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Final Year Project

Effects of Music Attrition on Linguistic Pitch Processing

By

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Division of
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Abstract

Most studies on the relationship between music and language have focused mainly on the lifelong musician, with much less being known about the long-term effect of music on "ex-musicians" – individuals who have ceased musical training and practice. This study thus sought to determine whether transfer benefits of music in linguistic pitch processing persisted in such individuals who experience attrition in their musical skills, and what variables these benefits correlated with. Ten musicians, eleven ex-musicians and ten non-musicians bilingual in English and Mandarin Chinese were presented with sentences spoken in French, a language non-native to them. Based on a well-replicated experimental paradigm, the final word of each sentence was parametrically manipulated to create three conditions: prosodically congruous (spoken at normal pitch height), weakly incongruous (+25% pitch increase), and strongly incongruous (+110% pitch increase). Results showed a trend of ex-musicians discriminating subtle pitch violations (+25% pitch increase) better compared to non-musicians, but not as well as compared to musicians. A correlation was observed between this enhanced discrimination and the years since musicians and ex-musicians received musical training. As a whole, the findings suggest that while past musical training may result in enduring linguistic transfer benefits in pitch, this effect fades across time.

Keywords: music attrition, musical training, transfer benefits, pitch processing, second language acquisition

Effects of Music Attrition on Linguistic Pitch Processing

1. Introduction

The interest in the study of music has its roots way back in the ancient times, ever since the first reported empirical studies on pitch and octaves by Pythagoras (Deutsch, 1984; Levitin & Tirovolas, 2009). However, it is only since the publication of Rauscher, Shaw and Ky (1993) which made famous the misnomer called the "Mozart effect"[1] that the notion of music potentially bringing about non-music-related, cognitive benefits began to excite both the public and researchers (Jenkins, 2001; Schellenberg, 2006a). At the same time, as researchers deepened their studies on the origins of music and began seeing the connections between music and language (Besson & Schön, 2001; Jäncke, 2012; Levitin & Tirovolas, 2009), this line of thought fused with the former to spark a new research field on the transfer effects of music experience on language processing.

The complexity of language processing along with the heterogeneity of the musician population continues to make the study of music influence on language skills a rich research minefield. To this date, researchers have focused mainly on the general effects of music expertise on both language perception and production, of segmental as well as suprasegmental linguistic information. Studies with a more nuanced treatment of the different kinds of musical training (e.g. group versus individual music lessons; classical versus jazz; learning by ear versus emphasis on reading notation, etc.) and the different types of musicians (pianists versus drummers; musicians who learned only one instrument versus musicians who learned more than one instrument, highly-skilled versus less proficient musicians, etc.) are not as prolific. Despite this, current literature is in general consensus that musicians have superior pitch discrimination skills which are transferable in the domain of language (Alexander, Wong, & Bradlow, 2005; Strait, O'Connell, Parbery-Clark & Kraus, 2003; Wong, Skoe, Russo, Dees, & Kraus, 2007).

[1] The "Mozart effect" is a misnomer as the effect of enhanced spatial performance after listening to music composed by Mozart (Rauscher, Shaw, & Ky, 1993) was later on discovered to be actually caused by the listener's arousal levels and mood, and not directly due to the music itself (Husain, Thompson, & Schellenberg, 2002; Nantais and Schellenberg, 1999).

Some particularly practical findings about music-associated transfer skills in the domain of language are as follows: Musical training is found to correlate with good reading scores and comprehension skills (Butslaff, 2000; Corrigall & Trainor, 2011), with pitch perception correlating positively with phonemic awareness in children (Anwari, Trainor, Woodside, & Levy, 2002). This implies that musical training can be encouraged among children in order to help them acquire reading skills, especially if they have difficulty reading (Tierney & Kraus, 2013). Music ability has also been observed to predict second language phonological skills (Sleve & Miyake, 2006), which may be an especially useful finding for those passionate about acquiring foreign languages. Perhaps more importantly, such music-associated benefits have been found to be applicable even among the less able populations; research suggests that musical training can help facilitate reading in impaired children (Forgeard, Schlaug, Norton, Rosam, Iyengar, & Winner, 2008; Moreno, Marques, A. Santos, M. Santos, Castro, & Besson, 2009), while lifelong musical training has been shown to offset age-related auditory decline in perception of speech-in-noise among older lifelong musicians (Parbery-Clark, Skoe, Lam, & Kraus, 2009; Parbery-Clark, Strait, Anderson, Hittner, & Kraus, 2011).

Given these transfer benefits of musical training in linguistic processing, it is clear that there are sufficiently pragmatic reasons for further research in this area. One important area for further research which is crucial to fully understand and apply these transfer benefits is how long term these transfer benefits are. Do these linguistic benefits of musical training apply only to lifelong musicians? Without continuous training, are these benefits maintained, and if yes, for how long? Answering these questions are important considering that most individuals who have taken up musical training at some point in their life seldom end up pursuing it professionally. Therefore, in any attempts to use musical training to help children read, to help with second language acquisition, or older adults with better speech-in-noise discrimination, we would also need to find out how long musical training would have to persist for them to continue enjoying those transferred, linguistic benefits. The current study thus focuses on the long term transfer benefits of musical training in the domain of language by looking specifically at “ex-musicians” – individuals who received musical training at some point in childhood or adolescence, but ceased lessons and practice by young adulthood.

2. Literature Review

Based on a recent review by Costa-Giomi (2014), few studies have been conducted with regard to the long-term effects of musical training. Short-term effects of musical training are relatively well studied (Costa-Giomi, 2014), with consistent findings of weeks and months of musical training being both cognitively beneficial (e.g. to verbal intelligence and executive function (Moreno, Bialystok, Barac, Schellenberg, Cepeda, & Chau, 2011) and spatial-temporal skills (Gromko & Poorman, 1998)), as well as being linguistically beneficial (Moreno et al., 2009; Thompson, Schellenberg, & Husain, 2004). Nonetheless, rarely do any of these short-term studies further investigate how long these cognitive benefits lasted after musical training ceased.

It has only been more recent that some studies began to focus on this research gap. Two notable studies are Skoe and Kraus' (2012) study on the robustness of auditory brainstem activity to sound of 45 younger adults (age range: 18-31 years) varying in the number of years they received childhood music instruction, and White-Schwoch, Carr, Anderson, Strait, & Kraus's (2013) study on the speed of scalp-recorded auditory brainstem responses to sound of 44 older adults (age range: 55-76 years) who similarly differed in the number of years they received formal instrumental musical training in childhood. Similar to Schellenberg's (2006b) study which found intellectual benefits from childhood musical training which lasted into adulthood even after lessons and playing ceased, Skoe and Kraus (2012) and White-Schwoch et al. (2013) found auditory benefits, which are applicable in language processing to persist when individuals have ceased musical lessons and practice.

