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Durham Undergraduate Research in Music & Science

Musical Chords as Affective Priming Context in a Word-Evaluation Task: A Replication Study

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ABSTRACT

This study investigated how chord tonality influenced affective priming by measuring response time on evaluation of target words. Participants heard primes of either major or minor chords preceding a positive or negative target word. The primary hypothesis (H1) was that congruent primes would reduce reaction time by eliciting an automatic expectation of positive or negative emotion and so lead to quicker identification. The experiment supported this hypothesis, as did data from the hypothesis testing. A secondary hypothesis was investigated: knowledge of the hypothesis would lead to greater susceptibility to priming, so faster congruent reaction times (H2). This hypothesis was partially supported, validated by positive congruent pairings but not by negative congruent pairings. Thirdly (H3), a hypothesis that musicality would have no effect on affective priming; results showed that this was incorrect and that there was a correlation between increased musicality and affective priming response.

1. INTRODUCTION

A study by Lense et al. in 2013 claims that "emotional connection is the main reason people engage with music". This emotional response has been the subject of extensive research, over many years, studying the emotional responses of people to musical elements or excerpts. Most of the research in this field falls into three main categories: "self-report" systems, measures of psychophysiological responses and indirect measures (Juslin and Sloboda 2010).

The self-report system focusses on participants conscious responses to music either by surveys when exposed to the music or continuously whilst listening to music using a sliding scale software. Despite its subjective nature many studies have yielded significant repeatable results (Ibid). The advantages of self-report methods are that they can be cheap to produce, and they can be used in almost any context, for example, after or during a live concert (McAdams et al. 2004). The disadvantages include demand characteristics (where participants pick up on unintentional clues as to the expected outcome of the experiment which affect their responses), and that participants are unaware of all their internal processes (Juslin and Sloboda 2010).

Physiological research has the benefit of being objective, as measurements or observations can be recorded and repeated so direct comparisons between data can be made. On the other hand, it can be difficult to link the results to emotional responses such as subjective experience, emotion behaviour and nervous system reports (Mauss I.B, Robinson M.D). Past physiological experiments include studies on heart rate (Bernardi, Porta and Sleight 2006), cerebral blood flow (Blood and Zatorre 2001), and facial muscle activity using electromyography (Lundqvist, Carlsson and Hilmersson 2000). A study by Schmidt and Trainor (2001) shows that positively and negatively valanced musical extracts more strongly activate the left frontal cortex and the right frontal cortex respectively: the same areas that respond to positive and negative emotions. Most physiological experiments, and all mentioned here, have suggested that music instils a genuine emotive response at all relevant levels in the listener rather than the listener only perceiving an emotion (Juslin and Sloboda 2010) - this theory is known as emotivism (Vempala and Russo 2013).

Our experiment falls in the third category, indirect measures. These involve measuring how participants respond to stimuli or complete tasks after being presented with an affective stimulus such as a musical excerpt, the tasks could include performance in a memory task or rating the emotions of presented facial expressions (Vuoskoski and Eerola 2012). The benefits of this method are that they are not subject to demand characteristics or lack of insight into internal processes, however, they do have the disadvantage that the results cannot always be attributed to affect.

Studies have also been done into which elements of music generate an emotional response. One obvious feature that most Western listeners would identify as positively and negatively valanced are major and minor tonalities. Much research has been done into these tonalities, yet there is no scientific consensus on the cause of this association (Parncutt 2014). Research has shown that the historically accepted associations of these tonalities do not rely on musical training but are influenced by it, those who have experienced musical training feel the associations more strongly (Hevner 1935). It is widely thought to be a learnt association, usually learnt before the age of three (Gregory 1996).

Affective Priming. Affective priming is seeing how a prime (this can be visual or audio) affects an individual's response to a stimulus. In our experiment, it followed the effect of music on emotion, and whether a prime affects expectation for upcoming events. An example of affective priming can be seen in a study done by De Hauwer (2003) investigating the 'Stroop Effect'. Participants in De Hauwer's experiment were asked to name the colour which a colour word was printed in. Sometimes the colour and the colour word were congruent - for example, the word 'blue' printed in blue. However, sometimes the names of colours were printed in a different colour to that of the word - for example, the word 'blue' printed in red. The prime was the word, and the stimulus was the colour, because it was the colour and not the word that was to be identified. The results from this experiment showed that a mismatch, or incongruent pairing, between the colour word and the colour it was printed in, slowed down the reaction time (De Hauwer, 2003).

