EVENT-RELATED POTENTIALS REFLECT THE AFFECTIVE PRIMING CAPACITY OF MUSIC ON SPEECH

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Abstract

Music, like language, is a universal means of communication unique to humans, and the overlap of music and linguistic cognitive and neurological processes is well established. Performers and listeners alike are drawn to music as an avenue of emotional expression, as music is recognized for its rich emotional content. The study of affective priming indicates the communication of emotion-based concepts: stimuli that are related by affect give rise to response facilitation, an effect not observed to stimuli that are unrelated by affect. The measure of event-related brain potentials (ERPs) reveal, with exquisite temporal accuracy, that music clearly conveys emotion concepts in a manner commensurate to written language and prosody. To date, ERP studies of affective priming with music have involved written language and prosody, and have focused on the N400, an indication of semantic cognitive integration. The current study is the first to measure ERP responses in an affective priming paradigm of music and speech. In addition to the N400, the current study is the first of its kind to measure the N300, indicating cognitive categorization and the P300, reflecting recognition. Three sets of analyses – based on categorically correct responses, behaviourally correct responses and subjective responses – reveal N300 and N400 affective priming effects, corresponding to deliberate cognitive categorization and conceptual integration, respectively.

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List of All Abbreviations and Symbols

Abbreviation	Meaning
EEG	Electroencephalogram.
EOG	Electrooculogram.
ERP	Event-related brain potential.
ms	Milliseconds.
μV	Microvolts.
Hz	Hertz
Ag/AgCl	Silver/Silver Chloride
Fig.	Figure
N400	An ERP component characterized as a negative-going deflection occurring at approximately 400 ms post-stimulus onset.
N300	An ERP component characterized as a negative-going deflection occurring at approximately 300 ms post-stimulus onset.
P300	An ERP component characterized as a positive-going deflection occurring at approximately 300 ms post-stimulus onset.
HappyHappy	The condition of a happy music prime followed by the (related) word "happy".
SadSad	The condition of a sad music prime followed by the (related) word "sad".
HappySad	The condition of a happy music prime followed by the (unrelated) word "sad".
SadHappy	The condition of a sad music prime followed by the (unrelated) word "happy".

ACP	Anterior-centro-posterior topographical distribution.
CC	Analysis based on Categorically Correct responses.
BC	Analysis based on Behaviourally Correct responses.
SC	Analysis based on Subjectively Correct Responses.
ASA	Automatic Spreading Activation

Declaration of Academic Achievement

Jacob Morgan is primarily responsible for the background research, experiment design, participant recruitment and screening, experimenting, collation of the data, interpretation of results, preparation of figures and graphs, and writing of this report.

Tsee Leng Choy and Dr. John Connolly provided ancillary assistance throughout the preparation and reporting of this project, including significant contributions to the present work.

Ms. Choy is a senior colleague of Mr. Morgan, and assisted in the development of this project.

Dr. Connolly is the supervising researcher for this study, and assisted in the interpretation and writing of this project. Additionally, Dr. Connolly was forthcoming as an expert advisor and mentor for both Mr. Morgan and Ms. Choy throughout the whole of this project.

1. Introduction

C.P. Snow (1956, 1959) famously recognized that the "Two Cultures" of the arts and the sciences, rather than in opposition, are complementary. One area of inquiry at the concrescence of artistic expression and scientific discovery is that of music and linguistic cognitive sciences. The nature of music as a medium for human communication has been intuited by musical composers, theorists and anthropologists, performers and enthusiasts, and over the last half-century, explored by scientists (Meyer, 1956). The current study takes a neuro-cognitive approach to explore how music, like language, conveys meaningful emotion concepts (Koeslch et al, 2004; Daltrozzo and Schön, 2009; Painter and Koelsch, 2011; Patel, 2008).

1.1 Communication

Communication is a collaborative process in which an agent proposes a representation of an idea in such a way that at least one other agent can accurately interpret and understand the intended idea (Thomas, 1995). The goal of communication is concept transmission (Thomas, 1995).

Language is a common medium for communication among humans, as language is specific, compositional and communicative in nature (Slevc & Patel, 2011). In linguistic communication, a finite set of symbols are systematically manipulated and interpreted according to entrenched lexical, semantic and syntactic linguistic-cognitive rules.

Music is a means of human expression, composed of intentionally organized sound elements – such as pitch, rhythm and timbre – which combine according to structural patterns and cohere as a unified experience. A finite number of elements give rise to a theoretically infinite number of compositions. All known human cultures participate in some form of musical communication (Perlovsky, 2010). Composers and performers are able to present music in a manner that listeners interpret as meaningful, and the way in which the same piece of music is performed can drastically alter the interpretation of listeners (Juslin & Västfjäll, 2008; Juslin & Laukka, 2003). A musical experience can engage the careful listener in decoding and comprehending the conveyed intentions and meaning (Steinbeis & Koelsch, 2009).

