The semantic relationship between movement and enjoyment in groovy music: an ERP study.

David A. Prete

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Department of Psychology
University of Western Ontario
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Thesis Advisors: Daniel Cameron PhD candidate, Molly Henry PhD, Jessica A. Grahn PhD

Abstract

The desire to move while listening to music, referred to as groove, is a widely observed phenomenon. Groove is thought to be associated with enjoyment such that music that makes people want to move typically is highly enjoyed. Ratings between groove and enjoyment of music are strongly correlated however, people do not think of enjoyment when defining of groove. Given this discrepancy between these explicit tasks we investigated the relationship between groove and enjoyment using an implicit task, specifically semantic priming. We also recorded electroencephalogram (EEG) data to compare the N400 event related potential (ERP) components, a negative potential that indexes a semantic association between two stimuli. Music rated as high groove and low groove was followed by target words that were either related to moving, unrelated to moving, related to enjoyment or unrelated to enjoyment while participants completed a word discrimination task. The amplitudes of the N400 component were compared in a repeated measures ANOVA to determine if the musical stimuli primed for the target words. The analysis indicated an association between high groove music and enjoyment words, but no association between high groove music and movement words. This would indicate the groove and enjoyment are inherently connected and our definition of groove as being a desire to move to music may be imposed onto the music. Future research is need to explain why groove would not be associated with movement, despite being define by it.

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While listening to music, people tend to spontaneously move to the beat whether it be small movements such as tapping their foot or bobbing their head, or full body movements such as dancing. Within the field of psychology the extent to which a song makes an individual want to move is referred to as groove (Madison, 2006). A song that induces a strong desire to move would be considered *high groove* (HG) whereas a song that does not induce a desire to move would be considered *low groove* (LG). Anecdotally, this desire to move to the beat is also highly enjoyed, however the association between groove and enjoyment of music is not well understood. Some researchers posit that the two perceptions are separate, meaning music can be highly enjoyable without inducing a desire to move and music can induce a desire to move to music without it being enjoyed (Maddison 2006). Others argue that groove is a desire to move that is enjoyable (Janata, Tomic, & Haberman, 2011; Witek, Clarke, Wallentin, Kringelbach, Vuust, 2014; Vuust, & Witek, 2014). In the current study we examined whether groove and enjoyment are distinct psychological phenomena or are inherently linked such that music that induces a desire to move is always enjoyed

Groove and Movement

The desire to move to music is likely due to increased activity of the motor cortex that occurs while listening to music. Activation of the supplementary motor area and the pre-motor cortex has been linked to both beat perception of rhythms (Gahn & Brett, 2007; Grahn, & Rowe, 2009) synchronization to rhythms (Chen, Penhune, & Zatorre, 2008), and a recent model of timing perception states the importance of these regions for beat-based timing as well (Teki, Grube, & Griffiths, 2012). Analysis of audio characteristics of music across several genres has demonstrated that the number of events or tones in a sequence (event density) and clarity of the beat within the music are the best predictors of groove ratings (Madison, Gouyon, Ullén, & Hörnström, 2011). For music to induce a desire to move to the beat, the timing of the beat within the music must be clear. The role of the motor regions in beat perception of music likely play a role in groove perception as well.

Further support for the role of the motor system in groove perception stems from a recent study that showed increased excitability of the motor cortex while listening to high groove music compared to listening to low groove music (Stupacher, Hove, Novembre, Schütz-Bosbach, & Keller, 2013). While stimulating the primary motor cortex using transcranial magnetic stimulation (TMS) the motor cortex demonstrated greatest change in excitability when participants listened to high groove music, whereas the excitability did not differ while listening to low groove music. Spontaneous body movements also tend to increase while listening to high groove music but not to low or moderate groove music (Janata et al., 2011; Hurley, Martens, & Janata, 2014). Listening to high groove music makes people more willing to move, but this does not necessarily mean that this desire to move is enjoyable.

Groove and Enjoyment of Music

Groove as a psychological concept of inducing a desire to move to music is supported both on behavioural and neural levels, however this does not elucidate the association between groove and enjoyment. Madison (2006) found groove and enjoyment to be distinct characteristics with in music. Factor analysis of the ratings indicating how well 14 music and timing words described music lead to four factors: rhythmic complexity, groove, happiness and tension. Madison suggested the separation between groove and happiness indicated groove is distinct from enjoyment, however the happiness factor had high factor loadings for the words “happy”, “rocking” and “having swing”, indicating this factor measured more than just perceived happiness of the music. The latter two words imply movement, which intuitively should be related to groove even though this was not the case in the data. This discrepancy makes it hard to interpret what these four factors mean and how they relate to each other.

A more recent experiment examined how individuals define groove and how ratings of groove correlate with ratings of enjoyment (Janata et al., 2011). First, 153 individuals were asked to write down their personal definition of groove without being given a definition beforehand. The word frequency analysis of their answers revealed the most used words (other than “groove” and “music”) were “move”, “beat”, “rhythm” and “dance” all of which relate to moving to the beat in some form. Importantly the words “enjoy” and “want” were included in some definitions but only approximately 10% of them, suggesting that the majority of people do not think of enjoyment when they think of groove. Ratings of perceived enjoyment and groove for 148 music clips revealed a strong positive correlation between groove and enjoyment. This correlation has also been observed in a recent study examining the role of rhythm complexity on groove and enjoyment of music (Witek et al., 2014) as well as the previously mentioned TMS studying (Stupacher et al., 2013). Individuals also seem to agree that statements regarding enjoyment of a song are associated with the term groove (Janata et al., 2011). Thus, it would seem that during ratings task individuals’ associate groove and enjoyment, however this association does not come through when individuals must explicitly describe the concept of groove.

The discrepancy between definitions of groove and ratings of groove led us to examine the implicit association between enjoyment and groove using semantic priming. Semantic priming occurs when there is an association between two stimuli, for example the sentence “I like to eat sandwiches” would prime for target words such as “bread” or “jam” but not for the word ”shoe”. The extent of the semantic priming or the degree of relatedness can be indexed behaviourally by measuring reaction times, with faster reaction times indicating a stronger association, but also at the neural level using electroencephalogram to measuring the N400 event related potential (ERP) component (Kutas & Hillyard, 1980). The N400 ERP component is a negative peak at around 400 milliseconds after the onset of the target word. The amplitude of the N400 is inversely proportional to the relatedness between the prime stimulus and the target word, such that a large degree of unrelatedness between the prime and the target word will result in a larger amplitude (Kutas & Hillyard, 1980; Nigam, Hoffman, & Simons, 1992; Lau, Phillips, & Poeppel, 2008).This difference between related and unrelated N400 ERP components will be referred to as the N400 differential.