The Replication Study. This study is a replication project of the latter paper "Musical Chords as Affective Priming Context in a Word-Evaluation Task" by Sollberger et al (2003) which investigated how consonance vs dissonance of the affective prime influenced word evaluation. The consonant prime had a positive association and the dissonant chord a negative connotation. The prime and target pairings were either congruent (e.g. consonant chords with positive word) or incongruent (e.g. dissonant chord with positive word). This study aimed to determine whether active priming was affected by the congruence of primes and if priming was an automatic response. A manipulation study was also carried out to investigate whether knowledge of the hypothesis influenced the outcome of affective priming, the results of which concluded there was no effect.

Our study extends the research done by Sollberger, Reber and Eckstein, as we measured the effect tonality had in affective priming. In our experiment, we used major and minor chords rather than consonant and dissonant chords to see whether tonality would have the same effect as consonance. The stimuli used in our experiment also differed from the original study - the 16 target words we used were taken from a word evaluation study on the norms of English lemmas (A.B. Warriner et al., 2013).

The aim of this study is to evaluate if tonality of primes influences affective priming, using major or minor chords. The primary hypothesis (H1) predicts that congruent primes would reduce response time by eliciting an automatic expectation of positive or negative emotion and so lead to quicker identification of target words. Two secondary hypotheses are also considered. An extension on the manipulation study, testing if knowledge of the hypothesis influences affective priming (H2), and a hypothesis that level of musicality/musicianship would have no effect on active priming (H3), as observed in other studies (Steinbeis et al., 2011).

2. METHOD

Participants. 25 participants (14 male), aged 18 years plus, took part in the experiment voluntarily. Participation was open to all demographics, but the majority (87.5%) were students (18-24) from the university of Durham. From self-classification, 12.5% were non-musicians, 25% were music loving non-musicians, 50% were amateur musicians and 12.5% were semi-professional musicians.

Materials. We recorded 8 chords, 4 major and 4 minor. These chords were all heard in root position in equal tempered tuning at A=440Hz. Each chord consisted of three notes in closed position. The chords had roots of Bb4, B4, C5 and C#5, these chords were chosen so that the range and the different timbres would not affect the study as both of these have been shown to have an effect in previous affective priming studies (Costa 2012, Steinbeis and Koelsh 2010) . These primes were recorded on a *Yamaha Digital Upright Piano*, recorded using a *Logitech Blue Yeti* microphone and transformed into .mp3 files using *Audacity*.

Sixteen target words were selected from a word evaluation study on the norms of English lemmas (Warriner et al, 2013) which assessed the valence of words. 8 words were selected from strongly positive and 8 from strongly negative valence groups. This gave 128 combinations of congruent and incongruent pairs of primes and target words, 32 of which were selected for the experiment, 10 were selected for the practice task.

We used *PSYtoolkit* to create the experiment and the accompanying survey (Stoet 2010, Stoet 2017).

Procedure. Participants accessed the survey online via a link, distributed by email and social media. The first webpage of the link led the participants through the consent form, followed by demographic questions to attain gender and level of musicianship. The categories for level of musicianship were self-reported and specified "non-musician, music-loving non-musician, amateur musician, semiprofessional musician, professional musician".

The presentation of each prime-target pair can be called a trial (Sollberger, Reber and Eckstein 2013). Each trial began with a fixation point in the centre of the screen where the word would appear. This is to indicate the imminent beginning of the next trial and focus the participant. 500ms after this the prime chord would be heard and 200ms after the start of the chord the word would be displayed for 2000ms, during which time the participant would categorize it as either positive or negative using the keyboard keys 'm' or 'z' respectively. The next trial would then immediately begin.

The experiment began with a practice section. This consisted of 10 trials which would help familiarise the participants with the process and the keys that corresponded to each. This would ensure that the data we received was not influenced by unfamiliarity with the system. The practice experiment also told the participant if they were "correct", "incorrect" or "too slow" in their categorisation of the word; however, in the real experiment there was no indication of whether the answers were correct or not.

After the practice run, participants then started the real experiment, from which we recorded data. This was made up of 32 trials and we recorded the time taken to categorize the word and whether the answer was correct, incorrect or they ran out of time.