The underpinnings of musical and linguistic communication show significant anatomical, functional and cognitive overlap (Stenibeis & Koelsch, 2008; Koelsch, 2005; Peretz, 2006; Patel, 2003; Patel et al, 1998; Schon et al, 2008; Jäncke, 2012). Processes of musical meaning transfer are similar to suprasegmental aspects of language (Goerlich et al, 2011, 2012; Lima & Castro, 2011). Musical expertise has been positively associated with sensitivity to emotion conveyed through speech prosody, suggesting that emotion processing in music an in language engage shared resources (Lima & Castro, 2011). Meaning transfer through music is therefore not a strictly directional process dealing with reference of a signifier to a signified, or a satisfaction of binary truth conditions (Speaks, 2010), but is highly expressive and connotative (Slevc & Patel, 2011). Processes of musical meaning retrieval include aspects of storage, activation, representation, access and integration of a given musical and semantic association within a given context (Koelsch, 2011a). Communication through music, therefore, equally involves the qualities inherent to the music itself as well as the context-dependent interpretation of the listener (Goerlich et al, 2012).

1.2 Priming: Semantic

Communication can be clearly measured in the effect of cognitive priming. Priming is a cognitive effect of fitting a target into an expected context. A stimulus (the prime) will facilitate the response to a subsequently presented stimulus that is related (the target). Semantic priming studies investigate the semantic relation among stimuli (Anderson & Holcomb, 1995; Connolly and Phillips, 1994). For example, the word *nurse* will prime for the word *doctor*, as both are related as belonging to the overarching concept of *medicine*; however, neither *nurse* nor *doctor* will prime the word *bread*, as this target is not semantically related. Priming can take place between simple (Anderson and Holcomb, 1995) or complex (Connolly and Phillips, 1994) semantic items, and across modalities (Logeswaran, 2009).

1.3 Priming: Affective

Priming that occurs on the basis of emotion is called affective priming (Schirmer et al., 2005). In affective priming, a stimulus conveying a specific affect - such as a picture of a frowning human face expressing *sadness* or the word "death" - will facilitate the processing of a subsequently presented target stimulus, such as the related word "sad", and impeded unrelated targets, such as the word "happy" (Goerlich et al, 2012). In the current study, the communication of emotion concepts is investigated by an affective priming paradigm, in which primes of music excerpts and spoken word targets are used. Music is used to establish the context of an emotion concept, within which a target word is to be integrated.

There are several neurocognitive explanations of priming that are relevant to the current study. The affective primacy hypothesis proposes that humans are innately endowed with an evaluative mechanism affording the immediate evaluation of a stimulus for affective information (Zajonc, 1980, 1984). Thus, affective priming is thought to be an early and automatized process (Goerlich et al, 2012). The explanation of affective priming following from the affective primacy hypothesis proposes that, with the presentation of the prime, an associative network of is activated allowing for subsequently presented targets fitting within the same network to be processed with a greater ease than targets of a disparate network. The influence of the prime is exerted on the target at the level of conceptual interpretation, in an effect called automatic spreading activation (ASA) (Goerlich et al, 2012). Another explanation attributes the cause of affective priming to response competition (Goerlich et al, 2012). Thus, the affective prime automatically triggers a response affinity to subsequent stimuli of a similar affect, an effect not observed to affectively unrelated stimuli (Goerlich et al, 2012). The theories of ASA and Response Competition are far from mutually exclusive in their explanation of priming effects. However, the consideration of both theories does underscore that an experimental paradigm must be carefully designed such that the stimuli and experimental task engage particular affective and semantic processes (Goerlich, 2012). There is evidence that affective priming critically depends on participants' attention to the category membership of the primes (Gawronski et al, 2010). Again, while pre-experimental design is critical, the priming effect ultimately depends on the subjective associations between prime and target as inferred by the individual experiment participant. The consideration of subjective interpretation is of fundamental importance in priming studies involving music.

1.4 Event-Related Brain Potentials

Recent advances in technology have afforded an electrophysiological measure of priming. An electroencephalogram (EEG) can be used to read brain potentials in response to time-locked prime and target stimuli. The result is a profile of experimental event-related brain potentials (ERP): a representation of brain activity corresponding to an experimentally provoked cognitive process. ERP components are typically considered relative to a standard or control condition, such as a congruent as compared to incongruent prime-target stimulus pair (cite Luck). ERPs capture the unfolding of cognitive events in real time, with exquisite temporal resolution. As such, ERPs are an excellent measure of conceptual integration and comprehension.