Music and Semantic Priming

Semantic priming has been shown to be possible not only in response to language, but music as well (Koelsch et al., 2004; Daltrozzo and Schön 2009a; Daltrozzo and Schön 2009b; Zhou, Jiang, Wu, & Yang, 2015; Painter, & Koelsch, 2011). One of the first group of researchers to study semantic priming in music used both music clips and sentences as primes for visual words (Koelsch et al., 2004). After the presentation of the prime-target pairs participants judged whether or not the stimulus pairs were related or unrelated. Both music and language primes elicited the N400 ERP component and the unrelated target words elicited larger negative N400 compared to related words. Importantly, there was no significant difference between the N400 between the domains of language and music, indicating that both domains semantically primed the target words to the same extent. Koelsch et al., repeated the experiment using a memory task instead of a judgement task, to mitigate possible effects of influencing participants to think of words to describe the music causing the priming and not the music itself. This revealed the same results. They also controlled for the concreteness of the target words as well as the emotional content and again found the language and music elicited an N400 differential that was not significantly different between the two domains.

Daltrozzo and Schön (2009a) have supported the idea that music contains semantic meaning again by examining the N400 differential for short music clips used as primes as well as targets for visual words. During the condition in which the music was used as a prime the onset of the ERP was set to the presentation of the target word. Alternatively, when the visual word was the prime the onset of the ERP was set to the presentation of the target music clip. Participants judged the relatedness between the paired stimuli (either word-music pair or music-word pair). A significant N400 differential was found when the music clips were used as primes for the words and as targets for the words, indicating music has semantic meaning. It would seem that the semantic association between words and music is not caused by the task influencing participants to think about words to describe music. If this were true then no significant N400 differential would have been found when music was used as a target. The participant would not have enough time to think of a word to describe the music and have an association between they thought of and the prime word. However when the music clips were used as the target stimuli the N400 differential had a reduced amplitude and greater latency time compared to the N400 differential induced when the music clips were used as primes. This difference in amplitude and latency was not significant, but it demonstrates that the experimental design used during semantic priming can alter the N400 component observed.

To further investigate how the N400 can be altered Daltrozzo and Schön (2009b) compared semantic priming of musical primes and target words during a lexical decision task and their results from the previous study that used a relatedness judgement task (2009a). To ensure that the results would not be skewed due to length of the priming stimuli they used one second music clips as they did in the previous study. For both tasks a significant N400 differential was found suggesting music elicited semantic priming whether or not the participants were actively trying to find a relation between the music and words or thinking of words to describe the music. However, again the N400 differential found during the lexical decision task had a reduced amplitude and a longer latency compared to the N400 during the relatedness judgement task. The results from this study suggest that the N400 can be modulated based on the task. Music may contain semantic concepts that can be related to words, however if individuals are not trying to make a connection or think of the concept within the music the semantic concept within the music is less likely to come out.

Painter and Koelsch (2011) examined the extent of musical semantic priming by conducting a two part experiment with short music clips composed of musical instruments or non-instrumental sounds. In the first experiment participants judged the relatedness between the primes and the targets, however in the second experiment the participants recalled whether they had heard a probe stimulus given after every eight trials. In both experiments the music clips ranged from one to about three seconds long and were used as both primes and targets. A significant N400 differential was found for the musical clips regardless of whether they were used as primes or targets for the words, supporting Daltrozzo and Schön previous study (2009a). Contrary to the previous studies mentioned (Koelsch et al., 2004; Daltrozzo & Schön 2009b), the N400 differential was only found when the participants completed the relatedness task. No significant N400 differential was found during the memory task, suggesting that semantic priming only occurred when participants were relating the two stimuli.

These findings suggest that music can prime semantic meaning, but only under certain conditions and only during certain tasks. Short music clips or non-instrumental music contexts can only give meaning if an individual is actively looking for meaning with in the song. For longer music clips semantic priming is more likely to occur, possibly due to more information being given (Daltrozzo & Schön 2009b).

To elucidate the association between groove and enjoyment the current study used semantic priming paired with electroencephalogram (EEG) recordings. Specifically, we examined if listening to high groove music not only makes individuals think of movement, but also makes them think of enjoyment. To do this we used primes consisting of song clips from previous studies that have been rated as low groove or high groove (Janata et al., 2011; Leow, Rinchon, & Grahn, 2015). We used target words that are either: 1) movement related, 2) enjoyment related, 3) movement unrelated, and 4) enjoyment unrelated. To index semantic priming between the music clips and the words N400 ERP components were compared between the related and unrelated conditions from within each word condition, i.e. N400 for the movement related target words was compared to the N400 elicited for the movement unrelated words. The same was done for the enjoyment related and unrelated words. We predicted a significant difference between the N400 ERP components for movement related and unrelated words such that the movement unrelated words would elicit a larger negative amplitude compared to movement related words. This would indicate that high groove music makes people think of moving. We also predicted no significant difference between the N400 ERP for the enjoyment related and unrelated target words, suggesting individuals do not think of enjoyment while listening to high groove music. Lastly, we predicted no significant difference between the

N400 amplitude for either word condition or relatedness condition when primed by low groove music.

Methods

Participants

Data was collect from 11 participants (3 male) from Western University, with age ranging from 18 to 20 (*M* = 18.27, SD = 0.65). All participants were recruited through the undergraduate research participant pool and received 1 course credit per hour for their participation. All participants were right handed with normal or corrected to normal vision and had no known hearing impairments at the time of testing. All participants were fluent in English with 11 or more years of experience speaking English. Six of the 11 participants had four or more years of musical training, three had four or more years of dance training and five spoke at least one language other than English.

Stimuli

Music. The musical stimuli consists of songs from previous research (Janata et al., 2011; Leow, Rinchon, & Grahn, 2015) that have been rated as high groove and low groove The songs were chosen such that they were rated as highest groove and lowest groove, and at least 5 different four second music clips without lyrics could be made from the song. For a full list of the songs used appendix A. The songs chosen were edited into the 4 s clips using Audacity 2.0.5 (Audacity Team, 2014). All songs had a 44.1 kHz sampling rate as well as a fade in and fade out time of 100ms to mitigate abrupt cut-offs within the songs that could possibly be distracting. The clips were non-lyrical segments of the songs to ensure any association between the musical primes and the target words were a music-to-word association and not a word-to-word association. Peak normalization was applied to the music clips so that each song was played at

50 decibels above each participant’s individual hearing threshold. In total 180 music clips were used, 90 high groove music clips and 90 low groove music clips.

