Research Article

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Music training and the use of songs or rhythm: Do they help for lexical stress processing?

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Abstract: Previous studies revealed that musicians outperformed non-musicians in different language tasks and that the use of music or rhythm in teaching material can benefit language learning. Here, we examined whether music, as a learner's characteristic (musicians/non-musicians) or as a characteristic of the task (use of music or beat) can facilitate foreign language lexical stress processing. 25 non-musician and 21 musician French native speakers performed a discrimination task in which stimuli were either naturally spoken, spoken with a beat on the lexical stress, or sung. The participants heard 96 stimuli of three Dutch (non)words varying in the lexical stress position and mentioned which of the last two words was pronounced as the first. The results show that musicians outperformed non-musicians, that the accuracy rate is higher for sung stimuli and spoken stimuli with a beat than for spoken stimuli and that music training interacts with the musical characteristics of the stimuli.

Keywords: psycholinguistics, bilingualism, music, songs, foreign language acquisition, lexical stress processing

1 Introduction

1.1 Music and language research

Music and speech have much in common: both are complex auditory signals based on the same acoustic parameters (frequency, duration, intensity and timbre), they are hierarchically organized and are universals of human culture. Moreover,

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producing or decoding music and speech requires different functions, such as attention, memory and sensorimotor abilities (Kraus and Chandrasekaran 2010; Patel 2013; Peretz 2006). In view of these multiple parallelisms, it is not surprising that the potential link between music and language has generated much research in the last decades, among others in brain imaging studies or in behavioural analyses.

At the brain level, brain imaging studies have reported some common neural responses in music and speech processing, although some processing networks can be distinct (Peretz et al. 2015; Schön et al. 2010). Moreover, researchers observed lasting brain changes in response to music training. These changes are related to music and instrument domains, such as auditory, motor or visual-spatial brain regions (Gaser and Schlaug 2003; Pantev et al. 1998), but extends also to nonmusical domains, for example speech processing. Differences in neural responses between musicians and non-musicians have been observed for pitch processing (Marie et al. 2011; Schön et al. 2004; Wong et al. 2007), syntax processing (Jentschke and Koelsch 2009), speech segmentation (François et al. 2013) and speech sounds perception (Intartaglia et al. 2017).

In addition to these neurological differences between musicians and non-musicians, many behavioural studies report higher performance of musicians than non-musicians in several linguistic tasks, whether in their mother tongue or in a foreign language. At segmental level, phoneme differences are more accurately detected by musicians than by non-musicians (Chobert et al. 2011; Perfors and Ong 2012; Sadakata and Sekiyama 2011; Zuk et al. 2013). At suprasegmental level, weak pitch variations are better perceived by musicians than by non-musicians (Magne et al. 2006; Schön et al. 2004; Alexander et al. 2005; Lee and Hung 2008; Marie et al. 2011; Marques et al. 2007). Musicians also encountered fewer difficulties in speech repetition compared to non-musicians (Pastuszek-Lipińska 2007). Moreover, musicians outperform non-musicians in tasks of prosody perception and production. For example, Thompson et al. (2003) observed that music training enhanced the ability to extract prosodic information from spoken phrases and Stepanov et al. (2018) state that early musical training positively influence the discrimination of prosody patterns in a foreign language. Dankovicová et al. (2016) relate that difficult prosodic analyses, such as nuclear tone[1] identification, were better performed by musicians than by non-musicians. Kolinsky et al. (2009) concentrated on lexical stress processing by French musicians and non-musicians and reported that ‘music expertise enhances sensitivity to stress contrasts’ (p. 235). Music training seems thus to be positively linked with the performance in different linguistic tasks.

1 ‘The nuclear tone is the most prominent pitch movement in a tone unit’ (Crystal 2008, p. 335).

Besides studies comparing musicians and non-musicians' performance in linguistic tasks, researchers also examined the effectiveness of the use of music in the foreign language classroom. Indeed, foreign language teachers sometimes make use of songs or rhythmical activities (e.g. clapping hands) to improve vocabulary, pronunciation or listening abilities. The effectiveness of this music related methodology for the different foreign language skills has been analysed in several experimental or classroom-based studies (for a review, see Degrave 2019). Concerning vocabulary learning, students hearing a sung story seem to obtain better text recall than students hearing the spoken version of the song in an L2 task (Salcedo 2010). Furthermore, Ludke et al. (2014) tested participants listening and repeating musical, spoken but also rhythmic sentences in a foreign language. A significant difference between the sung and rhythmic/spoken conditions was found for the tests in which the participants had to speak in the foreign language (Hungarian), although performance was highest in the sung condition for all tests. As regards speech segmentation, Schön et al. (2008) relate that speech segmentation was better for the participants who heard a sung stream of syllables than for the participants hearing a monotone spoken stream of syllables. Concerning suprasegmental abilities, musical methodology seems also to have a positive effect: Moradi and Shahrokhi (2014) and Heidari-Shahreza and Moinzadeh (2012) compared the pronunciation and prosody perception of language learners after a training with sung material or with spoken material and observed that the participants in the musical condition obtained significantly higher results than the participants in the spoken condition.

1.2 Lexical stress perception

Although the research interest about the link between music and language has increased in the last years, little attention has been paid to the relation between music and lexical stress perception in particular. Lexical stress, i.e. a more prominent syllable of a word than the others, plays a crucial role in communication since the meaning of a word can change in function of the place of the stress (e.g. in Dutch: *VOORnaam* = *first nam*e; *voorNAAM* = *respectable*). However, its acquisition can be very challenging for foreign language learners, in particular for speakers of languages that do not use lexical stress (e.g. French). Dupoux and colleagues (Dupoux et al. 1997, 2001, 2008) even speak about stress 'deafness': they state that French speakers are, in some conditions, 'deaf' to stress contrasts. This stress 'deafness' can however vary, for example depending on the profile of the learner or on the characteristics of the task.