ERPs are interpreted as distinct components of a continuous waveform that correspond to cognitive and neurological activity, identified on the basis of characteristic morphological patterns, peak polarity and latency. Three ERP components are of relevance to this study: the P300, N300 and N400.

The P300 is a positive component associated with familiarity and recognition composed of two elements: the centroparietal P3b and the frontocentral P3a (Polich, 2009). Larger responses are found to recognizable or task-relevant items (P3b) and also associated with response inhibition and stimulus novelty (P3a) (Polich, 2009). There is a paucity of data regarding the P3a and P3b in studies of music. For this reason, the generic label of P300 will refer to these components, until a distinction becomes relevant. Within the context of this study, the P300 component is thought to reflect the recognition of related target stimuli.

The N300 is elicited in studies involving object categorization, where prime and target are mismatched (Franklin et al, 2007). It manifests as a broadly distributed negative component midline that occurs at approximately 300 milliseconds (ms). The N300 was observed in studies of semantic categorization (Franklin et al, 2007). It has also been seen, though not commented upon, in studies of affective categorization (Goerlich et al, 2011). While apparent in many studies (Goerlich et al, 2011; Daltrozzo et al, 2010; Painter and Koelsch, 2011), the N300 is often conflated with the related but distinct N400 response, and as a result has not yet received thorough examination (Franklin et al, 2007; O'Hare et al, 2008). In the current study, the N300 corresponds to the categorical mismatch of a target stimulus and a musically conveyed emotion context.

The N400 is a negative-going component with a parietal and right lateralized topographical distribution that occurs between 350-500 milliseconds (ms) following the presentation of any meaningful stimulus, and specifically reflects a disruption in the integration of a stimulus within a given conceptual context (Kutas & Federmeier, 2011; Connolly & Phillips, 1994; Koelsch et al, 2004; Daltrozzo & Schon, 2009). Reduced negative-going N400 responses are observed to target stimuli that fit within a given conceptual context, as compared to the greater negative-responses that follow targets incongruent with the conceptual context. The N400 is largely thought to reflect ASA processes (Goerlich et al, 2012; Kutas and Federmeier, 2011). Recent studies indicate that the N400 may reflect three distinct cognitive mechanisms: lexical access, lexical selection, and conceptual integration (Daltrozzo et al, 2010). In the current study, the N400 indicates a disrupted process of conceptual integration that results from the mismatch of a target stimulus and a given musical emotion context.

The distinction made between the N300 and the N400 is morphological and cognitive. The two component peaks show a latency separation of approximately 100 ms (during which a P300 may be observed). Each component is thought to correspond to different aspects of interrelated cognitive processes. The N400 reflects a wide variety of semantic mismatches, such as at the levels of categorical superordinate (prime: dog, target: bird) and subordinate (prime: dog, target: sparrow) (Hamm et al, 2002), where the prime is a complete concept in itself or requires supplementary information provided by the target (Franklin et al, 2007), and when the terminal word of a sentence does not meet cloze probability (Connolly and Phillips, 1994). The N400 has been established as the principal component of interest in studies of semantic priming

(Kutas and Federmeier, 2011). The N300 appears to reflect more particular aspects of conceptual integration, responding to between-category violations (Hamm et al, 2002) and violations in which the prime and target are symmetrically related (e.g., prime: stork, target: baby). The strong suggestion, therefore, is that the N300 reflects the comparative categorization of stimuli while the N400 reflects more elaborate conceptual integration processes.

1.5 Music Communicates: Semantics

Meaning can be communicated through music based on intra-musical and extra-musical associations (Koelsch, 2011a, b, c). Intra-musical associations emerge from the reference made strictly within the music, from one musical element to another, and inferred based on regular patterns of combination (Koelsch, 2011a, b, c). On the basis of intra-musical reference, "music means itself: one musical event (be it a tone, a phrase or a whole section) has meaning because it points to and makes us expect another musical event" (Meyer, p. 35, 1956). Such intra-musical associations are those involved in interval analysis, rhythmic and chord progressions, phrasal structure, and processes of tension and resolution (Patel, 1998; Steinbeis & Koelsch, 2008; Koelsch, 2005, 2011a,b; cite).