Words. A pre-experimental word list of 200 words, chosen by the experimenter, was created by visually inspecting a larger corpus of approximately 14 000 words (Warriner, Kuperman, & Brysbaert, 2013). The pre-experimental word list was divided evenly such that 50 words belong to one of the four following categories: enjoyment related (ER); enjoyment unrelated (EUR); movement related (MR); and movement unrelated (MUR). The 200 word list was presented to a pre-experimental group of participants who rated how much the words related to movement (i.e. how much the word made them think of moving) on a scale from 1 to 9. The following exemplars and instructions were given for the extremities and midpoint of the scale: 1 = the word makes you think of being still or not moving (e.g. mountain); 5 = the word is neutral meaning it doesn’t make you think of moving or of being still; (e.g. colour) 9 = the word makes you think of movement as soon as you see it (e.g. treadmill). This was done to ensure that the MR and MUR words were perceived as being related and unrelated. Enjoyment relatedness ratings for the list of words came from valence ratings of the words collected by the original study (Warriner et al., 2013). Valence was defined to the participants of as feeling “happy, pleased, satisfied, contented, and hopeful”. This definition is similar to a definition of enjoyment that these ratings can be used as enjoyment relatedness ratings as well.

Both ratings were then used to ensure that words included in the final word listed were at the extremities of one word condition (i.e. either movement or enjoyment), while being neutral in the other word condition. In order for a word to be considered related the average rating for the desired condition needed to be greater than 6.5 while being between 3.4 and 6.4 in the other word condition. For example, the word “*active*” had an average movement relatedness rating of

7.73, but an average enjoyment relatedness rating of 6.47. Even though the average movement relatedness rating was greater than the 6.5 criteria the average enjoyment relatedness rating was outside the neutral range. Therefore this word was not included in the final word list. The final word list (appendix C) consisted of 120 words, 30 per category. Sixty words were then randomly sampled from the final word list. The letters within each of the 60 words were randomly scrambled to created letter strings used in the word discrimination task that will be further explained below.

The target words, letter strings and music primes were paired into two list such that each word was followed by a low groove and high groove prime, but these pairings were counter balanced between the two lists (i.e. in one list the word was paired with a high groove prime and in the other list the word was paired with a low groove prime). Both lists were presented to each participant in counter balanced order, so not every participant heard list one pairings of the stimuli first followed by list two pairings.

Procedure

After participants read the letter of information and gave written consent (appendix A) they were brought to a sound attenuating booth to complete the experiment. They were placed at a comfortable distance in front of a computer monitor. All words were presented using the computer monitor and all music was presented using Sennheiser HD 25-1 II headphones. First, the participants completed a minimum hearing threshold task. During this task they heard white noise that either ascended or descended in intensity from -120 to -30 decibels. At the same time an arrow either pointed upwards or downwards was presented in the centre of the screen. Trials with white noise ascending in intensity were indicated by an upward arrow presented in the center of the screen. Trials with white noise descending in intensity were indicated by a downward arrow presented in the center of the screen. Participants were instructed to press any key on the keyboard as soon as the sound became inaudible or as soon as the sound became audible depending on whether the arrow pointed down or up, respectively. Participants completed twelve trials in total, 6 with ascending intensity and 6 with descending intensity.

After the participants completed the minimum hearing threshold task they started the semantic priming paradigm and word discrimination task. Participants were told that they would hear music clips followed by words or letter strings, and their task is to determine if a word or letter string was presented on the screen. When a cue was presented on the screen after the target was presented the participants were instructed to press “y” if they thought thy saw a word, and press “n” if they thought they saw a letter string. Each trial started with a 4s high or low groove prime presented with a blank black screen. The word or letter-string was then presented in the centre of the screen for 1s as white text against a black background. A stimulus onset asynchrony between the prime and word of 800ms was used to ensure any auditory offset components within the ERP would not confound with the desired N400 component. After the word was presented a white fixation cross was shown in the centre of a screen for 1.5s followed by the cue for participants to make their response to the word discrimination task. There was an inter trial interval of 3s that started after the participants made their response. During each trial the presentation time of the music clips, words (or letter string) as well as response time and the participants’ responses were recorded. The participants were given a break after every 45 trials, approximately every nine minutes. After the prime-word pairs for one list were presented (180 trials) the second list of prime-word pairs was presented with breaks every 45 trials as well. After completing a total of 360 trials the participant completed the demographics questionnaire and received compensation. In total the experiment took approximately 2 hours to complete.

An analysis of the behavioural data was not conducted for several reasons. Firstly, the word discrimination task used is a surface level task not require deep or semantic processing of the words. Therefore it should not have an effect on the N400 amplitude in anyway and was included to ensure the participants were attending to the stimulus. Reaction times were also not analysed due to the delay between the word or letter string presentation and the cue to respond. This delay of 1.5s would have allowed participants to determine the proper response and prepare their movements to make that response diminishing the effect priming would have on reaction times. Furthermore, the extensive research indicating the N400 as an index of association between prime stimuli and targets (for review see Lau et al., 2008) suggests that N400 is enough to measure semantic priming.

EEG Recording and Analysis

EEG data was collected using 64 Ag-AgCl channels positioned on the scalp using the extended 10-20 system (Jasper, 1958). Two reference electrodes were placed on the left and right mastoid, which were later used to offline reference the EEG data. The data was recoded using BiosSemi amplifier (BioSemi, Amsterdam, The Netherlands). The sampling rate was 1024Hz, but later down sampled to 256Hz. Data was offline band-pass filtered at 0.1-40 Hz. Independent component analysis was used to separate the EEG data into statistically different components in order to remove artifacts such as eye blinks, saccades and heart rate. Finally, threshold rejection was applied to each trial such that any trial that exceeded an amplitude of 100 microvolts below or above zero was removed.

After processing the data was separated into epochs from 100ms before to 1000ms after the words presentation. To examine differences in the N400 component the amplitude of the ERP was averaged in a time window from 300ms to 500ms after the word presentation at Cz.

The Cz electrode was chosen because a grand average topography across all participants and all conditions revealed the largest negativity centered around Cz (figure 1) and the N400 differential results in a negative spike within the time window.