3. RESULTS

H1, Response Latencies. Response latencies which were higher than 2000ms were not included in the results, to minimize the effects of distracted responses bringing up the average times. Incorrect answers were also excluded from the results, as an incorrect answer suggests that the participant was not fully concentrating on the experiment. The data for one participant had to be excluded from our data analysis because the majority of their answers were incorrect.

Variance test (ANOVA) was used to analyse the data and test if there is an effect on the response time between the prime and target congruence. The results of this ($F(1, 47) = .91$, $p = .35$) indicate the variance between the categories congruent pairing of prime and target and incongruent pairing was non-significant ($p < .05$).

To further assess the data, comparison of the mean response times is seen in Figure 1 and 2. By taking the average response time for each congruent or incongruent pairing category it is seen that congruent pairings elicited a shorter reaction time. The average for congruent pairings is $M = 758$ms, 11ms faster than for incongruent pairings. The average reaction time overall was $M = 763$ms, with both the positive and negative congruent pairings giving times of 756ms and 759ms respectively. The incongruent pairings had longer average reaction times, with the negative primes/positive stimuli pairings having an average of $M = 770$ms and the positive primes/negative stimuli pairings having an average of $M = 768$ms.

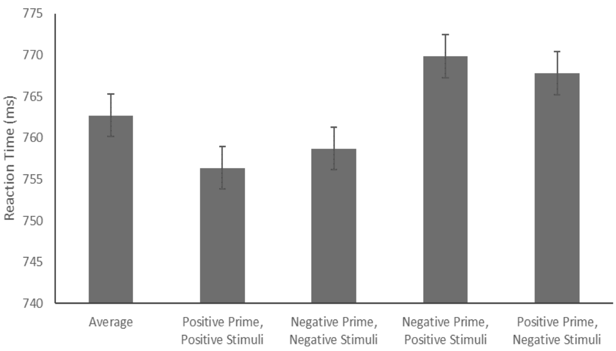

Figure 1. Mean reaction time by prime and target word pairing

H2, The Effect of Knowledge of the Hypothesis. From 25 participants, 12.5% of these participants guessed the "accurate" hypothesis and 87.5% were classed as "not accurate". The data shows that the group who failed to guess the main hypothesis accurately followed the predicted trend more (Table 1).

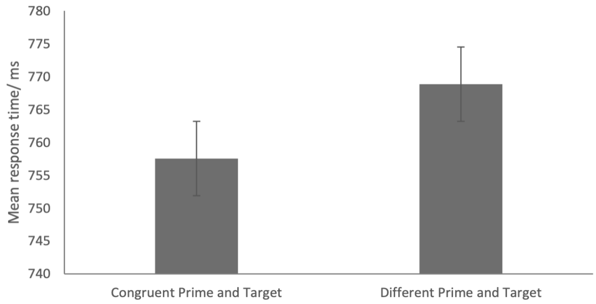

Figure 2. Mean reaction time by congruence

ANOVA resulted in $F(1, 5) = .09$, $p = .78$ for the group that guessed the hypothesis accurately, and $F(1, 41) = 1.63$, $p = .21$ for the group that didn't guess the hypothesis correctly. This indicates that for both groups there is variance between the response time of congruent and incongruent pairings, with a greater variance for the "accurate" hypothesis group. Both analyses have lower p-values than for the primary hypothesis, and there is lower p-value for the inaccurate hypothesis group.

Table 1 shows that the mean response times of the group that guessed the hypothesis "inaccurate" were shorter. The positive congruent pairing has the smallest response time for the "accurate" hypothesis group, whereas the negative congruent pairing has the shortest response time for the "inaccurate" group. For those who correctly identified it, the positive congruent pairings had an average reaction time of 700ms, which is faster than the average for the incongruent pairings (738ms and 745ms). However, the negative congruent pairings had an average reaction time of 812ms - slower than both the incongruent averages. For the group who did not predict our main hypothesis, the positive congruent average reaction time was 764ms and the negative congruent time was 751ms. Both of these reaction times were quicker than the incongruent averages (773ms and 772ms).