Ex-musicians in Skoe and Kraus' (2012) study exhibited more robust neural responses to sound compared to non-musicians, with their average signal-to-noise ratio (SNR) brainstem response correlating with how recently musical training occurred as opposed to the amount of musical training. On the other hand, White-Schwoch et al.'s (2013) study found ex-musicians to be better at encoding consonant-vowel transitions across speech compared to non-musicians, with their performance correlating with the amount of musical training they received, unlike in Skoe and Kraus' (2012) study. Despite the different variables being measured and the different correlations found, both studies converged to depict how even with a relatively limited period of childhood musical training (around 3 years for Skoe and Kraus' (2012) study and about 4-14 years in White-Schwoch et al.'s (2013)), neural changes brought about by musical training

persisted way into adulthood (about 7 years later for Skoe and Kraus' (2012) study and about 40 years later in White-Schwoch et al.'s (2013)).

It appears that these two studies are among the few, if only research conducted to investigate the long-term effects of musical training on language processing. However, as both studies used either pure tones or native speech sounds as experimental stimuli, it remains unknown whether the long-term effects found would apply even in non-native speech processing, especially if more complex stimuli is presented (e.g. on the sentence level compared to non-lexical pure tones in Skoe and Kraus (2012) or speech syllables in White-Schwoch et al. (2013)). In addition, as both studies only used brain imaging methods, it is not a certainty that these neural traces of musical training would also be reflected behaviourally even though enhanced brainstem encoding has been observed to be linked with enhanced auditory perception (Parbery-Clark, Skoe & Kraus, 2009; Wong et al., 2007). Not only so, neither of the two studies compared their ex-musicians and non-musicians with lifelong musicians to see how ex-musicians fared in comparison to both groups. Specifically, do ex-musicians perform more similarly to musicians or non-musicians? Lastly, it is also unclear why the two variables, (i) amount of musical training and (ii) years since musical training seemed to be mutually exclusive in their correlation with the ex-musicians' performance in each study.

Therefore, to supplement these two studies and thus better understand the long-term effects of musical training on linguistic processing skills, the present study seeks to answer the following two research questions with a behavioural task:

(1) Do individuals who received musical training but have since stopped playing their instruments, thereby experiencing attrition in their musical expertise, retain similar advantages as their lifelong musician counterparts in processing non-native speech?
(2) Do the transfer benefits in processing non-native speech, if any, correlate with any of the following variables (i) years of musical training, (ii) years since musical training, and/or (iii) hours of practice?

Linguistic pitch was selected as the variable to be manipulated in this study, given that pitch is one of the major shared sound parameters between speech and music, and musicians have been consistently found to show transfer benefits in linguistic pitch processing. It would thus be interesting to investigate if ex-musicians, namely musicians who no longer take formal lessons or practice their instrument enjoy this specific transfer benefit as well. An experimental

paradigm involving a parametric manipulation of pitch modelled after that of Marques, Moreno, Castro, and Besson's (2007) study was chosen given that that particular paradigm has been replicated both behaviourally and electrophysiologically with relative success (Magne, Schön, & Besson, 2006; Moreno et al., 2009; Schön, Magne, & Besson, 2004), and also to enable comparison with Marques et al.'s (2007) findings of musicians showing enhanced discrimination of subtle pitch incongruity even in a non-native language.

3. Methodology

3.1 Participants

Thirty-six native bilinguals of English and Mandarin Chinese who grew up in Singapore participated in the study. All participants were recruited via an online screening questionnaire (see Appendix A). A total of five participants were excluded from the final data analysis (see results section for exclusion criteria). The final group of participants thus consisted of 10 musicians (seven females, M_{age} = 20.6 years (SD = 1.71)), 11 ex-musicians (eight females, M_{age} = 20.8 years (SD = 1.75)), and 10 non-musicians (five females, M_{age} = 20.82 years (SD = 1.16)),

Musicians were individuals who were actively involved in music-making activities. They were either still receiving musical training (i.e. taking formal music lessons), or were actively involved in music-related activities such as teaching, performing in gigs, and playing in ensembles. All musician participants had been practicing their instruments for at least two hours per week for the past two years. Ex-musicians were individuals who had taken formal music lessons or participated in music ensembles in school before but now rarely play their instruments. More than half of the ex-musicians no longer play their instruments at all in the past two years. On average, musicians acquired their (first) instrument at the age of eight and had an average of 11 years of musical training; ex-musicians generally acquired their (first) instrument at the age of 12 and had an average of four years of musical training (see Appendix B). Non-musicians were individuals who had never taken formal music lessons nor participate in any music-related activities outside of the compulsory music lessons which were part of the local school curriculum.

Given the multilingual linguistic landscape of Singapore, most participants also indicated having some proficiency in one or more other languages[2] except French. All participants had normal hearing based on an audiometric test (25dB HL for octave frequencies from 500Hz to 4000Hz) administered by the experimenter. All participants were paid to participate in the experiment, which lasted for about half an hour.

3.2 Materials

Stimuli used in the experiment comprised 120 French spoken declarative sentences[3] (see Appendix C), with an equal number of sentences (40) being auditorily presented in three different conditions: The final word of each sentence was either prosodically congruous, weakly incongruous, or strongly incongruous. All final words were disyllabic as in Marques et al.'s (2007) study, but were balanced in whether they were vowel-ending or consonant-ending. Sentences were recorded at a normal speaking rate by a native female French speaker in a soundproof room and digitized (sampling at 44.1kHz and 16 bit) using Audacity® Version 2.0.5.0 (Audacity Team, 2013). The mean duration of the sentences was 2.98s (*SD* = 0.37) and the mean duration of the final words was 448ms (*SD* = 95).