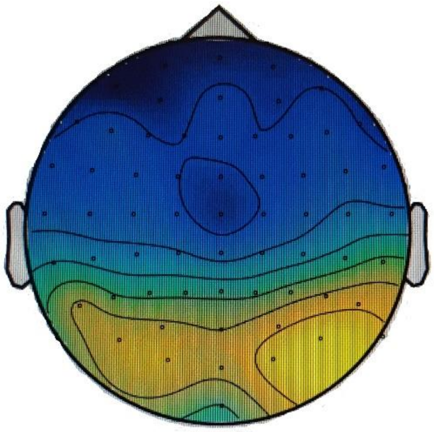

Figure 1- Grand average amplitude potential distribution across all participants and all conditions within the 300 to 500ms time window. The dark blue represents a negative scalp distribution of the amplitude and the yellow represents positive. The scale ranges from -1µV to 2.5µV.

Cz is also the site of the largest negativity found in previous music-priming literature as well (Daltrozzo, & Schön, 2009b; Painter & Koelsch, 2011; Zhou et al., 2014) A 2x2x2 repeated measure AVNOA was then conducted on the average amplitude calculated with within subject factors of groove (high groove, low groove) word condition (movement, enjoyment) and relatedness (unrelated, related).

Results

The analysis revealed a main effect of word category ($F(1, 10) = 5.17$, $p = .046$, $\eta^2 = 0.341$) such that a larger negative amplitude was elicited by movement words ($M = -1.18$, $SD = 2.82$) compared to enjoyment words ($M = -.489$, $SD = 3.11$) across groove and relatedness conditions. Unrelated words also lead to significantly larger negativity (*M* = -1.23, *SD* = 3.08) compared to related words (*M* = -.442, *SD* = 2.84) across groove and word conditions ($F(1, 10) = 13.58$, $p = .035$, $\eta^2 = 0.374$).

A marginally significant two-way interaction between word condition and relatedness ($F(1, 10) = 6.54$, $p = .094$, $\eta^2 = 0.255$) revealed a larger difference in N400 amplitudes between enjoyment-related (*M* = .176, *SD* =3.03) and enjoyment-unrelated (*M* = -1.16, *SD* = 2.83) target words compared to the difference between movement-related (*M* = -1.06, *SD* = 2.44) and movement unrelated target words (*M* =-1.30, *SD* = 3.15). More importantly, as illustrated in the ERPs in Figure two, a marginally significant three-way interaction was revealed ($F(1, 10) = 4.58$ $p = .091$, $\eta^2 = 0.259$) such that the largest difference in N400 amplitudes occurred between enjoyment-related and enjoyment-unrelated words primed by high groove music.

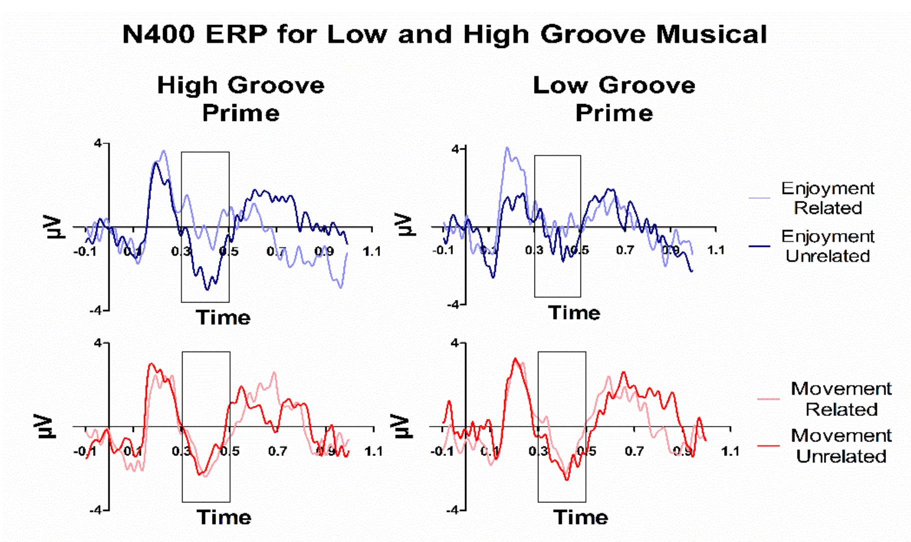

Figure 2- ERP data from 100ms before the word presentation to 1000ms after word presentation primed by either low or high groove music. The blue line represents the enjoyment words and the red lines are the movement words. Darker lines are the unrelated words and lighter lines are the related words. The boxes represent the N400 time window from 300ms to 500ms after word

presentation. There is a significant difference between N400 amplitude for the enjoyment related and unrelated words when primed by high groove, no other differences.

The enjoyment unrelated words had a more negative amplitude compared to the enjoyment related words ($t(10) = 2.70$, $p = .022$), as can be seen in figure three.

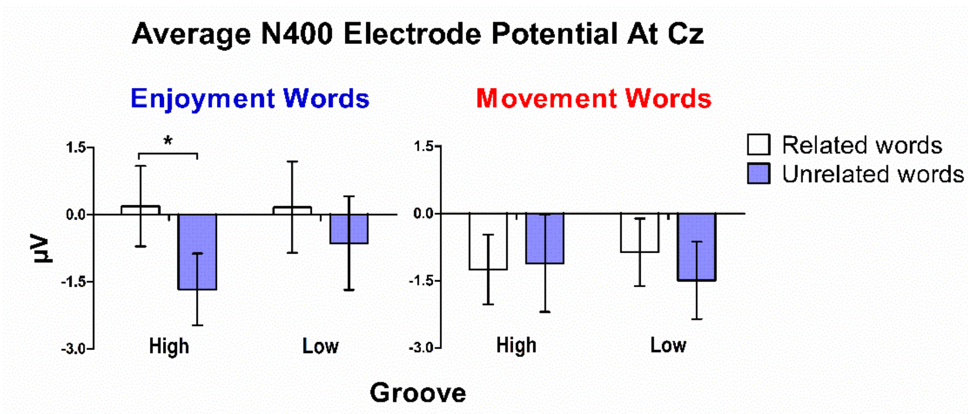

Figure 3- Average N400 amplitude from 300ms to 500ms after word presentation measure at the electrode Cz. The y-axis measure in microvolts and the x-axis is the different groove conditions. The white bars represent the related words and the purple bars represent unrelated words. $*p < 0.5$.