Concerning the profile of the learner, researchers observed varying sensitivity to lexical stress depending on type of L1 (Altmann 2006; Caspers 2009; Peperkamp et al. 2010): speakers of L1s with predictable stress (e.g. French) exhibit more difficulties to detect lexical stress, whereas L1speakers of languages with unpredictable stress (e.g. Spanish) do not encounter stress 'deafness'. Moreover, the influence of L2 proficiency on stress 'deafness' has been examined but remains not clearly answered: while Schwab and Joaquim (2011) observed differences in learners' ability to perceive lexical stress in function of L2 proficiency level, Dupoux et al. (2008) and Tremblay (2009) did not. However, Tremblay (2009) observed an influence according to daily L2 use on stress perception. Furthermore, some researchers state a 'training effect' since they observed a progression in lexical stress perception during the tests (Michaux 2016; Schwab and Joaquim 2011).

As regards the characteristics of the stimuli, two main features influencing stress 'deafness' have been stated. First, the memory load of the task: Dupoux et al. 1997 observed that French participants made few errors in a same/different task in which non-words differed only in the stress position (e.g. *BOpelo-boPElo*). Nevertheless, stress deafness increased when the task was memory loaded (e.g. *ABX* task instead of a same/different task). Second, the phonetic variability of the stimuli: Dupoux et al. (2001) and Tremblay (2009) have reported that stress 'deafness' increases with phonetic variability, such as multiple tokens or different talkers. This suggests that French speakers can use acoustic stress cues to perform a perception task in a standard same/different task, but that stress 'deafness' occurs at 'a more abstract, processing level, which is revealed only with tasks that are more demanding as far as memory and perceptual abilities are concerned' (Dupoux et al. 2001, p. 1607).

1.3 Lexical stress processing and music

Since stress 'deafness' can vary depending on the learner and on the task, this study aims to analyse whether music can influence lexical stress processing. It has indeed been shown that music as a characteristic of the learner (e.g. music training) can have a positive effect on various linguistic abilities. The question is thus whether this effect extends to lexical stress processing. Moreover, music as a characteristic of the task (use of songs or rhythmical activities) seem to facilitate foreign language abilities, but the question arises whether these musical methodologies are efficient in a lexical stress processing task. Surprisingly, only few behavioural studies exist in the field. Concerning the effect of the characteristics of the learner, Kolinsky et al. (2009) conducted a study testing musicians and non-musicians in a sequence repetition task (the participants reproduce each sequence by typing the associated keys in the correct order) and in a speeded classification task (the participants identify non-words, ignoring stress variations). The results show that musicians exhibit reduced stress 'deafness' for weak stress contrast and that their 'enhanced sensitivity to stress contrasts does not lead them to be poorer than nonmusicians when stress variations must be ignored' (p.243). Turning to the effect of the characteristics of the task, Heidari-Shahreza and Moinzadeh (2012) and Moradi and Shahrokhi (2014) conducted pretest/posttest experiments with a training with musical or nonmusical material. Heidari-Shahreza and Moinzadeh (2012) investigated the effect of listening to musical stimuli compared to spoken stimuli for stress perception and observed that the musical group obtained higher scores than the control group. Moradi and Shahrokhi (2014) examined the impact of using songs on segmental and suprasegmental production: after 25 sessions, the group who worked with songs had a better pronunciation in a reading task than the group who worked with the spoken version of the songs. These studies show that music, either as a characteristic of the learner (musicians vs. non-musicians) or as a characteristic of the task (the use of songs in teaching methodology) seems to positively influence lexical stress processing. More research and other types of experiments are however needed to confirm the benefit of music on lexical stress acquisition. Moreover, to date, empirically grounded research on musical teaching methods and foreign language acquisition are rather scarce (Good et al. 2015; Ludke 2016). Furthermore, there is little published data analysing simultaneously the impact of music training and of musical foreign language teaching methods for lexical stress processing. Larrouy-Maestri et al. (2013) reported that the positive effect of the use of music in a linguistic task observed by Schön et al. (2008) benefitted only musical experts, compared to language experts or non-experts. More study is thus needed to state whether music related language methodology is equally beneficial for musician as for non-musician learners.

1.4 Present study and research questions

In this study, we explored the relation between music and lexical stress processing from two perspectives: music as a characteristic of the learner (musicians vs. non-musicians) and music as a characteristic of the task (musical vs. non-musical stimuli). To this end, musicians and non-musicians heard stimuli of three words or non-words varying in stress position and had to mention which word matched with the first. The stimuli were either spoken, spoken with a beat on the lexical stress, or sung. We tested French native speakers – who do not use lexical stress in their L1 – perceiving Dutch – a lexical stress language – since French speakers encounter

many difficulties in Dutch lexical stress perception (Michaux 2016). The main research questions of this study are:
1. Do musicians significantly outperform non-musicians in a foreign language lexical stress processing task?
2. Does the use of a melody or beat in a task have a positive effect on lexical stress processing?
3. Is the use of a melody or beat in the task equally beneficial to musicians and non-musicians in a lexical stress processing task?

Moreover, as mentioned above, previous studies have shown that various (non-musical) factors affect ‘stress deafness’. Based on these observations, this study will also examine the effect of non-musical variables on lexical stress processing, namely:

1/ the effect of foreign language proficiency level; 2/ the effect of the use of words and non-words; 3/ the effect of the block; 4/ the effect of memory load.

2 Experiment

2.1 Materials

32 trisyllabic Dutch words (verbs) and non-words whose lexical stress fell on the first or second syllable were selected as test items. The real words exist in Dutch with the two stress positions inducing a lexical variation (e.g. *DOORbreken* (= *to collapse*) vs. *doorBREken (= to break through)),* whereas the non-words are non-existing (e.g. *DOORkoven, doorKOven).* The 32 items were first recorded several times on a naturally spoken way by two native Dutch speaker musicians (one male and one female), using a Tascam-07 MKII recorder and a Sennheiser PC131 head-set microphone. Second, in order to determine melodies for the sung stimuli, the recorded spoken items were analysed with Praat (Boersma and Weeninck 2009). Based on the melodic contours of the spoken items, we created melodies of three notes, each note corresponding to one syllable. The stressed syllables had higher frequencies, had an accent and lasted twice as long (an eighth note) as the unstressed syllables (a 16th note). The given tempo was defined in order to correspond to the mean tempo of the spoken words. The melodies were on three different keys (C major, F major and E flat major) (see Appendix A and B for examples of the music scores). Afterwards, the two Dutch speaker musicians were recorded for the song stimuli, which they recorded several times. They could make use of a metronome and a piano to make sure that they sung in tune and in time. The audio recordings were checked by two musicians and linguist-specialists in

order to ensure that the sung audio recordings were accurate (in tune and in time, with clearly intelligible speech sounds).