Extra-musical associations refer beyond the music to engage semantic and episodic memories. There are three avenues for extra-musical association. These include *iconic or onomatopoeic reference*, where a music pattern or form resembles the quality of a certain object, the object itself, or an abstraction of some object (Koelsch, 2011a,c). For example, it might be said that a music phrase sounds like the chirping of birds, or that one excerpt sounds wider than another, or more round, warm, fluid, and so on. Musical reference can also be based on *symbolic* and social convention to associate certain patterns and forms with a time, place or people, such as the effect of a national anthem (Koelsch, 2011a,c; Cross, 2008). Lastly, the dynamics of musical elements, such as the progressions of intervals and nuances in performance technique, can indicate the existence of a very specific emotion or intention, called *indexical* musical reference (Juslin & Laukka, 2003; Koelsch, 2011a,c). The research presented here investigates indexical musical reference, such that an excerpt of music indicates a specific emotion concept.

1.6 Music and Semantics: ERP

ERP measures reveal that music, like language, is semantically interpreted. Koelsch and colleagues (2004) found that target written words that accurately described a preceding musical context elicited less of an N400 response than did words that did not suit the music. In a similar paradigm using music excerpts only one second long, Daltrozzo & Schon (2009) found a similar N400 response to both music excerpts priming written words and, the converse, written words priming music. Similarly, using piano chords, Steinbeis and Koelsch (2006, 2008) found an effect in the N400 on both chords following words, and words as targets following chords. Painter and Koelsch (2011) argued for the equality of musical and vowel sounds, and found N400 priming effects in the comparison of out of context sounds manipulated for timbre and words that did or did not accurately describe the sound. Participants were asked to indicate if prime-target pairs of sound-word, word-sound, word-word and sound-sound either “fit” or “did not fit” together. An N400 effect was found to targets that were unrelated to the priming context, indicating that on average, participants were able to make the “fit” or “not fit” distinction. When, in a follow-up experiment of the same design, participants were not instructed to actively integrate prime-target meaning, the N400 effect disappeared. The authors concluded that listeners could conceptually interpret the timbre of a sound for extra-musical semantic associations. Furthermore, the study underscores the crucial role that specific task instruction has on a response.

1.7 Music Communicates: Emotion

The current study investigates music as an avenue for emotional expression. It is in large part the emotional quality of music that draws listeners, which has prompted some to consider music a form of pre-verbal or ineffable emotional communication (Hauge and Tonsberg, 2003; Stansell, 2001; cf. Bodner et al., 2007; Garielsson & Juslin, 2003). There is behavioural (Poulin-Charronnat, et al, 2006; Lima & Castro, 2011; March, 2010) and electrophysiological evidence (Daltrozzo & Schon, 2009; Koelsch et al, 2004; Steinbeis & Koelsch, 2008, 2010) that music can convey linguistically specified emotion concepts.

Music is a universal and ancient medium for human emotional expression (Perlovsky, 2010). The expression and perception of emotion through music is regulated by culture-bound musical traditions, such as interval consonance/dissonance and phrasal structure. However, the perception of certain emotion concepts in music is vastly cross-cultural. Western listeners and people of the isolated Mafa tribe in Cameroon agree on the perception of music as happy, sad or fearful/unpleasant, (Fritz et al, 2009). Western listeners correctly interpreted joy, sadness and anger as conveyed by Indian ragas (Balkwill & Thompson, 1999) while Japanese listeners were able to identify the same emotions as expressed according to the Western and Hindustani musical conventions (Balkwill et al, 2004). There is some regularity with which these universal emotions are perceived in music across cultures. The different influences of qualities inherent to music, the innate capacities of listeners and the culture-bound conventions of emotion interpretation through music are issues beyond the scope of the current study. It is the consistency with which emotion expressed in music sufficiently establishes that music does communicate emotion concepts among humans.

Emotion perception in music is robust. Peretz and colleagues (1998) presented a case study of patient IR who, as the result of neurological trauma, was rendered insensitive to the tonal contrasts of music. IR was nonetheless able to discriminate excerpts of music on the basis of emotional quality, and agreed with healthy individuals on the perceived emotional content of music pieces even when the excerpts were as brief as one second (Peretz et al, 1998). That the ability to accurately interpret a piece of music for its emotional content endures neurological trauma indicates that music conveys emotion reliably and strongly.

There are a number of technical terms that require unpacking. *Affect* is an umbrella term, encompassing all evaluative processes. *Valence* is the affective content of a stimulus, measured as a generally positive or negative affective charge. *Emotions* are intense affective responses to an object that exerts some affective influence on the experiencer. *Mood* is a less intense affective experience, without a clear object of influence. The subjective experience itself is *feeling*. It is important that these definitions do not conflate the ideas of *emotion induction* and *emotion perception* (Steinbeis & Koelsch, 2009; Juslin & Vastfall, 2008). *Emotion Induction* is any instance where a stimulus induces the feeling of an emotion; *emotion perception* is any instance where a stimulus is recognized as conveying an affect. While emotion induction and emotion perception generally converge, so that a stimulus will cause the feeling and recognition of the same emotion, one is not a necessary or sufficient condition for the other. Emotion perception is a primarily cognitive process whereas emotion induction is primarily non-cognitive; therefore, exercises in the perception of emotion in music – such as the categorization of music based on perceived affective content – may well proceed without any feeling (Juslin & Vastfall, 2008).