To create the prosodically incongruous conditions, the pitch (F0) of the final words was modified using Praat (Boersma & Weenink, 2004) without changing the original pitch contour of the words (see Figure 1). However, instead of the increase in 35% and 120% to create the weakly incongruous and strongly incongruous conditions respectively as has been done in Schön et al., (2004), Magne et al., (2006), Marques et al. (2007), and Moreno et al., (2009), an increase in 25% and 110% was used respectively. This change was tailored to fit the linguistic context of Singapore where most of its population are bilingual in English and Mandarin Chinese. Given that bilinguals are found to have enhanced encoding of F0 (Krizman, Marian, Shook, Skoe, & Kraus (2012), and experience with tonal languages such as Mandarin Chinese

[2] Aside from two participants (ex-musicians) who indicated having (low) proficiencies in Spanish and German respectively, none of the other participants had any proficiencies in any Indo-European languages.

[3] French sentences were compiled from a combination of sources and later modified with the help of a French native speaker. The sources include Smith's (2002) paper, the online translation database Tatoeba (http://tatoeba.org/eng/), and the French-English dictionary on the online Reverso portal (http://dictionary.reverso.net/french-english/).

can improve non-native tonal perception (Krishnan, Gandour, & Bidelman, 2010; Wayland & Guion, 2004), this adjustment was decided upon in order to reduce the possibility of a ceiling effect for the weak prosodic incongruity discrimination. The values of 25% and 110% in F0 increase were selected based on results of preliminary pilot testing which showed the error rates across the experimental conditions to be similar as those found by Marques et al.'s (2007).

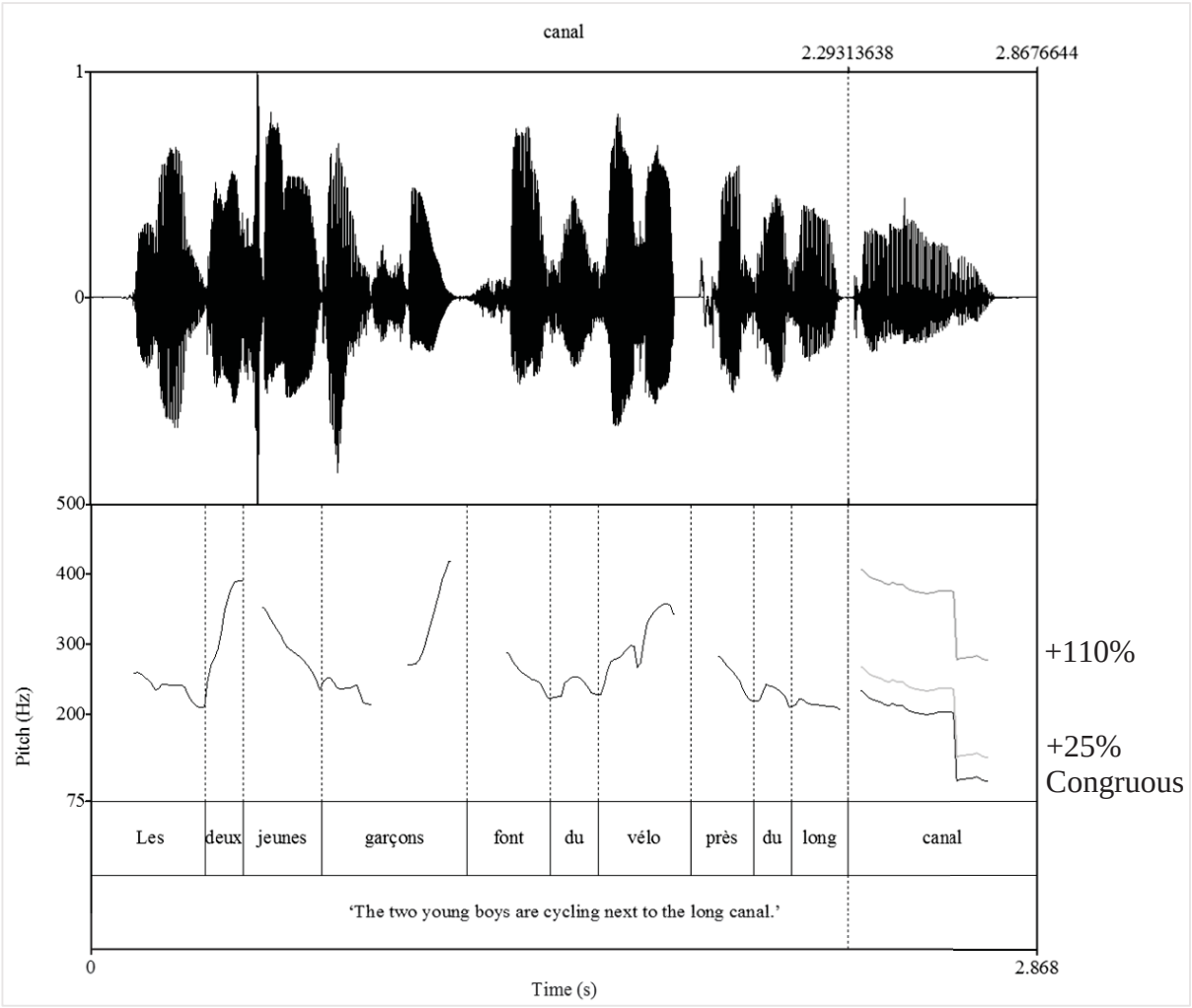

Figure 1. An example of the sentences used in the experiment: *Les deux jeunes garçons font du vélo près du long canal.* 'The two young boys are cycling next to the canal.' The top panel shows the time waveform of the utterance, while the bottom panel shows the fundamental frequency (F0 in Hz) for the natural utterance (congruous) and for changes in pitch of the final words (weakly incongruous condition of +25%; strongly incongruous condition of +110%).

3.3 Procedure

Participants were seated comfortably in a soundproof booth, and instructed to listen carefully to the sentences which were presented to them using the E-Prime 2.0 software through headphones. They were told beforehand that the sentences would be in French, and that comprehension of those sentences was not expected nor required. Instead, they were to focus their attention on the final word of each sentence, and decide whether it seemed strange or normal as quickly and as accurately as possible within a response limit of three seconds. Participants pressed the "S" key on the keyboard for "strange" (both weak and strong incongruity conditions) and the "N" key for "normal" (congruous condition). They were instructed to press "S" as long as the final word seemed even just a little strange.

A practice block of six trials with feedback on the correctness of their responses was given to familiarize participants with the task. This was followed by the experimental session consisting of four blocks of 30 sentences each, with breaks given between each block. Sentences from each experimental condition occurred equally frequently within each block and in pseudorandom order. No more than three "strange" final words ever occurred consecutively, and no pitch-manipulated variants of the same sentence occurred within the same block. Sentence blocks were counterbalanced across participants; half of the participants in each group heard blocks one and two first, while the other half heard blocks three and four first. Participants' responses were recorded via E-Prime.