Table 1. Average response time of "accurate" and "inaccurate" hypothesis testing, and the response times of different parings of primes and targets (*SD* in brackets)

Accurate Hypothesis	Positive target response time /ms	Negative target response time /ms
M = 748		
Major prime	700 (171)	745 (57)
Minor prime	738 (191)	812 (223)
Inaccurate hypothesis		
M = 765		
Major Prime	764 (209)	772 (196)
Minor Prime	773 (206)	751 (189)

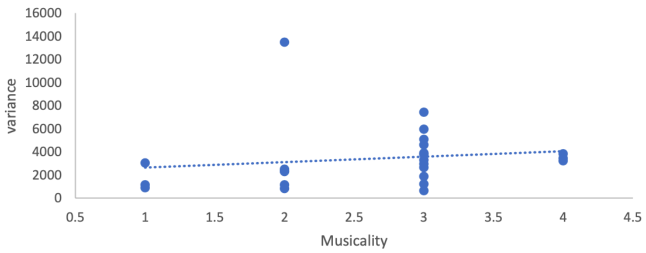

Figure 3. Variance of reaction times and levels of musicianship, 1 = non-musician, 2 = music-loving non-musician, 3 = amateur musician, 4 = semi-professional musician, 5 = professional musician

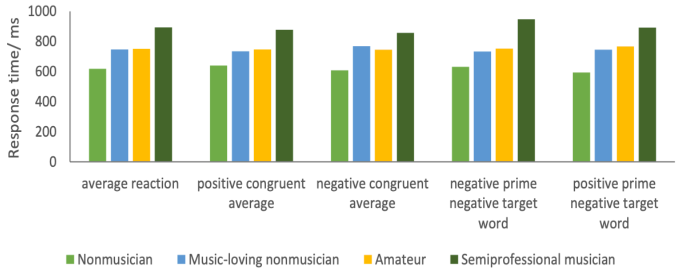

Figure 4. Comparing musicality to response in evaluating target words, categorised into congruent and incongruent pairings

H3, Musicality. The hypothesis H3 predicted that different levels of musicianship would not influence our results. However, Figure 3 shows that variance of each participant between congruence of pairings increases with musicality. There is a small positive correlation between levels of musicianship and variance: $r = .15$. Contrary to our hypothesis, this suggests that levels of musicianship do influence affective priming.

This is confirmed by Figure 4, where the greatest difference in response time between congruence categories can be seen visually to be the participants with greatest musicality (semi-professional musician). For those who categorised themselves as semi-professional musicians, the difference between the average reaction times of congruence compared with incongruence is 51ms. Whereas, for those who categorised themselves as non-musicians, the difference is only 12ms. This trend suggests individuals with more musicality are more susceptible to the 'Stroop effect' with major and minor primes.

A trend of increased musicality and increased response time is seen in Figure 3. This is most prominent in the negative congruent pairing. Table 2 shows that at higher levels of musicality (self-reported musicians) there is a shorter mean response time to congruent pairings than incongruent. Non-musician categories did not show a clear correlation between response time and congruence.

Table 2. Deviation from average response time due to congruent or incongruent pairings, compared to a level of musicality, where negative values indicate a faster than average response time and positive values represent a slower response time

	Average Reaction /ms	Positive congruent average /ms	Negative congruent average /ms	Negative prime incongruent average /ms	Positive prime incongruent average /ms
Non-musician	0	21.3322	-9.9803	12.9929	-24.4178
Music-loving non-musician	0	-12.8334	22.8332	-13.6459	-0.93463
Amateur	0	-4.5543	-5.6217	1.0990	15.5876
Semi-Professional musician	0	-15.8161	-36.3831	53.6184	-2.4971

4. DISCUSSION

H1. As in Sollberger, Reber and Eckstein's original experiment, we found that the results supported our main hypothesis. The difference in average reaction times between congruent pairings of primes and stimuli and incongruent pairings was 11ms. Our ANOVA data gives a high *p*-value ($p = .35$) which suggests the statistical results were not significant; however, the analysis of the mean (Figure. 1 and 2) shows a clear trend in congruence and affective priming. This suggests that affective priming does have an effect on a participant's response to stimuli, and that congruency between a prime and stimulus gives quicker average reaction times. This conclusion is in line with the findings of many other studies, for example, Duckworth did a study on evaluating stimuli and found that exposure to something positive or negative can affect how a stimulus is viewed (Duckworth, 2002). In his study on the 'Stroop effect', De Hauwer found that congruency between a prime and stimulus led to quicker average reaction times (De Hauwer, 2003).