From the recorded items, from which the most clearly articulated recordings had been selected, 96 trials were constructed. 32 trials were naturally spoken, 32 were sung and 32 were naturally spoken with a beat on the stressed syllable. To create the trials with the beat, a sound of 440 Hz and of 0.150 s was added on each stress of the recorded spoken items.

Each trial consisted of three stimuli, *X, A* and *B*. The three stimuli received the stress on the first or on the second position. *X* had the same stress position as *A, B, neither A nor B, both A and B*. Therefore, contrary to the *ABX* tasks or *AXB* tasks of Dupoux et al. 1997; Tremblay 2009, not only two answers were potentially correct (*A* or *B*) but four, namely *A, B, neither A nor B, both A and B*. The advantage is that the participants are forced to listen to the three stimuli, contrary to a task with only two potential correct answers: with only two potentially correct answers, the task may approximate simple discrimination tasks where *B* (or *A*) is judged as the same or different from *X*. *A* (or *B*) are then ignored. Moreover, with four potential correct answers, we can further analyse the memory load of the task. Indeed, Dupoux et al. 1997 have shown that in the *ABX* task, performances are less accurate when *X* is *A* (long distance between the two words, as a consequence more memory loaded) than when *X* is *B* (shorter distance between the two words, therefore less memory loaded). Here, we can further analyse the memory load of the task, examining also accuracy rate when *X* is neither *A* nor *B* and when *X* is both *A* and *B*. Furthermore, the participants could also choose a 'I don't know'-answer, in order to avoid answering by guessing.

To promote acoustic and phonetic variability (see Dupoux et al. 2001), the trials had the following characteristics: the first stimulus was said by a man and the last two by a woman; tokens of each stimulus were different; the three stimuli were separated by a short silent period (i.e. 200 ms.). All the trials lasted between 2.900 and 3.297 s ($M = 3.098$ s, SD = 0.124). This difference in time is simply explained by the speaking time for each word.

The 96 experimental trials were split into three blocks, with each condition represented in each block. An extra practice block of six trials with the same conditions but with different items was added before the beginning of the test. The complete list of the 96 test-trials and of the 6 exercise-trials with their characteristics can be found in Appendix C.

2.2 Procedure

Each participant was tested individually in a quiet room, in a single session. All instructions were given in French. After signing a consent form, they performed the perception test. For this test, the participants were seated in front of a laptop (640 × 480 pixels; resolution 1.66 GHz) and heard the stimuli through Sennheiser PC131 headphones. Presentation of the stimuli, response and reaction time recording were controlled using E-Prime and responses were given on a Serial Response Box (Psychology Software Tools Inc. (PST), www.pstnet.com). The participants were required to listen attentively to the trials consisting of three words and to decide, as quickly and accurately as possible, which word pronounced by the woman (the last two) had the same pronunciation as the word said by the man (the first). The participants were forewarned that the stimuli were spoken in Dutch, were existing and non-existing words and that they were sung, naturally spoken or spoken with a beat. It was also mentioned that music or beat could help them to perceive the pronunciation, in order to avoid that participants, who are used to experimental tests, consider automatically the melody or the beat as distractors. Subjects used a five-button box to answer: the first word/ the second word/ none of them/ both words/ I don't know. Each trial started after each previous answer. Before the experimental session, the participants were given a practice block of six trials to familiarize them with the task. They received feedback on whether their response was correct or not. Feedback also mentioned the correct answer and a transcription of the trials indicating the stressed syllables. After the training session, the experimental part started. It comprised three blocks of 32 trials. Trials from the different experimental condition occurred within each block and were presented in a random order.

After the perception test, subjects completed a questionnaire assessing their language and music history. All the participants were paid to participate in the experiment that lasted for less than 30 min.

2.3 Participants

Two groups of university students from the UCLouvain participated in the experiment: 29 non-musicians and 27 amateur musicians. Data for 10 participants were discarded. Four from the non-musician group, because they exceeded our selection criteria for non-musicians (no more than two years of musical training and no practice since min. 10 years); 6 from the musician group because they did not reach our musicianship criteria (min. six years of musical training and current regular practice). Thus, the final group included 25 non-musicians (7 men; 22 right-handed; aged 18–25 years (M = 21.44, SD = 1.981)) and 21 musicians (7 men; 19 right-handed; aged 18–25 years (M = 21.05, SD = 2.012). Musicians played from 1 to 4 instruments (M = 1.3 – see Appendix D for a list of the instrument played), had received music lessons between 6 and 15 years (M = 10.48, SD = 2.46) and have practiced music between 10 and 20 years (*M* = 13.62, SD = 2.58). All musician and non-musician participants were French-native speakers. They had all learned at least one language that uses lexical stress contrast (e.g. Dutch, Spanish, English) as a foreign language, but not before the age of 6 and not in intensive programs (such as exchange years). Their knowledge of Dutch differed, since the number of years of Dutch classes varied between 0 and 14 (*M* years of Dutch = 5.52; SD = 4.60). They had always studied in French-speaking schools (no school in a foreign language, no school using the 'Content and Language Integrated Learning' (CLIL) approach). The participants had no hearing, language or attention problems according to self-report.

2.4 Data analysis

The dependent variable in this experiment is the participants' response accuracy for each 96 stimuli (0 or 1) for each participant. One point is given for a correct answer and zero for an incorrect or 'I don't know' answer. The within-subject independent variables are the type of stimuli (spoken, spoken with a beat, sung), the type of word (words, non-words), the response position (*A*, *B*, *neither A nor B*, *both A and B*) and the block (1, 2 or 3). The between-subject independent variables are the musical profile (musicians, non-musicians) and the number of years of Dutch.

