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Brief article

Musical structure modulates semantic priming in vocal music

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Abstract

It has been shown that harmonic structure may influence the processing of phonemes whatever the extent of participants' musical expertise [Bigand, E., Tillmann, B., Poulin, B., D'Adamo, D. A., & Madurell, F. (2001). The effect of harmonic context on phoneme monitoring in vocal music. *Cognition*, 81, B11–B20]. The present study goes a step further by investigating how musical harmony may potentially interfere with the processing of words in vocal music. Eight-chord sung sentences were presented, their last word being either semantically related (La girafe a un très grand **cou**, *The giraffe has a very long* ***neck***) or unrelated to the previous linguistic context (La girafe a un très grand **pied**, *The giraffe has a very long* ***foot***). The target word was sung on a chord that acted either as a referential *tonic chord* or as a congruent but less referential *subdominant chord*. Participants performed a lexical decision task on the target word. A significant interaction was observed between semantic and harmonic relatedness suggesting that music modulates semantic priming in vocal music. Following Jones' dynamic attention theory, we argue that music can modulate semantic priming in vocal music, by modifying the allocation of attentional resource necessary for linguistic computation.

Keywords: Semantic and musical priming; Musical expertise; Vocal music; Modularity

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1. Introduction

The relationship between language and music has been a matter of much debate (see (Patel, 2003; Peretz & Coltheart, 2003). Several studies have reported independent processing, while others, including recent imagery studies, provide consistent evidence that the neural pathways involved in each domain are considerably intertwined.

The most convincing evidence supporting independence comes from double dissociation cases. Some brain-damaged patients with musical expertise preserved their musical abilities but exhibit severe deficits in cognitive functions, notably language (Assal, 1973; Basso & Capitani, 1985; Luria, Tsvetkova, & Futer, 1965; Signoret, Van Eeckhout, Poncet, & Castaigne, 1987). At the same time, several studies have documented brain damage with selective deficits in musical abilities (Peretz, Belleville, & Fontaine, 1997; Peretz et al., 1994; Steincke, Cuddy, & Holden, 1997). Patients suffering from amusia recognize songs through their lyrics but not through their melody, suggesting that melody and lyrics are processed independently (Hébert & Peretz, 2001; Peretz et al., 1994). Recent behavioral and electrophysiological studies run on normal participants further demonstrate that melodic and semantic incongruities in songs are processed independently (Bonnel, Faïta, Peretz, & Besson, 2001) and elicit different Event-Related Potentials (ERPs) (Besson, Faïta, Peretz, Bonnel, & Requin, 1998). The songs used in these studies ended on a target word that was semantically related or unrelated, and sung either on a musically congruent or incongruent note (e.g. out of key note). In the single task condition, participants had to detect one of the incongruities (semantic or melodic). In the dual task condition, they had to detect both incongruities. The critical finding of Bonnel et al. (2001) was that the dual task did not result in a decrease in performance, suggesting that the processing of linguistic and musical incongruities taps into two separate and independent pools of resources.

The dependent model has also been supported by both behavioral and neurophysiological evidence. Studies on song memory have shown that melodies are better recognized when they are heard with their original text rather than with the text of other songs. Similarly, words of songs are better recognized when they are heard with their original melody rather than with a different one (Crowder, Serafine, & Repp, 1990; Morrongiello & Roes, 1990; Samson & Zatorre, 1991; Serafine, Crowder, & Repp, 1984; Serafine, Davidson, Crowder, & Repp, 1986; but see, Peretz, 2001). The dependent model is also supported by neurophysiological evidence. It has been demonstrated that syntactic violations in language elicited identical ERP to harmonic violations in music (Patel, Gibson, Ratner, Besson, & Holcomb, 1998). This suggests that this ERP component reflects the operation of a mechanism shared by both linguistic and musical processes. How the processing of music and language overlap was made even more apparent by the discovery of an early-right anterior negativity (ERAN) in music which is reminiscent of the early left-anterior negativity (ELAN) associated with linguistic grammatical processing (Koelsch, Gunter, & Friederici, 2000; Patel et al., 1998). The ERAN is sensitive to the degree of musical expectancy induced by the preceding harmonic context. Recent neuroimaging research found that ERAN like ELAN originates in Broca's area and its right hemisphere homologue (Maess, Koelsch, Gunter, & Friederici, 2001; Tillmann, Janata, & Bharucha, 2003), and it has been argued that the entire cortical language network serves the processing of Western tonal harmony (Koelsch, Gunter et al., 2002).