When enjoyment related and unrelated words were primed by low groove music no significant differences were found. The N400 amplitudes for movement related and unrelated words were not significantly different with either low or high groove primes.

Discussion

The analysis of the EEG data revealed two significant main effects. The main effect of relatedness revealed that the N400 amplitude for unrelated words larger negative amplitude compared to the related words. This was expected based on previous research that has found target words unrelated to the prime elicit larger negative amplitudes compared to targets related to the prime (Kutas & Hillyard, 1980; Koelsch et al., 2004; Lau, Phillips, & Poeppel, 2008). Overall this suggests that the related were related and the unrelated words were unrelated for both word categories as intended. The difference between related and unrelated words also suggest some semantic association between the primes and the targets did occur. However, the exact association cannot be determined by this main effect alone because related and unrelated refer to the relatedness to the word category. It does not indicate how the words were not related or unrelated to the prime.

The main effect of word condition indicated that movement words elicited larger negative amplitudes compared to enjoyment words across groove and relatedness conditions. It may be tempting to interpret this N400 difference between movement and enjoyment words to mean that enjoyment is associated to listening to all types of music, but this effect may also be driven by the amount of concrete words in each condition. Enjoyment itself is an abstract concept and so words regarding enjoyment are also more likely to be abstract. In contrast, movement is a more concrete concept because it is a physical state that can be felt and seen. Even though one of the first music-to-word priming studies found no difference between abstract and concrete words (Koelsch et al., 2004) word-to-word priming studies have found that concrete words elicit a more negative N400 compared to abstract words (Kounios, & Holcomb, 1994; West, & Holcomb, 2000). Given that movement words are inherently more concrete than enjoyment words and concreteness was not controlled for across word conditions, it is likely this main effect is not due to the an association between music and enjoyment, but increased concreteness of the movement words. Further analysis of the current words is needed to determine whether concreteness influenced the N400 and the extent of this influence on the observed results.

Contrary to our predictions amplitude of the N400 differed most between enjoyment-related and enjoyment-unrelated words primed by high groove music indicating an association between enjoyment and high groove music. No difference was found for the enjoyment related or enjoyment unrelated words primed by low groove music. Also contradictory our predictions, no difference was not observed between movement-related and movement -unrelated words regardless of the type of prime. This would suggest that listening to music that induces a desire to move elicits thoughts of enjoyment of the music not thoughts of moving or dancing to the music.

These results are surprising because groove is typically defined as a desire to move to the music (Madison, 2006; Janata et al., 2011; Hurley et al., 2014; Witek et al., 2014). Moreover, spontaneous definitions of groove typically include an aspect of moving to music not enjoyment of music (Janata et al., 2011) and high groove music increases motor cortex excitability (Stupacher et al., 2011). It is possible that our desire to move to music is moderated by enjoyment of music such that we are more willing to move to music we enjoy than music we do not enjoy. Listening to highly enjoyed music elicits activation of reward regions in the brain and increases release of dopamine similarly to other reward stimulus such as food (Salimpoor, Benovoy, Larcher, Dagher, & Zatorre, 2011; Salimpoor, van den Bosch, Kovacevic, McIntosh, Dagher, & Zatorre, 2013). It is possible this reward could also increase activation in regions of the brain the drive individuals to move toward rewarding stimulus. However, music has no specific target to move towards so the movement is expressed via spontaneous motor movements such as tapping a foot or bobbing a head with the pulse in the music, also known as the beat.

Increased motor excitability could stem from a clearer sense of the beat and the greater number of musical events typically present in high groove music (Madison et al., 2011) leading to increased beat perception. This would facilitate activity of motor and pre-motor regions that track the beat in music (Grahn & Brett 2007; Teki et al., 2011) increasing overall motor cortex excitability and spontaneous movements. Improved beat perception in high groove music could also improve predictability of the music adding to the enjoyment of the song (Witek et al., 2014; Vuust & Witek, 2014). According to predictive coding of music a part of enjoyment of music comes from the ability to predict the next events. Overly complex music is not highly because they are either not predictable at all. Overly simple music is not enjoyed either because it becomes monotonous. High groove music may be in this “Goldilocks zone” of predictability optimizing enjoyment (Witek et al., 2014). It may be that movement is imposed on definitions of groove because of the increased activity of the motor regions, but the increased motor activity is inherently connected with enjoyment of music.

The association between groove and enjoyment would be in agreement with the previous research that has demonstrated a strong correlations between enjoyment ratings and groove ratings of music (Janata et al., 2011; Witek et al., 2014; Hurley et al., 2014). It would seem that the first thought individuals have while listening to music is whether or not they enjoy it, and music that induces a strong desire to move is more likely to be enjoyed. Even though individuals seem to think of movement not enjoyment when defining groove (Janata et al., 2011), when words are not used groove is strongly associated with enjoyment. This may be rooted in our tendency to talk about emotions in terms of physical states (Lakoff, & Johnson, 1980; Slepian, & Ambady, 2014). For example positive feelings (e.g. happiness) are typically described as feeling “up” or “warm” whereas negative feelings (e.g. sadness) are described as being “down” or “cold”. It is possible that defining high groove music incorporates a similar approach used with metaphors to describe emotions. Anecdotally, this can be found with music in general, when music that elicits strong emotions is referred to as “moving”. We are connecting the enjoyment of the music to a bodily state to root the abstract concept with something more concrete. Music that induces a strong desire to move is really music that is highly enjoyed.

Limitations and Future Directions

Yet there are several caveats to be made. First, even though the N400 amplitude between the enjoyment-related and enjoyment-unrelated words primed by high groove is numerically different, but only statistically marginal. The lack of significance may be influenced by the small sample size and low amount of trials. Typically semantic priming studies use 40 to 50 per condition (Koelsch et al., 2004; Daltrozzo, & Schön, 2009a; 2009b; Zhou et al., 2014) whereas the current study used 30. Although the number of trials is constrained by requiring the ratings for the words in each condition to be orthogonal (i.e. movement unrelated words must also be enjoyment unrelated words), future research should aim for larger sample size to ensure confidence in the results.