3.4 Hypothesis and Predictions

Given the findings of Skoe and Kraus (2012), the present study hypothesized that ex-musicians will retain some transfer benefits of music in linguistic pitch processing even after musical training and practice has ceased. It was thus predicted that ex-musicians will be significantly more accurate than non-musicians at discriminating the weakly incongruous final words which are difficult to detect as they involve very subtle pitch violations. However, as ex-musicians would have experienced music attrition due to their having ceased musical training and practice, the transfer effects of music in their linguistic pitch processing skills are hypothesized to be weaker than that of musicians. Thus, they were predicted to perform less accurately than musicians in discriminating the weakly incongruous final words. For the other two prosodic conditions (congruous and strongly incongruous), all participants were predicted to perform on par and at ceiling because they should be easy to discern; the congruous condition

involves a pitch contour typical of declarative sentences, while the strongly incongruous condition very overtly violates expectations of normal sentence-ending contours.

Since the present study consisted mainly of young ex-musician adults just as in Skoe and Kraus' (2012) study, it was also predicted that similarly, a correlation would be observed between discrimination of the subtle pitch violations and the years since musical training among ex-musicians and musicians, and not with the years of musical training as in White-Schwoch et al.'s (2013) study on older ex-musician adults. The present study also tests the hypothesis that other variables, namely, the number of practice hours of musicians and ex-musicians would also show correlation with their performance in the weakly incongruous prosodic condition.

4. Results

4.1 Data Analysis

To filter out fast guesses and also outliers within an individual's responses, trials with reaction times below 150ms and trials with reaction times above three standard deviations from individual means were excluded (9.42% of the data). The data of four participants were further excluded because too many trials (more than 25% of the original 120 trials) were rejected based on the first criteria. Another participant had to be excluded due to abnormally high false alarm rates (zero hits for the congruous condition), and for showing poor overall discrimination (the participant perceived all final words in all conditions to be "strange").

The remaining hit rates and reaction times were averaged across participants, and a repeated-measures analyses of variance (ANOVAs) was carried out using participant type (musicians vs. ex-musicians vs. non-musicians) as a between-subject factor, and prosodic congruity (congruous, weakly incongruous, and strongly incongruous) as a within-subject factor. As Mauchly's test revealed that the assumption of sphericity had been violated for the main effect of prosodic congruity in both measures of hit rates, $\chi^2(2) = 60.70$, $p < .001$, and reaction times, $\chi^2(2) = 7.02$, $p = .030$, the Greenhouse-Geisser correction was applied.

4.2 Hit Rates

Analysis of hit rates showed a main effect of prosodic congruity, $F(1.06, 29.6) = 196$, $p < .001$, with the weak incongruities being the hardest to detect (overall hit rates: 36%) compared to the congruous and strongly incongruous final words (overall hit rates of 95% and 97% respectively).

Contrary to expectations, no main effects of participant type were found, $F(2, 28) = 0.61$, $p = .548$, and neither was the prosodic congruity by participant type interaction significant, $F(2.11, 29.6) = .23$, $p = .807$. Thus, while all participants performed similarly in the congruous and strongly incongruous conditions as predicted, their performance in the weakly incongruous condition were unexpectedly similar as well (see Figure 2). Specifically, this statistical unsignificance was due to the expected ceiling effect for both congruous and strongly incongruous condition (hit rates of over 90% for all participants across both conditions) and the unexpected floor effect obtained for the weakly incongruous condition (hit rates of less than 50% even for musicians who were expected to perform way above chance level, suggesting that the weakly incongruous condition was too difficult).

In general, however, for the weakly incongruous condition, there was a trend of musicians having the higher hit rates (39%) compared to ex-musicians (36%), with non-musicians performing the poorest (35%).

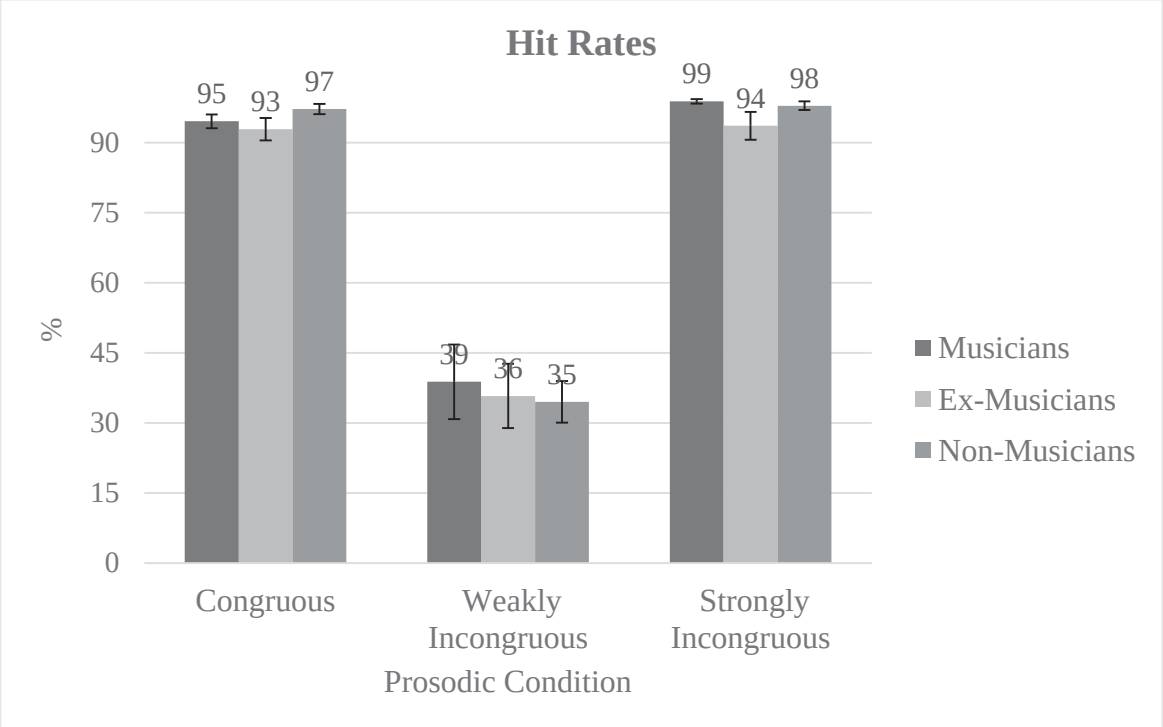

Figure 2. Hit rates of musicians, ex-musicians and non-musicians for each prosodic condition.