Investigating vocal music processing is of methodological importance to further highlight the complex relationship between music and language processing. If language and music are related in some way, then evidence for interactive effects should be more easily underscored with vocal music. In contrast, evidence for independent processing would definitely confirm the modular nature of both domains. Up to now, the research on vocal music supporting an independent model has used unaccompanied melodies (Besson et al., 1998; Bonnel et al., 2001). By contrast, research in favor of a dependent model has used harmonic chord sequences. To our knowledge, the only research that has manipulated the harmonic structure in vocal music supports a dependent model by showing that musical context influences phoneme monitoring in vocal music (Bigand, Tillmann, Poulin, D'Adamo, & Madurell, 2001). Phoneme monitoring was faster when the target phonemes were sung on a referential tonic chord than when they were sung on a congruent but less referential subdominant chord.

The present study goes a step further by investigating how harmonic structure interferes with the processing of semantic information. Using chorales as musical sequences, participants were required to perform a lexical decision task on the last sung word (Fig. 1). The target word was either strongly or moderately semantically related with the sentence and sung either on a strongly or moderately harmonically related chord. A lexical decision task was used, and we expected correct responses for word targets to be faster when the last word was sung on a tonic chord than when it was sung on a subdominant chord.

2. Method

2.1. Participants

Forty-two students participated in the experiment: 27 students who did not have any formal training in music or any practice of a musical instrument (referred to as *nonmusicians*); and 25 candidates for the final diploma in music conservatories (referred to below as *musicians*). All participants received course credit or were paid $7 for their participation.

2.2. Materials

2.2.1. Linguistic material

Forty-eight sentences of eight syllables were created. In half of them, the last word (a monosyllabic word) was semantically related either strongly or moderately (La girafe a un très grand **cou**[1] versus La girafe a un très grand **pied**[2]). The other half of the sentences were identical except that they ended on a nonword that derived from the word target by the addition or subtraction of a single phoneme (La girafe a un très grand **crou**). These sentences were selected from a pilot study showing that semantically spoken related words were processed

[1] The giraffe has a very long **neck**.
[2] The giraffe has a very long **foot**.