Our data adds further support to the 'Stroop effect' with musical primes, though to a lesser extent than the original study and this is shown by the ANOVA statistics obtained in both experiments. One possible reason for this could be that the automatic effect for consonance and dissonance is stronger than for major and minor. This could be because the major and minor valences are learnt but the negative associations for dissonance are instinctual. This is shown in a study concerning the musical preferences of infants: when presented with two images, one that played a major chord when looked at and one that played a minor chord, the six-month-old children showed no preference (Crowder, Reznick and Rosenkrantz, 1991). When this was repeated with consonant and dissonant chords the infants showed a preference for the consonant chords. The preferences shown in this study may not correlate with positive or negative affect as we have no other way of communicating with the infants. A separate study found that children as young as three showed that they possessed positive connotations for major tonalities and negative connotations for minor tonalities showing that it is learnt at a very early age (Kastner and Crowder, 1990). On the other hand, this difference could be due to the smaller participant group we had as it did not align with a normal distribution, it was positively skewed.

H2. Our second hypothesis was that participants who knew our main hypothesis would be more likely to follow its trend; however, our results showed something different. We found that the variance of the group who did not know the hypothesis was larger and therefore the data was less consistent. This could be due to a greater difference in reaction times to congruent and incongruent pairings. However, this is only one explanation and more analysis would be needed to find out if this theory is true.

Table 1 shows that for the group who correctly guessed the hypothesis, the positive congruent pairing has on average a quicker reaction time. However, both the incongruent pairings have on average faster reaction times than the negative congruent pairing. The anomaly is that negative congruent pairings have a longer response time of 812ms., this has the highest error by standard deviation and suggests this may not be a reliable result. In the incorrect hypothesis group however, both the positive and the negative congruent pairings have quicker reaction times than the incongruent pairings. This result does not support our hypothesis as, the group who correctly predicted our main hypothesis seemed to, on average, follow the trend less than the group who guessed incorrectly. Only 3 out of 24 (12.5%) participants were able to correctly identify our main hypothesis and this sample is too small to base any conclusions on. A more accurate way of measuring whether knowing the hypothesis has an effect on affective priming would be to inform half of the participants of the main hypothesis before they take part in the experiment. Their results could be analysed against those who did not know the hypothesis and the data would demonstrate whether knowing the main hypothesis affects affective priming.

H3. In our experiment, we expanded on previous studies done on musicianship and affective priming and we predicted, as other studies had shown, that different levels of musicianship would not have an effect on affective priming, hypothesis H3. Steinbeis found in his study ('Affective priming effects of musical sounds on the processing of word meaning') that musical expertise does not have an effect on affective priming (Steinbeis, 2010). However, our results seem to go against this hypothesis and would suggest that different levels of musicianship do have an effect on priming. We found that those who had a higher level of musicianship were more affected by affective priming - the difference between the average reaction time for congruent pairings and incongruent pairings was 51ms. This difference between the two groups is much larger than in any of the other levels of musicianship: for amateur musicians the average difference was 14ms, and for the music-loving non-musicians and the non-musicians, the difference in the average reaction times between congruent and incongruent pairings were 13ms and 12ms respectively. However, interestingly these two groups of non-musicians showed that, on average, incongruent pairings led to a faster reaction time. This could be because musicians would be more likely to identify major chords as positive and minor chords as negative, whereas non-musicians only hear a chord and may not automatically categorise it as a major/positive chord or minor/negative chord.

The variance of reaction times shows how spread out the data is from the mean and therefore how consistent it is for each level of musicianship. Our results show that the higher the level of musicianship, the larger the variance and therefore, the wider the data spread is. This suggests that different levels of musicianship do have an effect on affective priming. A possible explanation for this could be that as an individual is exposed to more analytical methods of understanding music, these considerations (examining tonality of the chord) become innate and so slow the evaluation of words. However, this is only one possible explanation and further analysis of the data is needed (Figure. 3) to see whether this assumption is true.

Pearson's coefficient (*r*) shows correlation between two data sets, however, this *r* value here is arbitrary due to the random numerical values assigned to different levels of musicianship.

If different numerical values were used (e.g., 1,2,4,8) then the r value would be altered. Pearson's coefficient is useful in showing that there is a small positive correlation between variance in reaction times and different levels of musicianship; however, the exact r value is arbitrary.