Emotion perception is distinct from the *cognitive appraisal* of one's emotional state in relation to the external world. Rather, *emotion perception* is an impersonal – but highly subjective – process of categorization. In the present study, affect is conveyed through music and language, prompting in the listener an emotion perception, the neurocognitive and behavioural responses to which are of focus.

1.8 Music and Emotion: ERP

ERP measures have successfully found affective priming involving music and other auditory and visual stimuli (Daltrozzo and Schon, 2009; Steinbeis and Koelsch, 2008, 2011; Painter and Koelsch, 2011; Goerlich et al, 2011, 2012; Bostanov and Kotchoubey, 2004; Logeswaran and Bhattacharya, 2009; Sollberger et al, 2003). Thus far, affective priming has been measured by the N400. Sollberger et al (2003) used an affective priming paradigm to successfully find the semantic processing of emotional stimuli. Daltrozzo and Schon (2009) found a similar effect using written words and excerpts of music, both when the music excerpts were the primes and the words were targets, and vice versa. Steinbeis and Koelsch (2011) investigated how three structural qualities of music convey emotion, using primes of digitally synthesized chords manipulated for consonance, mode and timbre followed by targets of written words that denoted an emotion concept, and found a larger N400 response to unrelated prime-target pairs. Therefore, affectively based comparisons have yielded N400 priming effects between music excerpts and visually presented target words (Daltrozzo and Schon, 2009; Steinbeis and Koelsch, 2011) and speech prosody (Goerlich et al, 2011, 2012). Taken together, these findings suggest that music can establish a affectively based emotion context comparable to written language.

1.9 Summary

The study presented here is the first to use ERPs to examine music-based affective priming in the auditory modality in healthy individuals, using recordings of orchestral music. Our objective was to examine music as a means of accessing and measuring emotion, as musical meaning is most often communicated through emotion. The focus of this study is on the perception of emotions expressed in music, measured directly from the brain. Primes consisted of happy or sad musical orchestral excerpts, paired with happy or sad spoken target words; organized into 4 conditions by emotional valence (happy, sad) and congruence (congruent, incongruent). We hypothesized a larger N300 and N400 to emotionally incongruent trials and a larger P300 to emotionally congruent trials (by virtue of the recognition of the emotional similarity between the prime and target).

2. Methods and Materials

2.1 Participants

Eighteen (8 males, 10 females) healthy McMaster University undergraduate students participated in this study (age range 19-23 years, M = 20 years old). All were native speakers of English and dextral (lateralization quotient > 90 according to the Edinburgh Handedness Inventory) with normal hearing and normal or corrected-to-normal vision. None were currently involved in musical pursuits or had professional or post-secondary musical training. Participants either received course credit or were paid $20CAD per hour for their participation (see Appendix A for example of screening forms). This study was approved by the appropriate research ethics board and all participants provided written consent.

2.2 Stimuli

Primes consisted of 160 happy and sad classical musical excerpts (~1000 ms each) and targets were recorded words "happy" and "sad" (200ms each) by a native Canadian male speaker. The spoken words were neutral in prosody and stable in volume. The musical excerpts were taken from recordings of performed classical music (see Appendix B for catalogue of music stimuli). Most of the musical excerpts have been validated and used in previous work (Peretz et al, 1998; Koelsch et al, 2004). Emotional ratings for the musical excerpts were established by the testing of a focus group (N = 10, Accuracy rate 87%). Responses were indicated on a 4-point Likert scale (1: very sad, 2: sad, 3: happy, 4: very happy) so that sad excerpts had lower scores than happy excerpts. These scores were converted so that the 1-4 scaling reported throughout reflects the degree to which the musical excerpt conveys the intended emotion rather than the actual emotion; that is the scale was converted to reflect the extent of emotion clarity for the excerpt rather than its emotional valence. From the original sample of 172 excerpts, 12 did not meet criteria and were discarded (4 happy, 8 sad), leaving 160 (80 happy, 80 sad). Of these, happy musical excerpts received a 91% agreement and a mean rating of 3.3; sad musical excerpts received an 82% agreement and a mean rating of 3.3 (see Appendix C for affective ratings of all stimuli). However, it is important to note that sad excerpts were rated with approximately a 10% greater consistency than were happy excerpts (see Discussion). All stimuli were taken from monaural recordings, edited using Audacity software (Version 1.3.12) (Boston, USA: Free Software Foundation, Inc.), and presented binaurally at 65 dB SPL (sound pressure level) through insert earphones using Presentation software (Version 14.9) (Albany, CA: Neurobehavioural Systems, Inc).