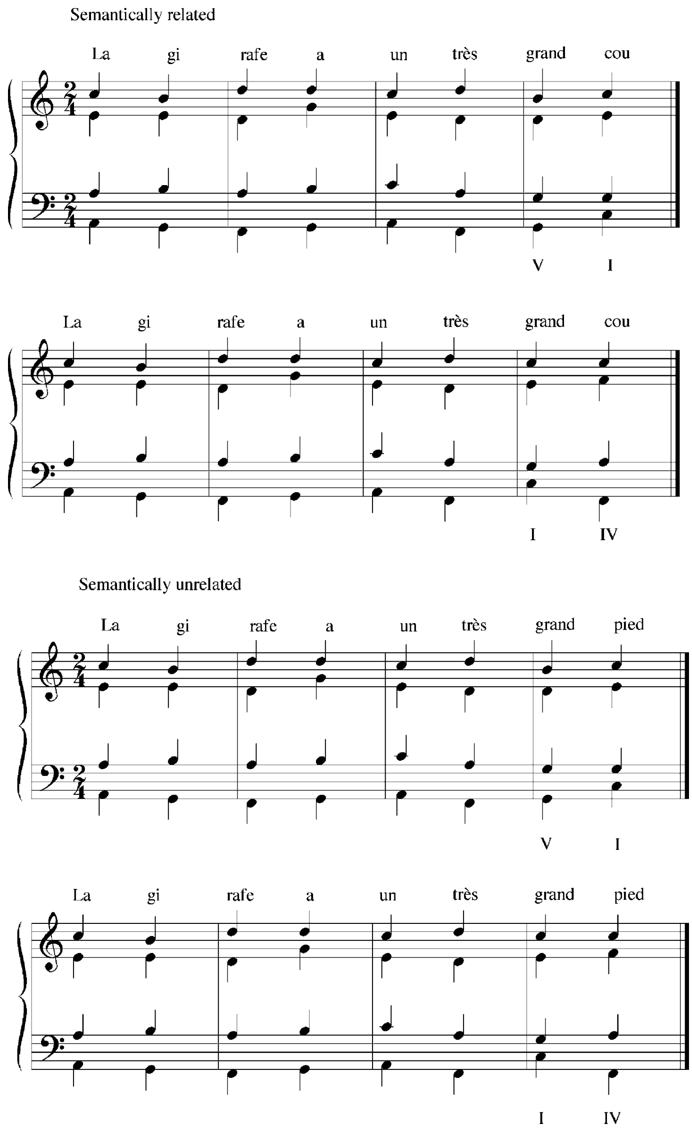

Fig. 1. One example of the sung chord sequences used in the experiment.

better, $F1(1,26) = 12.76$, $p = 0.001$, $MSE = 350.11$, and faster than unrelated ones, $F1(1,26) = 86.61$, $p < 0.001$, $MSE = 67915.37$ for correct response times. The 24 sentences resulting in a stronger semantic priming effect were selected for the vocal study.

2.2.2. Vocal material

Forty-eight 8-chord sequences from Bigand et al. (2001) were used. The first six chords of each sequence were held constant. The harmonic function of the target chord was manipulated by changing the last two chords. The last chord functioned either as a stable tonic chord (I) or as a less stable subdominant chord (IV). In order to neutralize local harmonic priming effects, the last two chords were always one step apart on the circle of fifths, creating a local perfect cadence (V–I). The target chords never occurred previously in the context sequence. The 48 sentences and the 48 chord sequences were combined, resulting in 96 sung sentences, so that there were 12 sentences ending on a semantically related word sung either on a tonic or a subdominant chord (resulting in 24 sung sequences), and 12 sentences ending on a semantically unrelated word sung either on a tonic chord or a subdominant chord (resulting in another set of 24 sung sequences). The same design was applied to the nonwords, leading to a total of 96 sung sequences. This manipulation is illustrated in Fig. 1 for a correct target word. The sequences were sung on 6 different musical keys.[3] A preliminary control experiment was run to demonstrate that there was neither semantic nor harmonic priming when the last two words of the sung sentences were used as stimuli.

2.3. Apparatus

The sentences were sung by four professional French singers, and recorded in a professional studio. During the recording, the singers heard, over headphones, the musical sequences played by a piano at a strict tempo and without any expressive deviation. They were asked to adjust their singing as much as possible to the piano part. The sung sentences were recorded by Protools software—(version 5.1) and were then captured by SoundEditPro software at CD quality (16 bits and 44 kHz). The experiment was run with Psyscope software (Cohen, MacWhinney, Flatt, & Provost, 1993).

2.4. Procedure

Each participant was asked to decide quickly and accurately whether the last sung lyric was a word or a nonword. They were alerted by a feedback signal if they gave an incorrect response. Crossing the Semantic relationship (related versus unrelated), the Harmonic function (tonic versus subdominant) and the Lexicality (word versus nonword) resulted in 96 sung sentences that were presented in a random order. Musical expertise (musicians versus nonmusicians) defined the within-subject variable.

3. Results

Percentages of correct responses are displayed in Fig. 2 (top). A 2 (Musical Expertise) × 2 (Harmonic Function) × 2 (Semantic Relationship) ANOVA revealed significantly more correct responses for semantically related words (92.63%) than for unrelated words (80.77%), $F(1,50) = 58.91$, $p < 0.001$, $MSE = 123.42$. This effect of semantic priming was

[3] Sound examples of the stimuli may be found on the WEB at the following address: http://www.u-bourgogne.fr/LEAD/people/bigand.