Analyses were run with SPSS 25 through a generalized linear mixed model (GLMM) with a random intercept for participants. This model allowed us to take into account the dependence between our observations due to repeated measures. The GLMM was used for several reasons. First, the GLMM allows us to take into account both the variability induced by participants and the variability induced by items in the same analysis. Second, the GLMM can be used with binary variables (here: 0 (incorrect or *I don't know* answer), 1 (correct answer)). Third, the effect of both within- and between- participants, as well as the interactions, can be tested in one model.

The GLMM was run with the type of stimuli (spoken, spoken with a beat, sung), musical profile (musicians, non-musicians), number of years of Dutch lessons, type of words (words, non-words), response position (*A*, *B*, *neither A nor B*, *both A and B*) and block (block 1, 2 or 3) as the fixed main effects. The model also included the interaction between musical profile and type of stimuli.

The results are described below in two parts. First, we concentrate on the effects of the musical characteristics of the task and of the participants, namely

1. The effect of musical profile (musicians vs. non-musicians);
2. the effect of the type of stimuli (spoken, spoken with a beat, sung);

3. the interaction between the type of stimuli and the musical profile.

Second, we present the potential effects of the non-musical characteristics of the task and participants on lexical stress processing. These non-musical characteristics are:
1. the effect of foreign language proficiency (measured by the number of years of Dutch lessons);
2. the effect of words/non-words;
3. the effect of the block (1, 2 or 3);
4. the effect of memory load (through the different response positions).

3 Results

The results of the GLMM are presented in Table 1.

Table 1: Generalized linear mixed model on response accuracy in relation to musical and non-musical characteristics.

	*df*1	*df*2	*F*	*p*
Musical characteristics				
Musical profile	1	4 403	7.445	0.006
Type of stimuli	2	4 403	128.365	<0.001
Type of stimuli * musical profile	2	4 403	3.057	0.047
Non-musical characteristics				
Years of Dutch	1	4 403	4.253	0.039
Type of words	1	4 403	3.323	0.068
Block	2	4 403	16.822	<0.001
Response position	3	4 403	154.736	<0.001

Note: Musical profile: musicians/non-musicians; Type of stimuli: spoken, spoken with a beat, sung; Type of words: words/non-words; Block: block 1/2/3; Response position: X = A/X = B/ X = neither A nor B/ X = both A and B.

3.1 Musical characteristics of the task and of the learners

The effects of musical profile and the type of stimuli were significant. The means (*M)*, the standard errors (SE) and the confidence intervals (CI) values are detailed for these variables in Table 2.

The effects of musical profile and the type of stimuli were significant. Musicians significantly outperformed (M = 0.819, SE = 0.030) non-musicians (M = 0.681, SE = 0.039). The multiple comparison with sequential Bonferroni correction indicates that the participants obtained significantly higher scores for

Table 2: Means, standard errors and confidence intervals (CI) for the variables *Musical Profile* and *Type of Stimuli*.

		M	SE	CI Inferior	CI Superior
Musical profile	Musicians	0.819	0.030	0.753	0.870
	Non-musicians	0.681	0.039	0.600	0.752
Type of stimuli	Sung stimuli	0.894	0.014	0.863	0.919
	Spoken stimuli with a beat	0.684	0.030	0.622	0.740
	Spoken stimuli	0.620	0.032	0.555	0.681

the sung stimuli ($M = 0.894$, SE = 0.014) than for the spoken stimuli with a beat ($M = 0.684$, SE = 0.030) ($p < 0.001$), and then for the spoken stimuli ($M = 0.620$, SE = 0.032) ($p < 0.001$). The results are also significantly higher for the spoken stimuli with a beat than for the spoken stimuli ($p < 0.01$).

Moreover, the GLMM shows that the effect of a musical profile interacts with the type of stimuli. Figure 1 presents the perception scores of the three types of stimuli for the two musical profiles (musicians and non-musicians) and Table 3 gives the means (*M*), the standard errors (SE) and the confidence intervals (CI) values.

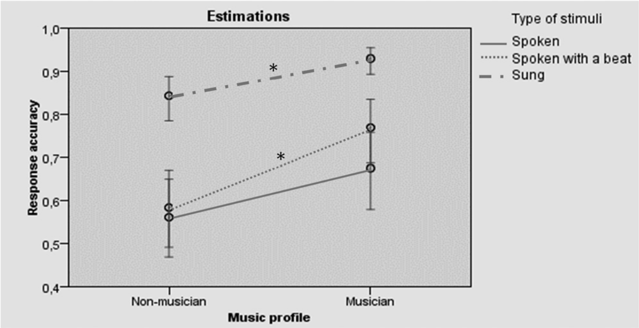

Figure 1: Response accuracy for the two musical profiles in function of the three types of stimuli.

Table 3: Means, standard errors and confidence intervals (CI) for the two musical profiles in function of the three types of stimuli.

		M	SE	CI inferior	CI superior
Non-musician	Spoken	0.561	0.047	0.469	0.650
	Spoken with a beat	0.584	0.046	0.492	0.671
	Sung	0.844	0.026	0.785	0.888
Musician	Spoken	0.675	0.046	0.580	0.758
	Spoken with a beat	0.770	0.038	0.687	0.835
	Sung	0.930	0.015	0.893	0.955

This figure and this table are interesting in several ways. First, we see that musicians obtain higher scores than non-musicians for the three types of stimuli (spoken, spoken with a beat, sung). The multiple comparison with sequential Bonferroni correction indicates that the difference in processing for the spoken stimuli between musicians (M = 0.675, SE = 0.046) and non-musicians (M = 0.561, SE = 0.047) is not significant. The difference is however significant for the spoken stimuli with a beat (musicians: M = 0.770, SE = 0.038; non-musicians: M = 0.584, SE = 0.046; $p < 0.01$) and for the sung stimuli (musicians: M = 0.930, SE = 0.015; non-musicians: M = 0.884, SE = 0.026; $p < 0.01$). Second, both musicians and non-musicians obtain the highest scores for the sung stimuli and the lowest for the spoken stimuli. The difference is significant between spoken and sung stimuli for both musicians ($p < 0.001$) and for non-musicians ($p < 0.001$). The difference is also significant between spoken stimuli with a beat and sung stimuli for both musicians ($p < 0.001$) and non-musicians ($p < 0.001$). However, the difference of correct answers between the spoken stimuli and the spoken stimuli with a beat is significant for the musicians ($p = 0.001$) but not for the non-musicians. This is clearly illustrated on the graph: whereas both groups show a similar difference between sung and spoken stimuli, the difference between spoken stimuli and spoken stimuli with a beat is very low for non-musicians compared to musicians. Hence, whereas both musicians and non-musicians obtain clearly better scores for the sung stimuli, the beat is particularly useful to musicians.