2.3 Paradigm

The auditory affective priming paradigm was similar to prior work (Daltrozzo and Schon, 2009, Experiment 1; Koeslch et al., 2004; Goerlich et al., 2011). Stimuli were presented to each participant as a series of prime-target pairs according to two manipulations: (1) Emotional content of the musical prime (happy or sad); and, (2) Congruence of the word target with prime (related or unrelated). There were four conditions of prime-target pairings: (1) Happy music, Happy word (happy prime, related target; *HappyHappy*); (2) Sad music – Sad word (sad prime, related target;*SadSad*); (3) Happy music – Sad word (happy prime, unrelated target; *HappySad*); and (4) Sad music – Happy word (sad prime, unrelated target; *SadHappy*). The same excerpt of music served as the prime in both an unrelated and a related pair, but never in succession. The prime and target were separated by an inter-stimulus interval (ISI) of 800 ms. Following the target word, there was a pause of 1000 ms before a visual prompt appeared asking participants to indicate if the prime and target were related or unrelated in their affect, as a right and left mouse click, respectively. The inter-trial interval was 700 ms (Figure 1).

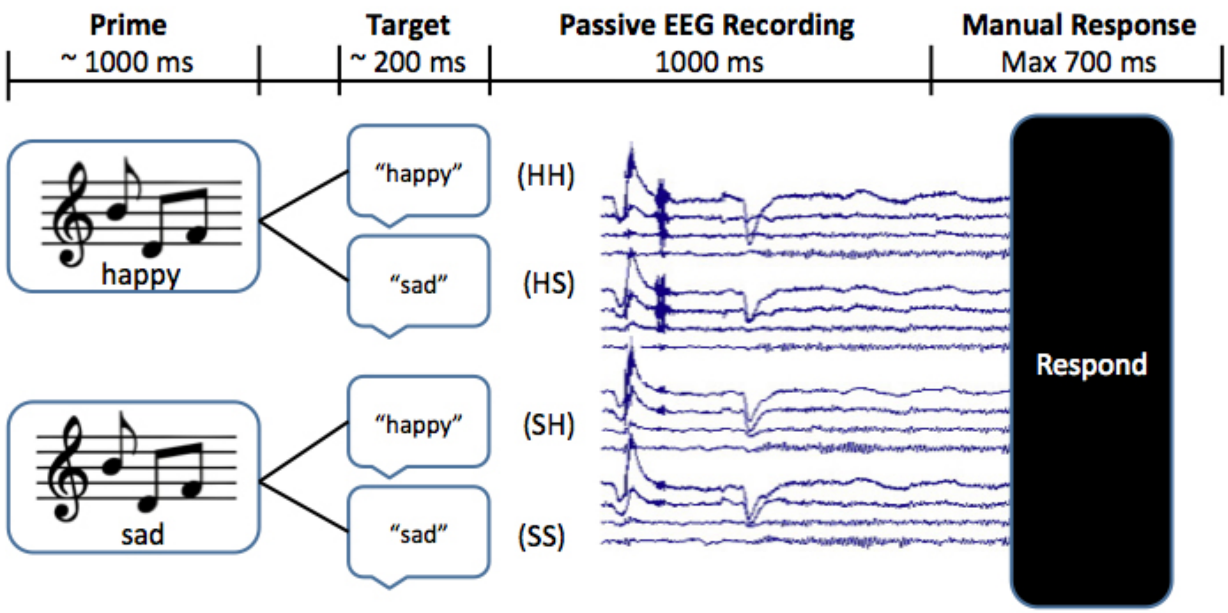

Figure 1. A schematic of the procedure of one experimental trial for each of the four conditions. A music prime, sounding either *happy* or *sad* is presented, followed 800 ms later by a related or unrelated target word, either "happy" or "sad". Following the presentation of the target, the EEG is allowed to record for 1000 ms before participants are prompted to manually indicate their interpretation of the prime-target relation. After 700 ms, the process is repeated.

2.4 Procedure

Participants were seated approximately 1 meter away from the computer screen with the computer mouse comfortably within reach. Participants were instructed to listen to each musical excerpt prime for its emotional content, and decide if the target word accurately matched the emotion they perceived. They were instructed to withhold their response until seeing a visual prompt on the computer screen whereupon they were to manually indicate their decision using the mouse with a right or left click reflecting a prime-target match or mismatch, respectively.

Participants received four short breaks during the experiment. Following the experiment, participants were debriefed.