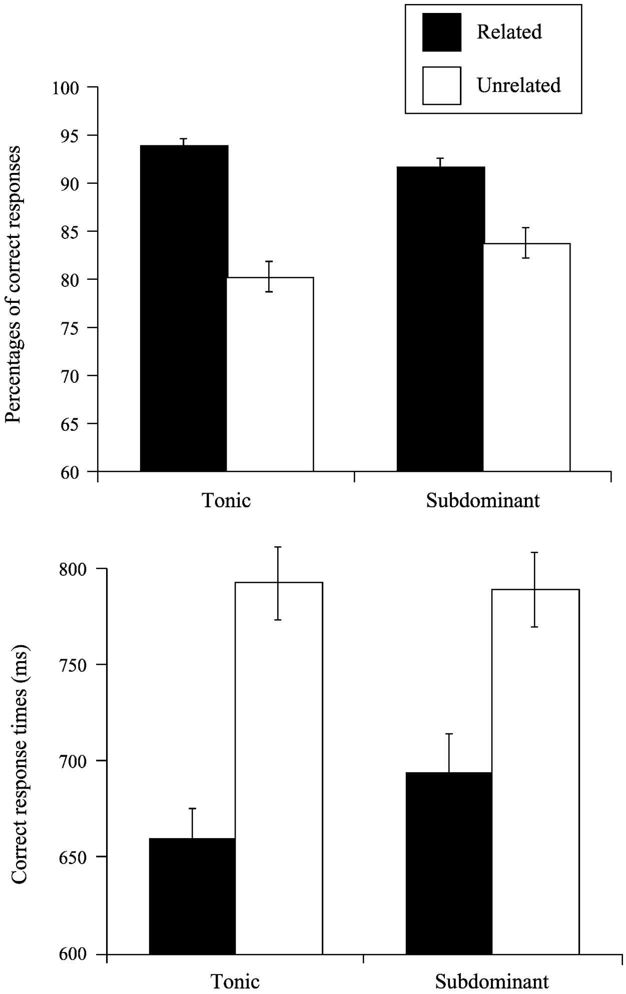

Fig. 2. Percentages of correct responses (top) and correct response times (bottom), average on musicians and nonmusicians, for related and unrelated words, and for tonic and subdominant chords.

stronger on tonic (+14.42%) than on subdominant targets (+9.29%) as attested by a marginally significant Harmonic Function × Semantic relationship interaction, $F(1,50) = 3.64$, $p < 0.062$, $MSE = 88.37$. There were no other significant effects.

Correct response times (Fig. 2, bottom) mimic correct response rates. Shorter response times were found for semantically related words (651.80 versus 765.88 ms for the unrelated words), $F(1,50) = 195.90$, $p < 0.001$, $MSE = 3395.97$, and this effect of semantic priming was more pronounced on tonic (135.30 ms shorter) than on subdominant target (92.88 ms shorter), as revealed by a Harmonic Function × Semantic Relationship interaction, $F(1,50) = 6.83$, $p = 0.01$, $MSE = 3418.11$. In addition, a significant Musical Expertise × Semantic Relationship interaction indicated a stronger effect of semantic relatedness with nonmusicians, $F(1,50) = 8.27$, $p = 0.006$, $MSE = 3395.97$. There were no other significant effects.

Table 1
Combination of the sung sentences used in the second control experiment

The giraffe has a very long	Experiment	Control
Context A	Neck/tonic	Foot/subdominant
Context B	Neck/subdominant	Foot/tonic
Context C	Foot/tonic	Neck/subdominant
Context D	Foot/subdominant	Neck/tonic

A further control experiment was run to assess whether this finding could be caused by anticipation cues within the sequence context. As described in Table 1, this control consisted in playing the related targets with contexts that were previously used in the unrelated condition (and vice versa). A new ANOVA was run, this time with the data of the control group, musicians and nonmusicians. This 3 (Nonmusicians, Musicians, Control)×2 (Harmonic Function)×2 (Semantic Relationship) ANOVA replicated our previous finding: there was a main effect of semantic relationship, on correct response rates (92.69 and 81.94%, for related and unrelated words, respectively), $F(1,66)=51.14$, $p<0.001$, $MSE=7082.48$. This effect was more pronounced for tonic than for subdominant chords, as attested by a Harmonic Function×Semantic relationship interaction, $F(1,66)=7.71$, $p<0.008$, $MSE=582.63$. The group variable (i.e. nonmusicans, musicians, control) never resulted in a significant interaction with the two other variables: in the control group, correct responses were more numerous for semantically related targets sung on tonic chords (11.27% more) than for those sung on subdominant chords (3.43%).