3.2 Non-musical characteristics of the task and of the learners

The effect was not significant for the type of words, but was significant for the number of years of Dutch, the block and the response position. The means (M), the standard errors (SE) and the confidence intervals (CI) values are detailed for these variables in Table 4.

The effect was not significant for the type of words (words/ non-words).

The effect was significant for the number of years of Dutch classes ($p < 0.05$).

Moreover, the effect was significant for the block. There were more correct responses in block 3 (M = 0.796, SE = 0.023) than in block 2 (M = 0.770, SE = 0.025) and then in block 1 (M = 0.697, SE = 0.030). The multiple comparison with sequential Bonferroni correction indicates that the differences are significant between block 1 and block 2 ($p < 0.001$) and between block 1 and block 3 ($p < 0.001$), but not between block 2 and block 3.

Table 4: Means, Standard Errors and Confidence Intervals (CI) for the non-musical variables.

		M	SE	CI inferior	CI superior
Words/nonwords	NonWords	0.743	0.026	0.690	0.790
	Words	0.769	0.024	0.718	0.813
Block	Block 1	0.697	0.030	0.636	0.751
	Block 2	0.770	0.025	0.717	0.815
	Block 3	0.796	0.023	0.746	0.837
Response position	X = both A and B	0.904	0.014	0.874	0.928
	X = A	0.853	0.019	0.812	0.886
	X = neither A nor B	0.607	0.034	0.539	0.671
	X = B	0.524	0.035	0.454	0.0592

For the variable 'number years of Dutch', the continuous predictors are set to the following value: 5.52

Furthermore, the effect was significant for the response position. The participants obtained higher scores when the correct answer is close to the *X* (*X* = *A*, *M* = 0.853, SE = 0.019) or when *X* = *both A and B* (*M* = 0.904, SE = 0.014)) than when the correct answer is far from the *X* (*X* = *B* (*M* = 0.524, SE = 0.035)) or when absent (*X* = *neither A nor B* (*M* = 0.607, SE = 0.034)). The multiple comparison with sequential Bonferroni correction indicates that all the means significantly differ from each other.

4 General discussion and further research

This experimental study evaluated lexical stress processing in a foreign language (Dutch, a lexical stress language) by French speakers, since French speakers do not use lexical stress in their L1 and encounter many difficulties in Dutch lexical perception (Michaux 2016). Our main research questions focused on the potential difference in processing induced by music, either as a characteristic of the learner (musicians/non-musicians) or as a characteristic of the task (task with or without music or rhythm). We also tested the effect of other non-musical characteristics on stress 'deafness', which had been described in previous studies (e.g. training or memory load effect).

Concerning the effect of music, three main observations can be reported.

First, the results of our *XAB* discrimination task show that musicians significantly outperformed non-musicians: stress 'deafness' is thus reduced for musicians compared to non-musicians. These results are in line with previous studies stating that musicians obtain higher results than non-musicians in different linguistic tasks, such as phoneme discrimination or pitch perception (e.g. Chobert et al. 2011; Magne et al. 2006; Marie et al. 2011; Sadakata and Sekiyama 2011). More specifically, our results confirm the link between music training and lexical stress processing, already reported by Kolinsky et al. (2009). Through a sequence repetition task and a speeded classification task, these authors observed that professional musicians (i.e. higher education students in a conservatory for music) outperformed non-musicians. In our study, we confirmed this observation through a different task (i.e. an *XAB* discrimination task) and we reported that reduced stress 'deafness' is found not only for professional musicians (as in Kolinsky et al. 2009), but also with amateur musicians. The reason why musicians outperform non-musicians in various linguistic tasks is still subject to considerable discussion. A much debated question is whether pre-existing differences between musicians and non-musicians, such as cognitive, socio-cultural or genetic, could explain the higher performance of musicians in various linguistic tasks (Chobert and Besson 2013; Mosing et al. 2016; Norton et al. 2005). Moreover, some other researchers state that this performance difference could be explained by the fact that music training improve some specific functions, such as executive or auditory functions, which in turn could influence test-taking abilities in linguistic domains (Amer et al. 2013; Moreno et al. 2011; Moreno and Bidelman 2014).

In further research, it would be interesting to test other kinds of musical characteristics of the learner than music training, such as musical abilities or engagement in musical activities. Previous experiments have already stated that musical aptitude, i.e. the 'raw' (untutored) abilities, can also be positively linked to enhanced language performance (Delogu et al. 2006; Gralinska-Brawata and Rybinska 2017; Milovanov et al. 2010; Slevc and Miyake 2006). Research is needed to confirm this link for lexical stress processing in particular. Moreover, we could also hypothesize that language abilities could be positively correlated with musical engagement without any specific music training or abilities (e.g. involvement in musical activities, listening to music, etc.). New experiments should be conducted to test these other musical characteristics.