Our theory that musicianship does influence affective priming is supported by the results of the hypothesis testing; the majority of participants (60%) identified major vs minor chords as the difference in the primes. 60% of the participant self-identified as either amateur or semi-professional musicians, suggesting a correlation between musicality and ability to recognise tonality. In comparing response time of congruent/incongruent pairings for different levels of musicality there was also a trend. The amateur and semi-professional musician categories showed a clear average decrease in response time for congruent pairings, which supports our primary hypothesis. However, the non-musician categories did not show any clear patterns. An interesting future hypothesis could be ascertained from this data: the results imply that increased levels of musicality increases the affective priming effect. This suggests that individuals more accustomed in analysis and understanding of music have more attuned automatic affective priming; perhaps due to a quicker subconscious analysis of whether a chord is major or minor, therefore neural links to positive or negative connotations are made faster. Participants with less ability to differentiate between major and minor chords at an automatic level, were less affected by affective priming of tonality. Our experiment studies the effect tonality has on affective priming; however, Sollberger's study looked at dissonance. These two musical elements are very different when researching the effect of musical training as previous studies have found that even young children favour consonance to dissonance (Zentner & Kagan, 1996). Whereas in our experiment we have found that musicianship and being familiar with the connotations of major and minor chords, does have an effect on affective priming. This would suggest that the associations with dissonance are innate, however, associations with tonality is learnt. However, due to the inconsistent nature of this data it is inconclusive, and further studies should be made to investigate this theory.

One problem with this area of our study is that participants did a self-report on their level of musicianship (from non-musician to professional musician). To improve this, a test could be taken before the experiment, which would ask participants about whether they play an instrument and to what level, how much musical training they have had and how often they listen to music. This test would determine participants levels of musicianship in a more accurate way than a self-report.

Evaluation. There ANOVA values that were obtained when comparing different hypotheses were non-significant. For our main hypothesis, despite a high p-value suggesting high possibility for the null hypothesis, the mean response times demonstrated the hypothesis was correct. However, the ANOVA for the second and third hypotheses showed higher p-values, and accordingly, the mean response time analysis was not always consistent with the hypotheses. This indicates that the sample size was too small for effective ANOVA analysis, which relies on an assumed normal distribution, whereas small sample sizes can be significantly skewed. Therefore, our results could have been improved significantly by including more data. This idea is supported by the large standard deviations, especially on the anomalous data average implying a large potential error. These errors would be reduced by a larger sample of participants, but also if the yield of 'accurate' hypothesis identification were higher.

To increase reproducibility of the study, it would benefit from better categorisation of demographic data. Our demographic survey did not include specific categorisation of age and so limited discussion comparing affective priming to age. The data analysis on musicianship and affective priming is not fully reliable due to a small data set and that the categorisation of musicianship was vague. It resulted in inconsistent data comparing musicianship with congruent/incongruent responses. In further studies this could be improved by quantifying musicality, for example using the Goldsmiths Musical Sophistication Index (Gold-MSI) (Müllensiefen, 2014).

Furthermore, it is known that different mean pitches create different affects for the listener (Chlan and Heiderscheit, 2018; Juslin and Sloboda, 2010). It has been suggested that register is a far more important aspect than mode or consonance (Costa 2012). This effect is important here as our replication and the initial study both have negative primes which have a lower average pitch than our positive primes. Our negative primes all had a flattened third compared to the positive primes where the negative primes in the original study had a flattened fifth, with some having an added minor second, compared to the positive primes. An experiment to test whether the pitch influences the outcome could have all minor chord roots a semitone higher than their major counterparts and run our experiment again with this new input.

Follow on Experiments. Interestingly, our study revealed that 80% of participants predicted our experiment was looking at the relationship between tonality and our perception of words. As a follow on from our study, it would be fascinating to look into whether major and minor primes could affect how words are perceived, and if tonality could cause 'mistakes' when categorising positive and negative words.

In future studies of this nature, an experiment on the correlation between musicianship and the effect of affective priming would be interesting to see, as our results hinted at a correlation between the two. It is possible that our experiment was an anomaly in this area as a large number of existing studies showed no correlation between musicianship and an increased susceptibility to the affective priming (Kamiyama et al., 2013; Sollberger, Reber and Eckstein, 2003; Steinbeis and Koelsch, 2011). There is still room for investigation in this area, especially seeing as what causes the major/minor connotations are debated. One could hypothesise that due to the learnt associations of major and minor tonalities, the musicians were more influenced by them due to a greater level of association and experiences. An experiment to test this would be set up similarly to ours but the participants would be found from two different groups, one made up of professional musicians and one made up of participants of little to no musical training or the experiment could include a more empirical test for musicianship.

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