A Pearson product-moment correlation coefficient was also computed to assess the relationship between hit rates for the weakly incongruous prosodic condition and three other factors: (i) years of musical training, (ii) average number of practice hours per week in the last two years, and (iii) years since musical training.

No relationship was found between hit rates for the weakly incongruous condition and years of musical training, $r(31) = .086$, n = 31, $p = .644$. Similarly, no relationship was observed between hit rates for the weakly incongruous prosodic condition and average number of practice hours per week in the past two years (for musicians and ex-musicians only), Pearson's $r(21) = -.032$, n = 21, $p = .089$. However, a strong positive correlation was observed between the hit rates for the weakly incongruous prosodic condition and the years since musical training (for musicians and ex-musicians only), Pearson's $r(21) = -.593$, n = 21, $p = .025$ (see Figure 3), suggesting that after musical training ceases, auditory enhancement for the discrimination of subtle pitch violations fades over time.

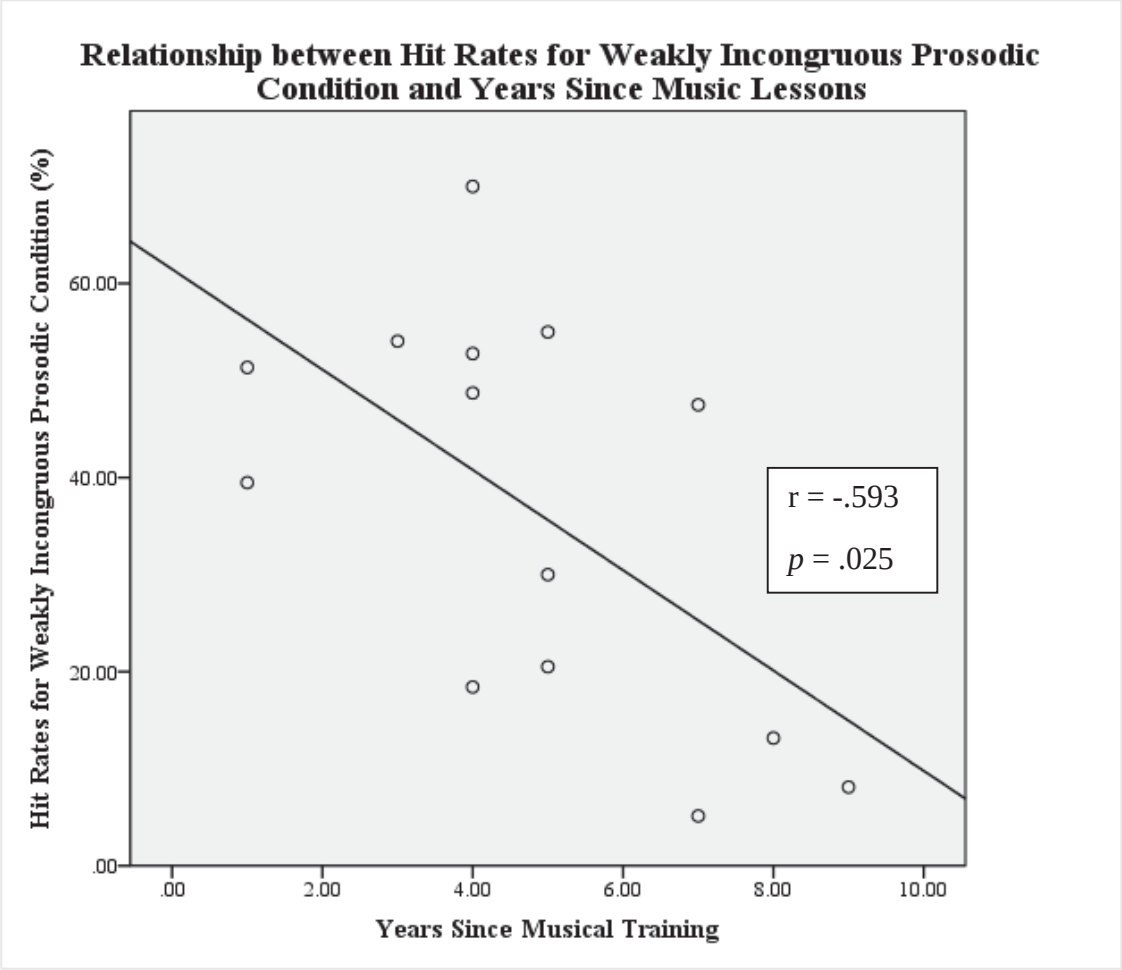

Figure 3. Hit rates for the weakly incongruous prosodic condition has a strong negative correlation with years since musical training.

4.3 Reaction Times

Analysis of reaction times showed a main effect of prosodic congruity, $F(1.63, 45.6) = 59$, $p < .001$, with the weak incongruities eliciting the longest response time (694msec), followed by congruous final words (581msec), with strongly incongruous final words being the easiest to detect (461msec). No main effects of participant type were found, $F(2, 28) = 0.15$, $p = .858$, and the prosodic congruity by participant type interaction was not significant, $F(3.26, 45.6) = .95$, $p = .429$ (see Figure 4), showing that participants across all group performed similarly in their reaction times for each prosodic condition.