A second observation is that our experiment gives evidence that lexical stress processing is facilitated with musical, but also rhythmical stimuli, compared to spoken stimuli. Indeed, the accuracy rate was significantly higher for sung stimuli than for spoken stimuli with a beat on the stress, and significantly higher for stimuli with a beat on the stress than for spoken stimuli. Two main explanations could be given for these results. First, it has been stated that the use of music in a linguistic task can support motivation (Mishan 2005), reduce anxiety (Dolean 2016) and sustain attention (Wolfe and Noguchi 2009). In this experimental study, it can be possible that the use of music or of a beat (i.e. adding a beat on the spoken stress) has enhanced attention of the participants, who might have been more focused and engaged when hearing sung stimuli or spoken stimuli with a beat, than spoken stimuli. A second possible explanation is that the use of music or of a beat emphasizes the phonetic aspects of verbal information, providing extra rhythmical of melodic cues, which can support the perception. The difference of perception between the sung stimuli and the spoken stimuli with a beat could be explained by the fact that the sung stimuli provided more cues (rhythmical and melodic) than the stimuli with a beat (only rhythmical) and that music could probably more sustain attention than only the presence of a beat. In further research, it would be interesting to explore the effect of rhythmical cue alone, using spoken stimuli with a clear, metrical rhythm (as in rap music) and to compare this effect with musical stimuli (stimuli whit a melodic line added to the rhythmical pattern).

Third, our research was the first experimental study analysing the potential interaction between musical profiles (musicians/non-musicians) and the type of stimuli (spoken/spoken with a beat/sung) in a lexical stress processing task. The results showed that although non-musicians results were consistently lower than musicians were, both musicians and non-musicians performed better with sung stimuli or spoken stimuli with a beat compared to spoken stimuli. Nonetheless, the difference in lexical stress processing is significant between musicians and non-musicians for both sung stimuli and spoken stimuli with a beat. Moreover, the difference between spoken stimuli and spoken stimuli with a beat was only significant for musicians. This could mean that rhythmical stimuli would benefit more musicians than non-musicians. A possible explanation is that musicians may show superior rhythm skills compared to non-musicians (Cameron and Grahn 2014; Rammsayer and Altenmüller 2006; Slater and Kraus 2016), which help the musicians to make use of the rhythmical cue (a beat on the lexical stress) in the perception task. This is in line with Larrouy-Maestri et al. (2013) who observed that a positive effect of the use of music in a linguistic task benefitted only musical experts compared to language experts or non-experts. Since little attention has been paid to the interaction between the musical profiles of the participants and the use of music in a linguistic task, more research would be needed.

Besides the music related questions, our study aimed also at examining some (non-musical) variables influencing stress 'deafness' which had been reported in previous linguistic studies. These were 1/ the effect of words/non words; 2/ the effect of L2 proficiency; 3/ the effect of the block; 4/ the effect of memory load.

The effect of word/non-word was not significant (p = 0.068). This could be explained by the fact that the participants probably did not know the existing words (less than 6 occurrences out of 100 documents in Tiberius and Schoonheim

(2013)) and that the distinction between the words and the non-words has thus not influenced their perception.

In order to control for the effect of L2 proficiency, we examined the effect of the number of years of Dutch at school on lexical stress processing. The GLMM indicates a positive significant effect. This corroborates the findings of Schwab and Joaquim (2011) who stated that knowledge of L2 provided more accurate and faster answers, but is contrary to Dupoux et al. (2008) and Tremblay (2009) who have reported that L2 proficiency level does not facilitate lexical stress perception. In our experiment, we tested participants who had never received Dutch lessons as well as participants with variable numbers of years of Dutch lessons. It would thus be interesting to test a more homogeneous group, to control for their Dutch level through a language test and to examine the correlation between their general proficiency level and lexical stress processing.

The training effect observed by Michaux 2016; Schwab and Joaquim 2011 in their experiments is in line with our results: the participants obtained higher scores in block 3, than in block 2 and in block 2 than in block 1, but the difference between block 2 and block 3 was not significant. This could suggest that there is an initial boost (from block 1 to block 2), but then performance plateaus. It would be however necessary to conduct an experiment with counterbalanced blocks, and more participants, to confirm or revoke the fact that stress 'deafness' can be reduced by training.

Finally, as Dupoux et al. (2001) have reported, the memory load of the task had an effect on the stress 'deafness'. Dupoux stated that French speakers had few errors in a same/different task, but much more in an *ABX* discrimination task, a more memory loaded task. They have also reported that, in the *ABX* discrimination task, the participants obtained better scores when $X = B$ than when $X = A$. This would mean that when the answer is far from the target ($X = A$), the task is more memory demanding since it requires to hold several stimuli in memory, and the results are thus lower, than when you can judge immediate identity ($X = B$). This was confirmed in our *XAB* discrimination task: the participants obtained lower scores when $X = B$ or when $X =$ *neither A nor B,* since participants have to hold several stimuli in memory. The highest accuracy rate was obtained for the $X =$ *both A- and B-* stimuli. In this case, the participants compared probably *B* with *A* and not with *X*, having heard that $X = A$. Consequently, the task is for $X =$ *both A and B* stimuli less memory loaded since 'judging immediate identity may be performed on a shallow memory store' (Dupoux et al. 1997, p. 415–416). In sum, our results confirm that stress 'deafness' varies with the memory load of the task.

In summary, these results provide additional insight into the lexical stress processing by French-speakers. Concerning the non-musical characteristics, we observed similar effects on lexical stress processing as reported by previous studies, i.e. an effect of L2 proficiency, no difference between words and non-words, a training effect and an effect of memory load. Concerning the musical characteristics, our experiment provides further support for the link between music and lexical stress processing. First, the results show that amateur musicians outperformed non-musicians in the *XAB* discrimination task. Therefore, the facilitating effect of music training on lexical stress processing reported by Kolinsky et al. (2009) is confirmed in another task and with non-professional musicians. Further research should be undertaken to analyse the potential effect of other kinds of musical characteristics of the learners, such as musical aptitude or engagement in music. Second, our experiment reveals that the use of music, but also the use of a beat can help learners to detect lexical stress, but that the participants obtain a higher accuracy rate with sung stimuli than with spoken stimuli with a beat. Further work is required to analyse the long-term recall of lexical stress when using music or rhythm in language methodology. Third, our experiment enables us to examine the interaction between the musical characteristics of the learner (musicians/ non-musicians) and the musical characteristics of the task (with or without music or rhythm). Analyses reveal an interaction showing that sung stimuli benefit both musicians and non-musicians, contrary to the use of beat that seems to benefit more musicians. In conclusion, these results show that lexical stress processing can be influenced by music, when music is a characteristic of the learners (i.e. music training) or a characteristic of the task (use of music or beat in the task).