Second, the lack of the predicted interaction between movement words, groove and relatedness may be due to a poor lexicon of words for movement. Movements are concrete actions that people generally complete without thinking about it. Conversely, because enjoyment is a more abstract concept thinking about enjoyment would require more words. The differences in lexicon specifically a larger lexicon for enjoyment compared movement could result in stronger semantic priming for enjoyment than movement when using words as targets. A possible solution for future research would be to use pictures of movement instead of words describing movement. Previous research has shown that pictures can also elicit an N400 effect (Nigam et al., 1992) and that it can be used to test if priming stimulus prime for movement specifically (Zhou et al., 2014). Using a design similar to the current study, but with pictures as targets instead of words might reveal a significant interaction for movement-related pictures as was observed for enjoyment words.

Furthermore, the primes for low and high groove music could be inherently different. The perceived enjoyment between low and high groove music was not controlled. It is possible that the high groove music also had higher ratings of enjoyment compared to the low groove music, which would then drive the semantic association between enjoyment and groove. Similarly there could be an inherent difference between the enjoyment unrelated and movement unrelated, such as concreteness, which may prevent a significant difference in N400 amplitude between movement-related and movement-unrelated words that is not present in the enjoyment words. Controlling for enjoyment of the music as well as using one unrelated word condition for comparison that is unrelated to both movement and enjoyment should be a goal of future research.

Conclusion

The current study was one of the first to look at the association between groove and enjoyment of music implicitly. We found that groove is associated with enjoyment and not a concept of movement despite defining groove as the desire to move to music. This definition may be imposed and actually reflect an embodied approach to describe highly enjoyed music with clearer sense of the beat. Further research is needed to what aspects of high groove music leads to greater enjoyment and why groove is defined by movement but necessarily semantically related to movement.

References

Chen, J. L., Penhune, V. B., & Zatorre, R. J. (2008). Moving on time: brain network for auditory-motor synchronization is modulated by rhythm complexity and musical training. *Journal of Cognitive Neuroscience*, 20(2), 226-239.

Daltrozzo, J., & Schön, D. (2009a). Conceptual processing in music as revealed by N400 effects on words and musical targets. *Journal of Cognitive Neuroscience*, *21*(10), 1882-1892.

Daltrozzo, J., & Schön, D. (2009b). Is conceptual processing in music automatic? An electrophysiological approach. *Brain research*, *1270*, 88-94.

Grahn, J., & Brett, M. (2007). Rhythm and beat perception in motor areas of the brain. *Journal of Cognitive Neuroscience*, *19*(5), 893-906.

Hurley, B. K., Martens, P. A., & Janata, P. (2014). Spontaneous sensorimotor coupling with multipart music. *Journal of Experimental Psychology: Human Perception and Performance, 40*(4), 1679.

Janata, P., Tomic, S. T., & Haberman, J. M. (2011). Sensorimotor coupling in music and the psychology of the groove. *Journal of experimental psychology*, *141*(1), 54.

Koelsch, S., Kasper, E., Sammler, D., Schulze, K., Gunter, T., & Friederici, A. D. (2004). Music, language and meaning: brain signatures of semantic processing. *Nature neuroscience*, *7*(3), 302-307.

Kounios, J., & Holcomb, P. J. (1994). Concreteness effects in semantic processing: ERP evidence supporting dual-coding theory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*(4), 804-823.

Kutas, M., Hillyard, A. S., (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science*, *207*(4427) 203-205.

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by*. University of Chicago press.

Lau, E. F., Phillips, C., & Poeppel, D. (2008). A cortical network for semantics: (de)constructing the N400. *Nature Reviews. Neuroscience, 9*(12), 920-33

Leow, L. A., Rinchon, C., & Grahn, J. (2015). Familiarity with music increases walking speed in rhythmic auditory cuing. *Annals of the New York Academy of Sciences*, *1337*(1), 53-61.

Nigam, A., Hoffman, J. E., & Simons, R. F. (1992). N400 to semantically anomalous pictures and words. *Journal of Cognitive Neuroscience, 4*(1), 15-22.

Madison, G. (2006). Experiencing groove induced by music: consistency and phenomenology. *Music Perception*. *24*(2), 201-208.

Madison, G., Gouyon, F., Ullén, F., & Hörnström, K. (2011). Modeling the tendency for music to induce movement in humans: first correlations with low-level audio descriptors across music genres. *Journal of experimental psychology: human perception and performance*, *37*(5), 1578.

Painter, J. G., & Koelsch, S. (2011). Can out-of-context musical sounds convey meaning? An ERP study on the processing of meaning in music. *Psychophysiology*, *48*(5), 645-655.

Salimpoor, V. N., Benovoy, M., Larcher K., Dagher, A., & Zatorre, R. J. (2011). Anatomically distinct dopamine release during anticipation and experience of peak emotion to music. *Nature Neuroscience*, *14*(2), 257-262.

Salimpoor, V. N., van den Bosch, I., Kovacevic, N., McIntosh, A. R., Dagher, A., & Zatorre, R. J. (2013). Interactions between the nucleus accumbens and auditory cortices predict music reward value. *Science*,*340*(6129), 216-219.

Slepian, M. L., & Ambady, N. (2014). Simulating sensorimotor metaphors: Novel metaphors influence sensory judgments. *Cognition*, *130*(3), 309-314. doi:10.1016/j.cognition.2013.11.006

Stupacher, J., Hove, M. J., Novembre, G., Schütz-Bosbach, S., & Keller, P. E. (2013). Musical groove modulates motor cortex excitability: a TMS investigation. *Brain and cognition*, *82*(2), 127-136.

Teki, S., Grube, M., & Griffiths, T. D. (2011). A unified model of time perception accounts for duration-based and beat-based timing mechanisms. *Frontiers in integrative neuroscience*, *5*.

West, W. C., & Holcomb, P. J. (2000). Imaginal, semantic, and surface-level processing of concrete and abstract words: an electrophysiological investigation. *Journal of Cognitive Neuroscience*, *12*(6), 1024-1037.

Witek, M. A., Clarke, E. F., Wallentin, M., Kringelbach, M. L., & Vuust, P. (2014). Syncopation, body-movement and pleasure in groove music. *PloS one*, *9*(4), e94446.

Vuust, P., & Witek, M. A. (2014). Rhythmic complexity and predictive coding: a novel approach to modeling rhythm and meter perception in music. *Frontiers in psychology*, *5*(1111) 1-14.

Zhou, L., Jiang, C., Delogu, F., & Yang, Y. (2014). Spatial conceptual associations between music and pictures as revealed by N400 effect. *Psychophysiology*, *51*(6), 520-528.