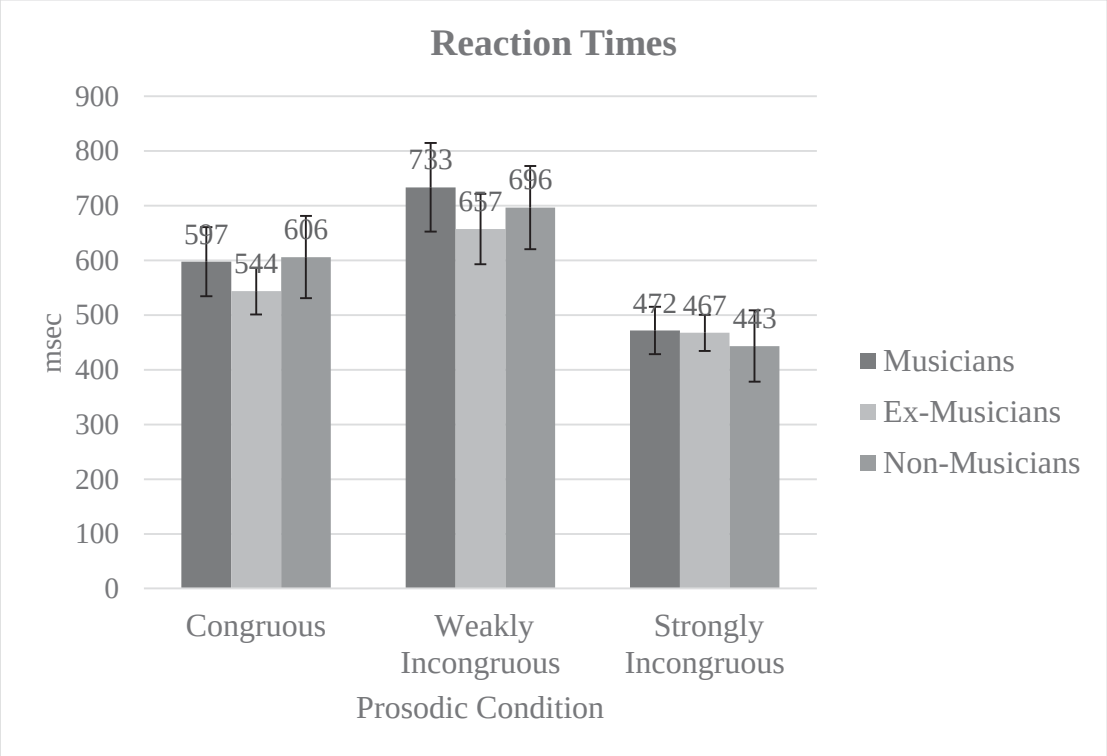

Figure 4. Reaction times of musicians, ex-musicians and non-musicians for each prosodic condition.

5. Discussion

Overall, results do not support the first hypothesis that ex-musicians retained transfer benefits in the domain of language as a result of past musical training. Even though an expected trend of ex-musicians detecting the weak prosodic incongruities better than non-musicians but not as well as musicians was observed, this between-group difference was not found to be statistically significant.

Considering that past studies employing this similar experimental paradigm have replicated significant differences between musicians and non-musicians in the weakly incongruous prosodic condition both behaviourally as well as electrophysiologically (Magne et al., 2006; Marques et al., 2007; Moreno et al., 2009; Schön et al., 2004), that there were no significant group differences at least between musicians and non-musicians found for this condition in the present study was rather surprising. A careful comparison of the four relevant studies (see Table 1) narrows down the potential reasons for the results obtained in this study.

Table 1. Comparison of sample characteristics, type of stimulus and hit rates for the weak incongruity condition of past findings with that of the current study.

Study	**Sample Characteristics**			**Stimulus Type**	**Hit Rates* (%)**	
	Mean Age (years)	Years of Musical Training	Number of Participants		Musician	Non-Musician
Schön et al. (2004)	31	15 on average	9 musicians**; 9 non-musicians	Native; French	85	70
Magne et al. (2006)	8	4 on average	13 musicians; 13 non-musicians	Native; French	≈ 85	≈ 65
Marques et al. (2007)	32	At least 14	11 musicians; 11 non-musicians**	Non-native; Portuguese	85	61
Moreno et al. (2009)	8	0.5	16 musicians; 16 non-musicians	Native; French	≈ 81	≈ 68
Current Study (2014)	21	11 on average	10 musicians; 10 non-musicians	Non-native; French	39	35

**Note*: The percentages given for the hit rates are only for the weakly incongruous prosodic condition.

***Note:* Schön et al.'s (2004) musicians were professional musicians; Marques et al.'s (2007) non-musicians were also not music lovers in addition to not having had musical training.

A quick glance at the hit rates of musicians compared to non-musicians for all four studies shows us that in general, both musicians and non-musicians performed above chance level, with musicians (hit rates above 80%) consistently outperforming non-musicians (hit rates above 60% but not exceeding 70%) regardless of their age group. For instance, Schön et al. (2004) tested adult participants with a mean age of 31 years old while Magne et al. (2006)

tested eight-year-old children, yet musicians of both studies had the same hit rates (85%) while non-musicians showed similar hit rates (70% and 65% respectively). This indicates that the absence of significance group differences in the current study was thus unlikely to be due to the ages of the participants. Importantly, even when participants had only half a year of musical training as in Moreno et al. (2009), or only four years in Magne et al. (2006), musicians showed high hit rates (81% and 85% respectively) as in the other studies, and there was still a marked difference in hit rates between musicians and non-musicians (about 20% difference in both studies). In other words, that musicians in the present study failed to show significantly higher hit rates compared to non-musicians was unlikely to be due to the lack of musical training.

Comparing results of the current study specifically to Schön et al. (2004) and Marques et al.'s (2007) also shows us that whether or not the stimuli was native to the participants was not crucial either. Musicians in both studies had the same hit rates (85%), indicating that they performed just as well in discriminating weak incongruities in a non-native language, and though non-musicians who listened to non-native sentences performed slightly worse (61% versus 70%), performance remained above chance levels. Not only that, given that the sample size of musicians and non-musicians in the current study was similar to that of Schön et al. (2004) and Marques et al.'s (2007), it is less likely that the lack of between-group differences in the current study was due to sample size constraints.

Collectively, these past findings suggest that at least for the current study, the ages of participants, the amount of musical training they had, the choice of non-native stimuli, and the sample size are not as important as the readjusted pitch increase of +25% instead of +35% in explaining the less robust differences observed between musicians and non-musicians. In short, it is most likely that the readjusted pitch increase made the weak incongruities too difficult to discern even for musicians who generally have enhanced auditory benefits as a result of musical training. This in turn led to low hit rates among musicians, thereby causing a floor effect and the absence of statistically significant group differences between musicians, ex-musicians and non-musicians in the weak incongruity condition.

A few other possible explanations can also be offered to explain why no significant group differences were found in the present study despite the trend showing that potential group differences exist. Firstly, compared to the non-musicians in Marques et al.'s (2007) study, who were not music-lovers, non-musicians in the present study listened to music as frequently as musicians and ex-musicians (based on self-reporting). Given that logically speaking, one

would not listen to music frequently without having at least some liking for it, some predisposition towards music may have also have been at play in contributing to the lack of robust group differences being observed in this study.