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Appendix A Example of the music sheet used for the stimuli with the stress on the first syllable

Appendix B Example of the music sheet used for the stimuli with the stress on the second syllable

Appendix C List of the test- and exercise-trials and their characteristics

Stimulus XAB	Block	Type of stimulus	Response position	Word/ nonword
doorboren – door**bo**ren – **door**boren	1	Spoken	X = B	Word
voorbrezen – **voor**brezen – voor**bre**zen	1	Spoken	X = A	Nonword
omrellen – om**re**llen – om**re**llen	1	Spoken	X = neither A nor B	Nonword
door**kle**ken – **door**kleken – door**kle**ken	1	Spoken	X = B	Nonword
om**tre**kken – om**tre**kken – **om**trekken	1	Spoken	X = A	Word
om**kne**den – **om**kneden – **om**kneden	1	Spoken	X = neither A nor B	Nonword
door**lo**pen – **door**lopen – **door**lopen	1	Spoken	X = neither A nor B	Word

(continued)

Stimulus XAB	Block	Type of stimulus	Response position	Word/ nonword
door**ko**ven – **door**koven – **door**koven	1	Spoken	X = neither A nor B	Nonword
doorlezen – **door**lezen – **door**lezen	1	Spoken	X = both A and B	Word
omgeven – **om**geven – **om**geven	1	Spoken	X = both A and B	Word
voor**spel**len – voor**spel**len – voor**spel**len	1	Spoken	X = both A and B	Word
omkrullen – om**kru**llen – **om**krullen	1	Spoken with a beat	X = B	Word
voltrerren – vol**trer**ren – **vol**trerren	1	Spoken with a beat	X = B	Nonword
omboken – om**bo**ken – om**bo**ken	1	Spoken with a beat	X = neither A nor B	Nonword
door**ker**ven – **door**kerven – door**ker**ven	1	Spoken with a beat	X = B	Word
door**le**len – **door**lelen – door**le**len	1	Spoken with a beat	X = B	Nonword
vol**ma**ken – vol**ma**ken – **vol**maken	1	Spoken with a beat	X = A	Word
om**ge**nnen – om**ge**nnen – **om**gennen	1	Spoken with a beat	X = A	Nonword
door**krui**sen – **door**kruisen – **door**kruisen	1	Spoken with a beat	X = neither A nor B	Word
omkruden – **om**kruden – **om**kruden	1	Spoken with a beat	X = both A and B	Nonword
door**kem**men – door**kem**men – door**kem**men	1	Spoken with a beat	X = both A and B	Nonword
omzeffen – om**zef**fen – **om**zeffen	1	Sung	X = B	Nonword
doorkruigen – **door**kruigen – door**krui**gen	1	Sung	X = A	Nonword
voorkliepen – **voor**kliepen – voor**klie**pen	1	Sung	X = A	Nonword
om**ren**nen – **om**rennen – om**ren**nen	1	Sung	X = B	Nonword
door**spes**sen – **door**spessen – door**spes**sen	1	Sung	X = B	Nonword
door**lo**ken – **door**loken – door**lo**ken	1	Sung	X = B	Nonword
voor**zeg**gen – voor**zeg**gen – **voor**zeggen	1	Sung	X = A	Word
door**bre**ken – door**bre**ken – **door**breken	1	Sung	X = A	Word
door**klie**ven – **door**klieven – **door**klieven	1	Sung	X = neither A nor B	Word
omkleden – **om**kleden – **om**kleden	1	Sung	X = both A and B	Word

(continued)

Stimulus XAB	Block	Type of stimulus	Response position	Word/ nonword
om**kne**ven – om**kne**ven – om**kne**ven	1	Sung	X = both A and B	Nonword
omkneven – om**kne**ven – **om**kneven	2	Spoken	X = B	Nonword
doorbreken – **door**breken – door**bre**ken	2	Spoken	X = A	Word
voorzeggen – **voor**zeggen – voor**zeg**gen	2	Spoken	X = A	Word
doorkerven – door**ker**ven – door**ker**ven	2	Spoken	X = neither A nor B	Word
voltrerren – vol**trer**ren – vol**trer**ren	2	Spoken	X = neither A nor B	Nonword
om**krul**len – **om**krullen – om**krul**len	2	Spoken	X = B	Word
om**zef**fen – **om**zeffen – om**zef**fen	2	Spoken	X = B	Nonword
door**spes**sen – **door**spessen – **door**spessen	2	Spoken	X = neither A nor B	Nonword
doorkruigen – **door**kruigen – **door**kruigen	2	Spoken	X = both A and B	Nonword
door**le**len – door**le**len – door**le**len	2	Spoken	X = both A and B	Nonword
om**gen**nen – om**gen**nen – om**gen**nen	2	Spoken	X = both A and B	Nonword
doorloken – door**lo**ken – **door**loken	2	Spoken with a beat	X = B	Nonword
doorboren – **door**boren – door**bo**ren	2	Spoken with a beat	X = A	Word
omkneden – **om**kneden – om**kne**den	2	Spoken with a beat	X = A	Nonword
omrennen – om**ren**nen – om**ren**nen	2	Spoken with a beat	X = neither A nor B	Nonword
voorkliepen – voor**klie**pen – voor**klie**pen	2	Spoken with a beat	X = neither A nor B	Nonword
om**kle**den – **om**kleden – om**kle**den	2	Spoken with a beat	X = B	Word
door**ko**ven – **door**koven – door**ko**ven	2	Spoken with a beat	X = B	Nonword
door**klie**ven – door**klie**ven – **door**klieven	2	Spoken with a beat	X = A	Word
om**trek**ken – **om**trekken – **om**trekken	2	Spoken with a beat	X = neither A nor B	Word
doorlopen – **door**lopen – **door**lopen	2	Spoken with a beat	X = both A and B	Word
voorspellen – **voor**spellen – **voor**spellen	2	Spoken with a beat	X = both A and B	Word
volmaken – vol**ma**ken – **vol**maken	2	Sung	X = B	Word

