of semantic priming in sentences and discourses.

In a similar way, the effect of global harmonic context in music may potentially be understood in the light of two theoretical frameworks. Effects of global context might result from activation spreading through a schematic knowledge set (as in Bharucha's (1987) model) or from the ease with which subjects integrate musical events into the overall structure of the piece. The former model focuses on *tonal hierarchies* (i.e., a nontemporal schema of Western tonal hierarchies stored in long term memory), the latter account focuses on an *event hierarchy* (i.e., a hierarchy of specific pitch-time events inferred from

the ongoing temporal sequence of musical events). An event hierarchy implies the activation of a tonal hierarchy *plus* the integration of the events in their specific temporal context (see Lerdahl & Jackendoff, 1983 for an extensive account).

In music, the harmonic priming effects of single chords and of chord sequences can be explained in the frame of a musical spreading activation model that represents the knowledge of Western harmony in a pattern of connections (Bharucha, 1987). According to Bharucha (1987, 1994), this knowledge may be conceived of as a network of interconnected units. Once learning has occurred (Bharucha, 1994; Tillmann, Bharucha & Bigand, 2000), these units are organised in three layers corresponding to tones, chords, and keys. When a chord is played, activation reverberates in the network until equilibrium is reached. The activation pattern of the chord units reflects Western tonal hierarchy and takes into account the key-memberships of a chord. In other words, a chord activates the units of related chords more strongly than the units of unrelated chords. When a chord sequence is played, activation due to each chord is accumulated and weighted according to recency. The accumulation of activation patterns over time determines the tonal hierarchy that underlies the incoming sequence. Highly activated events represent important events in the tonal hierarchy and the processing of these events is facilitated.

For all presented harmonic priming experiments, neural net simulations were performed according to Bharucha's (1987) model. The activation pattern of chord units simulates harmonic expectations of human subjects after a single chord context (Bharucha & Stoeckig, 1987) and also in long sequence contexts accounting for the facilitation of the processing of related chords (Bigand et al., 1999). The simple accumulation of tonal hierarchy patterns takes into account the priming effects observed for local and global contexts. The influence of tempo also suggests that tonal hierarchy patterns are added and weighted by decay (Tillmann et al., 1998). The musical spreading activation model simulates an effect of global relatedness for expected and unexpected sequences independently of the temporal order of chords (Tillmann & Bigand, in press). Results of the harmonic priming study described above suggest that the harmonic relatedness effect is based on automatic activation processes of tonal knowledge. The relatedness effect depends on the tonal hierarchy, but not on the temporal order of chords in a sequence. Consequently, it seems to be quite robust against the structural manipulations due to scrambling. In contrast to semantic priming effects that vanished in scrambled sentences, changing the temporal order of chords in a sequence did not eliminate the relatedness effects in harmonic priming.

The outcome of the simulations generally fit well with human performances suggesting that priming effects in music result from activation spreading via a schematic knowledge of Western harmony. In contrast to language, an integrative stage of processing seems not indispensable to account for global context effects in harmonic priming.

Future research in the field of music has to determine whether a spreading activation model can satisfactorily account for the context effects on chord processing or if other theoretical frameworks are required. The present findings suggest that Bharucha's connectionist model (1987) provides a possible explanatory framework. During chord sequences, activation consecutive to the context are accumulated in a buffer and this added activation determines the processing of the target. In other words, harmonic priming effects seem to be the result of activation spreading via a stable cognitive structure that links related chords.

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