Appendix A

Behavioral studies of rhythm and music perception

Principal Investigator:
Dr. Jessica Grahn
Department of Psychology, The University of Western Ontario, London, ON
Telephone: (519) 661-2111: Email: jgrahn@uwo.ca

Introduction

You are being invited to participate in a research study about human perception of music and rhythm. The purpose of this study is to investigate how humans perceive rhythm and music, and how rhythm and music might change our experience of or memory for other sights and sounds.

The purpose of this letter is to provide you with information required for you to make an informed decision regarding participation in this research. It is important for you to understand why the study is being conducted and what it will involve. Please take the time to read this carefully, and feel free to ask questions if anything is unclear or if there are words or phrases you do not understand.

Research Procedures

The experiments conducted as part of this study will test how humans hear, see, remember, and move when they listen to auditory rhythms (including music) or see visual rhythms. If you agree to participate, you will be asked to listen to or watch rhythmic stimuli. You may be asked to make simple responses about whether you detect the presence of or differences between stimuli, to tap or walk in time with the stimuli, and/or to make ratings about your impressions of the stimuli. You might also be asked to perform a task testing your memory or attention while you are listening to music. Finally, your brain activity might be recorded using a technique called electroencephalography (EEG), where electrodes placed on the scalp measure electrical signals that brain cells use to communicate. It is anticipated that the entire task will take no more than 3 hours. The task(s) will be conducted in the Brain and Mind Institute in the Natural Sciences building, the Social Sciences Building, or the Robarts Research Institute on the University of Western Ontario campus. There will be a total of 750 participants.

Inclusion and Exclusion Criteria

Individuals who are at least 17 years of age having hearing and vision adequate to perform the task are eligible to participate in this study. Individuals who are younger than 17 years of age or who have hearing damage or vision problems too severe to complete the task will be excluded from the study.

Risks and Benefits

There are no known or anticipated risks or discomforts associated with participating in this study. Although you may not directly benefit from participating in this study, the information gathered may provide benefits to society as a whole which include enhancing our scientific understanding of music perception and leading to advancements in medical care (for example, music or motor therapy) for disorders like Parkinson's disease.

Compensation

You will receive course credit (1 credit per hour) or monetary compensation ($10 per hour) for your participation in this study. If you do not complete the entire study you will still be compensated a pro-rated amount.

Voluntary Participation

Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time with no effect on your future academic status.

Confidentiality

Any information obtained from this study will be kept confidential and will be accessible only to the investigators of this study. In the event of publication, any data resulting from your participation will be identified only by case number, without any reference to your name or personal information. The data will be stored on a secure computer in a locked room. Both the computer and the room will be accessible only to the investigators. After completion of the experiment, data will be archived on storage disks and stored in a locked room. Any documents identifying you by name will be kept separately from your data, and will be destroyed after 5 years.

Representatives of the University of Western Ontario Health Sciences Research Ethics Board may require access to your study-related records or may follow up with you to monitor the conduct of the study.

Contacts for Further Information

If you would like to receive a copy of the overall results of the study, or if you have any questions about the study please feel free to contact the Principal Investigator at the contact information provided above.

If you have any questions about your rights as a research participant or the conduct of the study you may contact:

The Office of Research Ethics
The University of Western Ontario
519-661-3036
E-mail: ethics@uwo.ca

This letter is yours to keep for future reference.

Consent Form

Project Title: Behavioral studies of rhythm and music perception
Study Investigator's Name: Dr. Jessica Grahn

I have read the Letter of Information, have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction.

Participant's Name (please print): ____

Participant's Signature: ____

Date: ____

Person Obtaining Informed Consent (please print): ____________________________

Signature: ____________________________

Date: ____________________________

Debriefing Form

Title of research: Behavioral studies of rhythm and music perception

Investigators:
David Prete
Undergraduate Psychology Student
Email: dprete2@uwo

Dr. Jessica Grahn (Principal Investigator)
Department of Psychology, The University of Western Ontario, London, ON
Telephone: (519) 661-2111: Email: jgrahn@uwo.ca

Perception of rhythms is fundamental to normal hearing, speech, motor control, and music. However, sensitivities to certain patterns depend both on physical characteristics of the rhythm like modality (auditory, visual; Grahn, Henry, & McAuley, 2011; Grahn, 2012) and event timing (Grahn & Brett, 2007) as well as on individual differences such as musical expertise/training and exposure (Cameron & Grahn, 2014; Grahn & Rowe, 2009), auditory short-term memory (Grahn & Schuit, 2012), and activation (as measured by fMRI) in specific brain areas thought to underlie beat perception (Grahn & McAuley, 2009). Differences timing/rhythm abilities translate to differences in the ability to perceive, synchronize with, remember, or reproduce rhythmic stimuli (Grahn & Brett, 2007; Leow et al., 2014) or potentially even to the ability to understand spoken and written language (Gordon et al., 2014; Muneaux et al., 2004). Moreover, physical and subjective characteristics of music can affect specific cognitive functions like working memory and attention (Wallace, 1994).

The purpose of this large-scale project is to understand the reciprocal interactions between music, timing and rhythm abilities, movement, perception/cognition, and brain activity. By participating in this study, you have provided data that will help us to meet this goal. Your participation and responses are much appreciated.

If you have any further questions about this study please contact <Name and contact information for co-investigator acting as contact person> or Dr. Jessica Grahn (email: jgrahn@uwo.ca, office: NSC 229, number: 519 661 2111 ext. 84804).

If you have questions about your rights as a research participant, you should contact the Director of the Office of Research Ethics at ethics@uwo.ca or 519 661 3036.

For further information on this topic, you may wish to consult the following articles:

Relation between modality (auditory vs. visual) and rhythm perception:

J.A. Grahn, M. J. Henry, J.D. McAuley. **FMRI investigations of cross-modal interactions in beat perception: Audition primes vision, but not vice versa.** (2011). NeuroImage 54:1231-43.
J.A. Grahn. **See what I hear? Beat perception in auditory and visual rhythms**. (2012). Experimental Brain Research, 220:51-61.

Relation between event timing and rhythm perception:
J.A. Grahn, M. Brett. **Rhythm and beat perception in motor areas of the brain**. (2007). Journal of Cognitive Neuroscience, 19:893-906.

Relation between musical training/expertise and rhythm perception:
D.J. Cameron, J.A. Grahn. **Enhanced timing abilities in percussionists generalize to rhythms without a musical beat**. (2014). Frontiers in Human Neuroscience, 8:1003, doi: 10.3389/fnhum.2014.01003
J.A. Grahn, J.B. Rowe. **Feeling the beat: premotor and striatal interactions in musicians and non-musicians during beat perception**. (2009). Journal of Neuroscience, 29:7540-7548.