2.5 EEG Acquisition

EEG was recorded with 64 Ag/AgCl electrodes, located according to the International 10-20 System using the ActiView Active-Two amplifier system (Version 7.00) (Amsterdam, Netherlands: BioSemi). Additional electrodes were placed at the nose tip, and right and left mastoids to be used in offline analyses. The electrooculogram (EOG) was acquired from electrodes located over from the outer canthi and above the left eye for detecting horizontal and vertical (including blinks) eye movements. EEG and EOG were recorded with a sampling rate of 512Hz and a band-pass of 0.1-100Hz.

2.6 EEG Analyses

Data were filtered with a 0.1-30Hz band-pass and referenced offline to the mastoids using Brain Vision Analyzer software (Version 2) (Germany: Brain Products GmbH). EOG artifacts were removed using the algorithm developed by Gratton and Coles (1983). Data were epoched from a baseline of 200ms pre-stimulus to 1000 post-stimulus onset and assigned to one of the four experimental conditions. Each trial segment was manually inspected and trials containing EEG deviations ($\pm$ 100µV) were excluded from analyses (up to 10% of trials in a condition for a single participant). Peak detection of components was based on visual inspection. Three ERP components were examined in this study. The N300 was defined as the most negative peak in a 250-375 ms time window; the P300 was identified as the most positive peak in the 300-450 ms time window; and, the N400 was defined as the most negative peak in the 375-600 ms latency period. Peak amplitude was defined as the mean integrated voltage (in μV) for the 50 ms period around each identified peak within the assigned time window as just described.

2.7 Condition Comparisons

This study had four conditions: happy and sad music primes followed by related and unrelated spoken word targets (abbreviated for *PrimeTarget*: *HappyHappy, HappySad, SadSad, SadHappy*). Conditions are compared by holding either the prime or the target constant resulting in four comparisons: (1) *happy* music primes followed by related or unrelated word targets (*HappyHappy, HappySad*; Fig 3, 4, 5 A); (2) *sad* music primes followed by related or unrelated word targets (*SadSad, SadHappy*; Fig 3, 4, 5 C); (3) *happy* target words preceded by related or unrelated music primes (*HappyHappy, SadHappy*; Fig 3, 4 5 B); and (4) *sad* target words preceded by related or unrelated music primes (*SadSad, HappySad*; Fig 3, 4, 5 D).

Three separate analyses were conducted based on which trials were included in the final ERP data set. The first analysis included all trials in each condition regardless of a participant's response accuracy, grouping trials based on the properties of the stimuli independent of participant response, and was thus an analysis by stimuli. This analysis is referred to as "categorically correct" (CC). The second analysis grouped trials according to response correctness, and included only trials in which the participant responded correctly. This analysis is referred to as "behaviourally corrected" (BC) and is considered the typical ERP analysis procedure. The third analysis grouped trials according to participant response (see Painter and Koelsch, 2011), and thus is referred to as "subjectively correct" (SC).

It is known that ERP components associated with an objectively correct stimulus condition do not occur when a participant fails to identify the stimulus condition as correct. It is hypothesized that the amplitudes of all relevant ERP components in this study will be larger in this analysis compared to the amplitudes found in the first analysis (the CC analysis) because the latter analysis will include trials where the relevant components have not occurred due to the inclusion of trials incorrectly identified by the participants. The inclusion of trials with absent components in averaged data will result in smaller component amplitudes for this analysis compared with the inclusion of only correctly identified trials in the BC analysis. It is hypothesized that the ERP components in this analysis will be larger than those observed in the CC analysis and comparable to those seen in the BC analysis.

2.8 Statistical Analyses

Following peak detection, the electrode sites were grouped into 9 regions based on sites overlying the left and right hemispheres plus midline (given the factor name of Lateralization/Midline) and sites overlying anterior, central, and posterior sites (given the factor name ACP) (Figure 3). A repeated measures analysis of variance (ANOVA) was conducted with the factors Lateralization/Midline (3 levels), APC (3 levels) and Condition (4 levels). Conservative degrees of freedom were employed when appropriate and corrections were applied according to the methods of either Greenhouse and Geisser (1959) or Huynh and Feldt (1976), based on the severity of the sphericity violation. *Post-hoc* tests were conducted when necessary and Bonferroni corrections applied when appropriate.

3. Results

The ERP waveforms appear to converge in their early component morphology for all conditions. Following a negative peak at approximately 200 ms, the ERPs to related and unrelated target words diverge at approximately 275 ms, with responses to unrelated targets being more negative going and peaking at approximately 300 ms, interpreted as the N300. Meanwhile, at approximately 350ms, responses to related targets show a more positive-going peak, interpreted as the P300. After returning to convergence (or proximate) with ERPs to related targets, responses to unrelated targets show a second negative-going response from 400-600 ms, interpreted as the N400. A summary of all effects is schematized in Table 1.