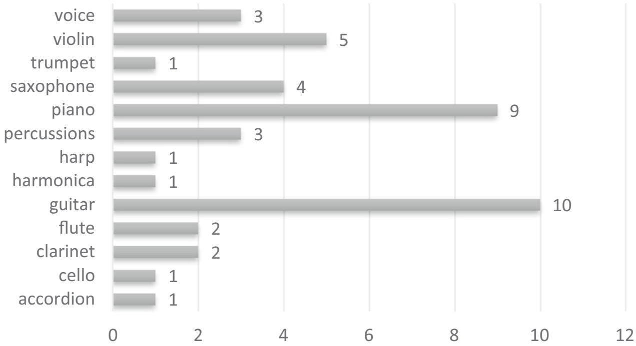
(continued)

Stimulus XAB	Block	Type of stimulus	Response position	Word/ nonword
omgeven – om**ge**ven – om**ge**ven	2	Sung	X = neither A nor B	Word
omkruden – om**kru**den – om**kru**den	2	Sung	X = neither A nor B	Nonword
omrellen – om**rel**len – om**rel**len	2	Sung	X = neither A nor B	Nonword
door**le**zen – **door**lezen – **door**lezen	2	Sung	X = neither A nor B	Word
om**bo**ken – **om**boken – **om**boken	2	Sung	X = neither A nor B	Nonword
voorbrezen – **voor**brezen – **voor**brezen	2	Sung	X = both A and B	Nonword
doorkemmen – **door**kemmen – **door**kemmen	2	Sung	X = both A and B	Nonword
door**krui**sen – door**krui**sen – door**krui**sen	2	Sung	X = both A and B	Word
door**kle**ken – door**kle**ken – door**kle**ken	2	Sung	X = both A and B	Nonword
omkleden – om**kle**den – **om**kleden	3	Spoken	X = B	Word
doorkemmen – door**kem**men – **door**kemmen	3	Spoken	X = B	Nonword
omkruden – **om**kruden – om**kru**den	3	Spoken	X = A	Nonword
volmaken – vol**ma**ken – vol**ma**ken	3	Spoken	X = neither A nor B	Word
door**klie**ven – **door**klieven – door**klie**ven	3	Spoken	X = B	Word
door**krui**sen – door**krui**sen – **door**kruisen	3	Spoken	X = A	Word
door**lo**ken – door**lo**ken – **door**loken	3	Spoken	X = A	Nonword
om**bo**ken – om**bo**ken – **om**boken	3	Spoken	X = A	Nonword
voorkliepen – **voor**kliepen – **voor**kliepen	3	Spoken	X = both A and B	Nonword
om**ren**nen – om**ren**nen – om**ren**nen	3	Spoken	X = both A and B	Nonword
doorlezen – door**le**zen – **door**lezen	3	Spoken with a beat	X = B	Word
omrellen – **om**rellen – om**rel**len	3	Spoken with a beat	X = A	Nonword
doorkleken – **door**kleken – door**kle**ken	3	Spoken with a beat	X = A	Nonword
doorbreken – door**bre**ken – door**bre**ken	3	Spoken with a beat	X = neither A nor B	Word
voor**bre**zen – voor**bre**zen – **voor**brezen	3	Spoken with a beat	X = A	Nonword

(continued)

Stimulus XAB	Block	Type of stimulus	Response position	Word/ nonword
om**zef**fen – **om**zeffen – **om**zeffen	3	Spoken with a beat	X = neither A nor B	Nonword
door**krui**gen – **door**kruigen – **door**kruigen	3	Spoken with a beat	X = neither A nor B	Nonword
omkneven – **om**kneven – **om**kneven	3	Spoken with a beat	X = both A and B	Nonword
om**ge**ven – om**ge**ven – om**ge**ven	3	Spoken with a beat	X = both A and B	Word
voor**zeg**gen – voor**zeg**gen – voor**zeg**gen	3	Spoken with a beat	X = both A and B	Word
door**spes**sen – door**spes**sen – door**spes**sen	3	Spoken with a beat	X = both A and B	Nonword
doorboren – door**bo**ren – **door**boren	3	Sung	X = B	Word
voorspellen – **voor**spellen – voor**spel**len	3	Sung	X = A	Word
omtrekken – **om**trekken – om**trek**ken	3	Sung	X = A	Word
voltrerren – **vol**trerren – vol**trer**ren	3	Sung	X = A	Nonword
doorkerven – door**ker**ven – door**ker**ven	3	Sung	X = neither A nor B	Word
door**lo**pen – **door**lopen – door**lo**pen	3	Sung	X = B	Word
door**le**len – door**le**len – **door**lelen	3	Sung	X = A	Nonword
door**ko**ven – door**ko**ven – **door**koven	3	Sung	X = A	Nonword
om**gen**nen – **om**gennen – **om**gennen	3	Sung	X = neither A nor B	Nonword
omkneden – **om**kneden – **om**kneden	3	Sung	X = both A and B	Nonword
om**krul**len – om**krul**len – om**krul**len	3	Sung	X = both A and B	Word
omgeven – om**ge**ven – **om**geven	Practice 1	Spoken	X = B	Word
voor**bre**zen – voor**bre**zen – **voor**brezen	Practice 2	Sung	X = A	Nonword
door**lo**pen – door**lo**pen – door**lo**pen	Practice 3	Spoken with a beat	X = both A and B	Word
om**kle**den – **om**kleden – **om**kleden	Practice 4	Sung	X = neither A nor B	Word
vol**trer**ren – **vol**trerren – vol**trer**ren	Practice 5	Spoken with a beat	X = B	Nonword
om**ren**nen – om**ren**nen – om**ren**nen	Practice 6	Spoken	X = both A and B	Nonword

Appendix D List of instruments played by the musician participants and number of players per instrument



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