Relation between auditory short-term memory, musical training, and rhythm perception:
J.A. Grahn, D. Schuit. **Individual differences in rhythmic abilities: behavioural and fMRI investigations**. (2012). Psychomusicology: Music, Mind, & Brain 22:105-121.

Relation between fMRI activation and rhythm perception:
J.A. Grahn, J.D. McAuley. **Neural bases of individual differences in beat perception**. (2009). NeuroImage, 47:1894-1903.

Relation between individual differences and synchronization abilities:
L.-A. Leow, T. Parrot, J. A. Grahn**. Individual differences in beat perception affect gait responses to low- and high-groove music**. (2014). Frontiers in Human Neuroscience, 8:811. doi: 10.3389/fnhum.2014.00811

Appendix B

Final Word List

Words	Word Category	Words	Word Category
sprint	MR	happiness	ER
move	MR	happy	ER
jog	MR	enjoyment	ER
accelerate	MR	fantastic	ER
jive	MR	joy	ER
jogger	MR	joyful	ER
motion	MR	excited	ER
jig	MR	love	ER
prance	MR	sunny	ER
dash	MR	good	ER
choreography	MR	joke	ER
race	MR	award	ER
tap	MR	awesome	ER
shake	MR	friendly	ER
hip-hop	MR	euphoric	ER
wiggle	MR	kiss	ER
step	MR	friendship	ER
stride	MR	humor	ER
trot	MR	smart	ER
thrust	MR	enjoy	ER
momentum	MR	loved	ER
zoom	MR	amusing	ER
twostep	MR	incredible	ER
wag	MR	laugh	ER
rhythmic	MR	enthusiastic	ER
strut	MR	generosity	ER
wave	MR	great	ER
zigzag	MR	summer	ER
promenade	MR	satisfying	ER
clap	MR	easy	ER
inactive	MUR	terrorism	EUR
statue	MUR	wreck	EUR
stationary	MUR	starvation	EUR
dormant	MUR	stress	EUR
halt	MUR	slavery	EUR
confinement	MUR	suffer	EUR
idle	MUR	slave	EUR
slumber	MUR	scum	EUR
pause	MUR	syphilis	EUR

static	MUR	sue	EUR
chair	MUR	helpless	EUR
stay	MUR	awful	EUR
stool	MUR	sewage	EUR
lay	MUR	terrorist	EUR
stalemate	MUR	anxiety	EUR
wait	MUR	sickness	EUR
sloth	MUR	shun	EUR
stop	MUR	arrogant	EUR
sit	MUR	angry	EUR
pose	MUR	snob	EUR
wall	MUR	unpleasant	EUR
stall	MUR	arrogance	EUR
tired	MUR	smog	EUR
stand	MUR	theft	EUR
adhesive	MUR	shame	EUR
stance	MUR	stench	EUR
glue	MUR	sinister	EUR
table	MUR	treachery	EUR
sleepy	MUR	trash	EUR
Slouch	MUR	unreliable	EUR
Rerorimst	Filler	shad	Filler
eivintca	Filler	timono	Filler
issppnahe	Filler	sttcafina	Filler
alguh	Filler	ssestr	Filler
unsh	Filler	msog	Filler
shncte	Filler	gwelgi	Filler
ufljyo	Filler	usnny	Filler
tsep	Filler	lgue	Filler
irdest	Filler	ovem	Filler
tcievian	Filler	haric	Filler
eeslplhs	Filler	rhtsut	Filler
iicentav	Filler	fsuefr	Filler
csmu	Filler	lsebrum	Filler
calp	Filler	tafsciatn	Filler
geroarnac	Filler	strhut	Filler
yats	Filler	eosewam	Filler
gwa	Filler	ttsuae	Filler
ivitacne	Filler	strma	Filler
fyndirel	Filler	bnreidecli	Filler
geul	Filler	asye	Filler
tloos	Filler	vdaeseih	Filler
use	Filler	gahehcpooyrr	Filler
jkoe	Filler	zaizgg	Filler
yuojlf	Filler	sobn	Filler

apeuantlns	Filler	ottr	Filler
ahtl	Filler	ues	Filler
sirmrorte	Filler	yoj	Filler
rmrtoiers	Filler	ebnierlaul	Filler
aitw	Filler	shad	Filler
ysnun	Filler	anstd	Filler

Note. List of the words and letter-strings used in the experiment for the word discrimination task described above.

Appendix C

Complete Song List

Song	Artist	Groove Category	Number of 4s clips
Lucky	Britney Spears	HG	5
Summer	Calvin Harris	HG	5
Ritmo Caliente	Eddie Palmieri	HG	5
Supersition	Stevie Wonder	HG	5
Sing Sing Sing	Benny Goodman and His Orchestra	HG	13
Lady Maradale	LaBelle	HG	6
In the Mood	Glenn Miller and His Orchestra	HG	10
Sco-Mule	Bernie Worrell, Chris Wood, Gov’t Mule, and John Scofield	HG	10
Look Ka Py Py	The Meters	HG	10
Flash Light	Parliament	HG	10
Dip it Low	Christina Milian	HG	5
Outa Space	Billy Preston	HG	10
Superman	Five For Fighting	LG	5
Farewell	Five for fighting	LG	5
Bryter Layter	Nick Drake	LG	5
Primavera	Ludovico Einaudi	LG	5
Fortuna	Kaki King	LG	13
Druid Fluid	Yo-Yo Ma, Edgar Meyer, Mark O’Connor	LG	12
Hymn for Jaco	Adrian Legg	LG	15
Beauty of the sea	The Gabe Dixon Band	LG	10
Dawn Star	Dean Magraw	LG	10
Flandyke Shore	The Albion Band	LG	10

Note. Complete list of songs used for the current experiment, the artist of the song the groove category it belongs to (HG = high groove, LG = low groove) and the number of 4 second clips created from that song.

Appendix D

Demographic Questionnaire

Gender:

Age:

Are you fluent in English? Y / N

How many years have you been speaking English? : ____

Do you speak any other languages? Y / N

If yes please list them:

____

____

To your knowledge do you have any hearing impairments? Y / N

Do you play any musical instruments? Y / N

If yes please list them: ____

How many years of musical training do you have? ____

Do you have any dance training? Y/N

If yes please list the types: ____

How many years of training did you receive? ____