Correct response times mimic the previous ones: there was a main effect of semantic relationship (675.92 and 790.26 ms, for related and unrelated words, respectively), $F(1,66)=225.23$, $p<0.001$, $MSE=858348.80$, and this effect was modulated by the harmonic function of the target as revealed by a significant Harmonic Function×Semantic Relationship interaction, $F(1,66)=5.86$, $p=0.02$, $MSE=20771.80$. Semantic priming effects were more pronounced on tonic chords than on subdominant chords, and this interaction did not vary as a function of the group variable. In the control group, correct response times were 125.83 and 104.83 ms shorter for semantically related targets than for semantically unrelated targets sung on tonic chords, and subdominant chords, respectively.

4. Discussion

The effect of semantic context on lexical decision tasks has been widely documented in psycholinguistics. The present study replicates this effect with vocal music and further reveals that subtle manipulations of semantic context result in extensive priming. The critical point has been to establish that both semantic and harmonic contexts influence the processing of a target word. This new finding goes one step further than Bigand et al. (2001) by demonstrating the interference effects of music at a higher level of linguistic processing. This has several implications.

The fact that musical context modulates a linguistic computation in which the participants were explicitly engaged suggests that musical structure is processed in an automatic and irrepressible way. This effect of musical context is astonishing for two additional reasons. First, the musical context used resulted from a fine manipulation of harmonic relatedness. Both tonic and subdominant chords belong to the key and define referential events in Western music (Krumhansl, 1990; Lerdahl, 1988). Second, the local harmonic relationship between the target and the chord that immediately precedes it was kept constant. As a consequence, the harmonic priming effect observed necessarily implies that the entire musical sequence was processed (see, Bigand, Madurell, Tillmann, & Pineau, 1999, Exp 2, for experimental controls). All of these points indicate that a sophisticated cognitive process is automatically involved in music processing. Moreover, the fact that musically trained and untrained listeners behave very similarly indicates that this process does not require an explicit knowledge of music. This is consistent with a large set of data showing that harmonic priming occurs at an implicit level and results from the implicit learning of Western tonal regularities (Tillmann, Bharucha, & Bigand, 2000) as with other data showing that the auditory cortex of nonmusicians can process musical relations automatically (Brattico, Näätänen, & Tervaniemi, 2002; Koelsch et al., 2000; Koelsch, Schröger, & Gunter, 2002; Trainor, McDonald, & Alain, 2002).

Another conclusion can be made concerning the dependence between musical processing and the linguistic processing of lyrics. Semantic priming is believed to be a fast acting process that occurs automatically. The present data demonstrate that music interferes with this automatic processing. This finding slightly differs from that reported by Bonnel et al. (2001). These studies are different, mainly because ours focuses on the implicit nature of the experimental task, whereas theirs focuses on the explicit nature of the task. In Bonnel et al. (2001), participants were required to pay explicit attention to music and/or semantic incongruities, whereas it was not the case in our study. Considerable differences exist between implicit and explicit processing, and participants usually perform better on an implicit task (Van der Linden, 1994, for a review). For example, the effect of harmonic structure on phoneme monitoring was recently replicated with a brain-damaged patient, IR, who was shown, through several explicit tasks, to have lost most of her musical abilities (Tillmann, Peretz, & Bigand, 2003). Some dissociation between music and language may thus be observed at an explicit level but it has not been observed when the task taps into implicit processing. Accordingly, we would suggest that the dependence of linguistic and musical processing might rely on the implicit or explicit nature of the processes involved. Explicit tasks usually require participants to focus attention only on one type of violation. Implicit tasks, by contrast, tap into processes that are mostly associative by nature. As a consequence, representations probed by implicit tasks are made of insecable chunks of knowledge that are not articulated into well-defined subunits (Perruchet & Vinter, 2002; Shanks, 1995). Implicit tasks, thus, are less likely to bias participants toward analytic processing of the one or the other structure than explicit tasks. The result is that participants are more likely to process both pieces of information as a whole. This difference in the tasks used could explain the difference between our finding and that of Bonnel et al. (2001).

The most challenging issue is to explain how musical and semantic priming combine in vocal music. An additive model would predict that the size of the semantic priming effect would not vary as a function of musical structure. Stronger processing facilitation should be observed for sung targets primed by both the semantic and the musical context, and processing should be weakest when the target is semantically and harmonically unrelated. The present data run counter to this prediction. The difference between the semantically related and unrelated conditions was larger for targets sung on tonic chords than those sung on subdominant chords. Musical and linguistic processing thus interfere at some stage of processing that remains to be specified.