In addition to that, the musical aptitude of participants in general could have had a hidden effect on the results. For instance, there could have been individuals who did not receive formal musical training (e.g. due to various socioeconomic factors) but nevertheless had a natural aptitude for music, which enhanced their performance in the weakly incongruous condition. This could account for the variance in performance in the weakly incongruous condition within each group (visible from the error bars in Figure 2), especially given that no correlation was observed between hit rates for the weakly incongruous prosodic condition and the years of musical training.

Other than these factors which may have affected between-group performances in the weakly incongruous condition, there is also the possibility that some participants may have been more sensitive to maturation and repetition effects after four blocks of sentence stimuli despite the breaks given in between blocks, which may have resulted in their lack of engagement and attention to the final word. This may have affected results too especially given the relatively small sample size of this study. To reduce this possibility, future studies using this experimental paradigm should consider designing some appropriate filler tasks in order to ensure that all participants remained alert and focused during the experiment. Furthermore, given that this experiment used to be carried out in a French context, more pilot testing is needed to determine a more appropriate pitch increase range for the weakly and strongly incongruous conditions. This is important to avoid the observed floor effects for the weakly incongruous condition in the present study.

Turning our attention to the second hypothesis of the study, results of the present study corroborated with those of Skoe and Kraus' (2012) in showing a correlational relationship between years since musical training and performance in pitch-related tasks, and not between years of musical training and said performance, which would resemble White-Schwoch et al.'s (2013) findings more closely. This is significant firstly in providing additional support to Skoe and Kraus'(2012) inference that while musical training may bring about pitch-related transfer benefits, the effect of musical training may fade over time. Interestingly, this effect of musical training does not seem to be maintained even with practice, as no correlation was observed between musicians and ex-musicians' discrimination of the weakly incongruous condition, and

the average number of hours they had been practicing their instrument(s) in the past two years. It may be that more intense engagement with music occurs during musical training then after training has ceased; after all, there is likely to be greater motivation to practice, and probably more intensive practice involved too when one is having regular music lessons or group-related music-making activities.

On another note, this correlation involving years since musical training observed both in the present study and in Skoe and Kraus' (2012) also suggests that years since musical training may be a more salient correlating variable when young adult musicians and ex-musicians are involved. Over time, when years since training have become more or less similar among older musicians and ex-musicians, the amount of years of musical training may then become a more salient variable correlating with enhanced linguistic performance, as in White-Schwoch et al.'s (2013) study. More studies would be needed, however, to test the validity of this idea.

6. Conclusion

The current study focused only on one aspect of linguistic processing, namely, that of linguistic pitch, and specifically in the context of non-native speech processing, in its search for evidence that ex-musicians retain neural traces of past musical training which manifests itself in transfer benefits in the domain of language. Significantly, this is most probably the first time that this experimental paradigm has been applied outside of a French context, in a predominantly multilingual society. Thus, more studies are needed to determine the most appropriate pitch increase to be used for the weak incongruity condition, and also to test if robust findings can be obtained when a bigger sample is used, and when tests for musical aptitude are included as part of the experimental design.

Future studies should also explore other potential variables associated with similar music-related transfer benefits, and how they may differ in correlational strength across different types of musicians and ex-musicians (e.g. old vs. young). In addition to the parameter of pitch used as a manipulated variable in this study, we may also test for potential group differences among musicians, ex-musicians, and non-musicians in Singapore using different types of stimuli (e.g. vowel duration, stress patterns, syntactic violations etc.). Not only that, we can also compare how the long-term effects of musical training may differ across these stimuli (e.g. if enhanced perception of pitch persists longer than enhanced perception of vowel

duration) depending on what type of musical training was received (e.g. voice training vs. learning drums).

In short, this study is a beginning to the journey of discovering the limits of musical training, of how long-term its transfer benefits are in the domain of language. Understanding the extent to which music attrition affects transfer linguistic benefits will have important applications in language acquisition, language learning, and even language maintenance programmes.

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Appendix A: Screening Questionnaire on Linguistic and Musical Background

1. What language(s)/dialect(s) do you understand? Rate your overall proficiency (speaking, listening, reading, writing) in each of them from a scale of 1(not proficient) to 7(very proficient). *e.g. English - 7, Mandarin Chinese - 6, Hokkien - 1, Korean – 3*

   _____

2. Have you ever had music lessons outside of those compulsory in school, or do you practice a music instrument on your own? If yes, please list the instrument(s) you studied, the years you took lessons for each instrument, the age at which you started playing each instrument, how proficient you are at each instrument on a scale of 1(not proficient) to 7(very proficient), and also the average hours per week and number of times per week you have practiced each instrument in the last two years.
   e.g. Yes; Piano, 1995-2006, 4 years old, 6, 3 hours per week, twice a week; Violin, 1999-2006, 8 years old, 3, 0 hours per week.

   _____

3. If you answered yes to question 2), please describe any music-related activities you have been involved in up to the last two years. (If you teach, list down the average number of hours per week in the last two years.)
   e.g. a member of the guitar ensemble since August 2013; giving private music lessons to children since 2012 (2 hours per week); performing at gigs since April 2014, etc.

   _____

4. How frequently do you listen to music?
   e.g. on your computer/phone/music player/YouTube etc.

   1 2 3 4 5
   Never Always

5. If you answered 2-5 for question 4), what kind of music do you usually listen to? If you list more than one genre, rate them according to the frequency of listening on a scale of 1(least frequent) to 5(most frequent).
   e.g. Classical, 4; Korean Pop, 3; Mandarin Chinese Pop, 2; Jazz, 1

   _____

Appendix B: Musicians' and Ex-Musicians' Musical Background

Table B1. Musical background of musicians

Musician	*Years of Training*	*Age Onset for Each Instrument (Years)*	*Instrument(s) Acquired (In order of acquisition)*	*Practice Hours**
1	10	8, 13	Piano, Flute	10
2	12	5, 11	Piano, Violin	2
3	7	9	Guzheng	3
4	18	5, 7	Piano, Saxophone	7
5	19	5, 13	Piano, Bassoon	3
6	11	7, 13, 13	Piano, Zhongruan, Liuqin	4
7	10	7, 17	Piano, Guitar	6
8	6	14	Violin	3
9	3	17, 21	Piano, Voice	2
10	16	4, 13, 17	Piano, Oboe, Saxophone	2
Mean	11.2	8.1	-	4.2

*average practice hours per week for the past two years are reported

Table B2. Musical background of ex-musicians

Ex-Musician	*Years of Training*	*Age Onset for Each Instrument (Years)*	*Instrument(s) Acquired (In order of acquisition)*	*Practice Hours**
1	5	13	Percussion	0
2	3	13	Percussion	0
3	9	7, 9	Piano, Cello	0
4	1	14	Electric Guitar	0
5	6	9	Piano	0
6	3	13	Zhongruan	0
7	3	9	Voice	0
8	7	7	Piano	1
9	8	8	Piano	0.125
10	1	18, 21	Clarinet, Drums	0
11	1	17	Guitar	0.5
Mean	4.27	11.63	-	0.15

*average practice hours per week for the past two years are reported

Appendix C: French Sentences

Practice Trial Sentences

Vowel-ending

1. C’est la première fois en trois ans qu’elle a eu un bon carnet.
   ‘It’s the first time in three years that she got a good grade.’
2. Tu ne le sais peut-être pas, mais sa vie est un vrai roman.
   ‘You may not know it, but you could write a book about his life.’
3. Il a traversé la rivière dans un petit bateau.
   ‘He crossed the river in a small boat.’

Consonant-ending

4. Quand j'avais dix-huit ans, j'aimais beaucoup cette chanteuse.
   ‘I liked this singer a lot when I was eighteen years old.’
5. Je dois faire le linge tant qu'il y a encore du soleil.
   ‘I have to do laundry while it’s still sunny.’
6. Si vous avez besoin de quelque chose, demandez-le au serveur.
   ‘If you need anything, ask the waiter.’

Experimental Trial Sentences

Vowel-ending

1. Ma maman m’a demandé hier d’inviter mon parrain.
   ‘Yesterday, my mother asked me to invite my godfather.’
2. Sa longue jupe rouge est vraiment très facile à porter.
   ‘Her long, red skirt is really very easy to wear.’
3. Tous les jours, la pie donnait à manger à ses petits.
   ‘The magpie gave food to its babies every day.’
4. Le cou du chien est entouré d’un magnifique collier.
   ‘The dog’s neck is encircled by a beautiful collar.’
5. Le journaliste dit que La Coupe du monde aura lieu le mois prochain.
   ‘The reporter said that the World Cup will take place next month.'

6. Comme prévu, elle a eu le coup de foudre pour la maison.
   'As expected, she fell in love with the house at first sight.'
7. C'est atypique pour une région montagneuse comme celle-ci.
   'It's atypical for a mountainous region like this.'
8. Je crois que je t'aime seulement parce que tu es futé(e).
   'I think I like you only because you're clever.'
9. Chaque dimanche matin, j'emmène le chien courir dans le jardin.
   'Every Saturday morning, I take the dog for a run in the garden.'
10. Son petit ami l'a quitté et elle s'est endormie en pleurant.
    'She cried herself to sleep after her boyfriend broke up with her.'
11. Finir le travail pour mardi sera du gâteau.
    'Finishing the job by Tuesday will be a piece of cake.'
12. Les parents doivent aussi apprendre à se séparer de leurs enfants.
    'Parents must also become independent of their children.'
13. Ce fut un plaisir de rencontrer un vieux copain.
    'Meeting my old friend was very pleasant.'
14. Cette journée n'a été qu'un gâchis de temps et d'argent.
    'This day was just a waste of time and money.'
15. Ce n'est pas le genre de musique sur lequel on peut danser.
    'It's not the type of music that you can dance to.'
16. Parfois je me dis qu'on ne se reparlera jamais.
    'Sometimes I think I will never talk to him/her again.'
17. Un bon régime alimentaire donne des bébés en meilleure santé.
    'A good diet makes for healthier babies.'
18. C'est évident qu'elle est en train de rattraper le temps perdu.
    'It's clear that she is making up for lost time now.'
19. Pour être franc, le plus facile serait que tu nous montres le chemin.
    'To be frank, the easiest thing would be for you to lead the way.'
20. Je ne peux supporter son oisiveté plus longtemps.
    'I cannot put up with his idleness any longer.'

Consonant-ending

21. J'aime beaucoup les fraises, les citrons et aussi les pastèques.
    'I really like strawberries, lemons, and also watermelons.'
22. Personne dans l'équipe n'a trouvé qu'il avait fait du bon travail.
    'Nobody in the team thought he did a good job.'
23. Ça fait un certain temps que je n'ai pas rangé(e) mon placard.
    'It has been quite some time that I haven't tidied my cupboard.'
24. Comme mon frère, j'adore faire la grasse matinée le dimanche.
    'Like my brother, I love sleeping in on Sunday mornings.'
25. Samedi dernier, on a eu un pépin avec la voiture.
    'Last Saturday, we had a bit of bad luck with the car.'
26. Pour le petit déjeuner, je mange du pain avec du fromage.
    'I eat bread with cheese for breakfast.'
27. C'est curieux, les copies de cette classe sont toujours très mauvaises.
    'It's strange, this class's papers are always very bad.'
28. Les deux jeunes garçons font du vélo près du long canal.
    'The two boys are cycling next to the long canal.'
29. Quelqu'un a dit qu'elle partira pour l'Espagne cet hiver.
    'Someone said that she will leave for Spain in winter.'
30. L'éducation représente plus que d'aller à l'école.
    'Education means something more than going to school.'
31. Nous nous sommes vraiment rencontrés au magasin par hasard.
    'It was really just an accident that we met at the store.'
32. Elle serait venue volontiers mais elle était en vacances.
    'She would have loved to come had she not been away on vacation.'
33. Je le lui ai dit, mais il ne voulait rien entendre.
    'I told him but he wouldn't listen.'
34. Pour se rafraîchir les idées, il s'allonge dans un pré tranquille.
    'He is lying down in a tranquil meadow to clear his head.'
35. Elle est si jolie que tout le monde se retourne sur son passage.
    'She is so pretty that she attracts attention wherever she goes.'
36. J'ai du mal à croire qu'il n'a jamais raconté de mensonge.
    'I find it hard to believe that he has never told a lie.'

37. Les éléphants sont forts, courageux et défendent leur compagne.

    ‘Elephants are strong and courageous, and they defend their mates.’

38. Ma montre et mon pull préféré ont disparu depuis une semaine.

    ‘My watch and my favourite sweater have been missing for a week.’

39. Si vous ne saviez pas, notre bureau est du côté nord de l'immeuble.

    ‘In case you didn’t know, our office is on the northern side of the building.’

40. On dit que le temps est le remède contre la colère.

    ‘It is well said that time is anger’s medicine.