It has been claimed that semantic priming in lexical decision may result from participants evaluating the semantic relationship between the target and the prime. Detecting a relation triggers fast "yes" responses since only words can be semantically related to the prime (e.g. de Groot, 1985; Neely, 1991). In the same way, it may be argued that, target-context congruency computation might have been influenced by harmonic congruency. Responses may have been faster and more accurate for targets occurring in doubly congruent sentences (i.e. contextually related words sung on the tonic) than for targets occurring in contextually congruent but harmonically incongruent sentences. This interpretation, however, is far from compelling since it is hard to conceive how detecting a musical congruency between targets and musical context may have any logical implication about the nature (word or nonword) of the target: both words and nonwords can be sung on chords related to the context.

Another possibility would be that the interactive effects of music and language could result from two checking mechanisms (one for a semantic relation and one for a harmonic relation) running concurrently (in parallel) and independently (Holender, 1992). Greater facilitation should thus be observed for target words (YES) that are both semantically (YES) and musically (YES) related, moderate facilitation should be found for target words that were either semantically (YES) or musically (YES) related. Responses times and error rates should be the greatest for target words (YES) that are neither semantically (NO) nor musically (NO) related. The significant two-way interaction between music and language did not support this additive model: moreover the worst performance was actually found in the semantically unrelated but musically related condition.

A third possibility would be that both checking mechanisms interfere. That is to say, the best performance should be found when targets were both semantically and musically related, or when they are both semantically and musically unrelated. This was obviously not the case. For all these reasons, it seems very difficult to account parsimoniously for the present data by some form of incongruity effects.

A more promising explanation comes from Jones' dynamic attention theory. Music displays several accents whose common function is to capture the listener's attention during the unfolding of a musical piece (Jones, 1987; Jones & Boltz, 1989). In Western music, tonic chords are more referential than subdominant chords and, for this reason, are likely to work as (culturally based) attentional markers, which capture more attentional resources (Bigand, 1993; Boltz, 1989). As a result, the amount of attentional resources available for the linguistic processing would be greater on tonic than on subdominant chords, resulting in different sizes of the semantic priming effect. That is to say, music draws attention first, at some preattentive stage, and then linguistic analysis takes place. In Bigand et al. (2001), processing phonemes sung on tonic chords was more accurate and faster than processing those sung on subdominant chords. This last interpretation is compatible with several ERP studies on musical priming showing that harmonic relatedness effect occurs very early in ERP component. Latencies earlier than the N400 observed for the semantic incongruities have already been found with chord sequences (Koelsch et al., 2002; Regnault, Bigand, & Besson, 2001).

In sum, music could modulate semantic priming in vocal music, by modifying the allocation of attentional resource necessary for linguistic computation. Several musical features (harmony in the present study) may interfere with the linguistic computation of lyrics exactly as prosodic cues do in spoken language. When musical and linguistic information are mixed in a single auditory signal, it would be as difficult to ignore the prosodic-like features displayed by music as it would to ignore prosodic cues in spoken sentences. An independent processing of music and language is thus extremely unlikely to occur in the normal hearing of vocal music, even when listeners explicitly attempt to focus on language, as in the present study.

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Appendix A

Semantically related	Semantically unrelated
Le cerf courait après la biche	Le cerf courait après le chat
Le chien courait après le chat	Le chien courait après la biche
La jeune fille l'embrasse sur la joue	La jeune fille l'embrasse sur la main
La jeune fille lui serra la main	La jeune fille lui serra la joue
Ce clown travaille dans un grand cirque	Ce clown travaille dans un grand bois
Le bûcheron travaille dans le bois	Le bûcheron travaille dans le cirque
L'hirondelle retourne dans le nid	L'hirondelle retourne dans le trou
La taupe se cachait dans le trou	La taupe se cachait dans le nid
Le champion gagna une belle coupe	Le champion gagna une belle cruche
Il versa de l'eau dans la cruche	Il versa de l'eau dans la coupe
La girafe a un très grand cou	La girafe a un très grand pied
Il trouva chaussure à son pied	Il trouve chaussure à son cou

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