3.1 Behavioural Results

Correct responses were responses that agreed with the "categorically correct" prime-target relationship (congruent/incongruent). The mean agreement across all prime-target combinations was 87% (SD = 3.2). Agreement in trials of happy primes followed by congruent targets was 91% (SD = 2.1) and when followed by incongruent targets was 85% (SD = 3.6); agreement in trials of sad primes followed by congruent targets was 87% (SD = 2.9) and when followed by incongruent targets was 86% (SD = 3.5). Reaction times were not considered as the paradigm did not involve either speed or accuracy instructions. Instead, participants only responded when a visual prompt was presented 1000 ms after the target, a duration sufficient to nullify the behavioural measure of priming (Anderson and Holcomb, 1995). A one-way within-subjects ANOVA revealed that stimulus pairings did not have a significant effect on participant agreement responses ($F(3) = 2.009$, $p = 0.1$), indicating that experimental conditions did not differentially influence participant agreement.

3.2 ERP results

Table 1 depicts results for all three ERP components in each of the three analysis procedures (as outlined in Section 2.7). Examination of the waveforms reveals clear N1P2 responses to the onset of the target words as well as the fact that this onset response complex was not affected by condition (Fig. 2, 4, 5 A-D). All waveforms are characterized by a N300, P300, and N400 sequence – components that were differentially affected by condition (Fig. 2, 4, 5 A-D). Component distributions (Fig. 2, 4, 5 E-H) also showed some sensitivity to experimental condition. The N300 was characterized by a generally left lateralized, fronto-central distribution but this was found to vary by condition. The P300 tended to exhibit the classic centroparietal distribution while the N400 exhibited conditionally dependent distributions. Component amplitudes can be seen to vary across conditions with generally larger N300 and N400 amplitudes observed to unrelated target words while P300 amplitudes tended toward larger amplitudes to related target words. Finally, the clear separation of the two negative components is not only demonstrated by an intervening positivity (the P300) but by the clear separation of component latency observed for every participant in this experiment (Fig. 2) and the notable distribution differences seen for N300 and N400 both within and between each conditional pairing (Fig. 3, 4, 5).

Comparison and Analysis

	Happy Primes, Related vs Unrelated Targets			Sad Primes, Related vs Unrelated Targets			Happy Targets, Related vs Unrelated Primes			Sad Targets, Related vs Unrelated Primes		
ERP	**CC**	**BC**	**SC**	**CC**	**BC**	**SC**	**CC**	**BC**	**SC**	**CC**	**BC**	**SC**
N300				+	+	+	+	+	+	+	+	+
P300					+					+		
N400	+		+	+	+			+		+	+	+

Table 1. A summary of the significant effects (indicated by the symbol "+"; $p < 0.01$) for each of the three components (rows from top to bottom: N300, N400 and P300) in each of the four comparisons (columns from left to right: *HappyHappy, HappySad; SadSad, SadHappy; Happy Happy, Sad Happy; SadSad, HappySad*) according to the three statistical analysis procedures (subcolumns from left to right: Categorically Correct (CC), Behaviourally Correct (BC) and Subjectively Correct (SC)).

3.2.1 *Categorically correct* (**CC**) *analyses*

The CC analysis was conducted based on the stimuli, independent of participant response. Such information is important when participants incapable of executing traditional motor or verbal responses are tested (see Discussion).

3.2.1.1. N300

There was a main effect of Condition ($F(3, 51) = 4.148$, $p < 0.05$, $\varepsilon = 0.779$, $h_p^2 = 0.196$) that subsequent pair-wise comparisons revealed was due to: 1) Larger N300 responses to unrelated compared to related targets following sad primes (*SadSad, SadHappy*) ($t(17) = 3.366$, $p < 0.005$) (Fig. 3C); 2) Larger N300 responses to unrelated targets following happy primes compared to related targets following sad primes (*SadSad, HappySad*) ($t(17) = 3.178$, $p <$ 0.005)(Fig. 3D); and 3) Larger N300 responses to unrelated targets following sad primes compared to related targets following happy primes (*HappyHappy, SadHappy*) ($t(17) = 2.388$, p

= 0.01) (Fig. 3B). However, this Condition effect must be interpreted within the context of the fact that Condition interacted with ACP (F(5, 102) = 3.383, $p < 0.005$, ε = 0.693, $h_p^2 = 0.184$), Lateralization/Midline (F(6, 102) = 3.33, $p < 0.05$, ε = 0.591, $h_p^2 = 0.164$), and then both ACP and Lateralization/Midline (F(12, 204) = 2.478, $p < 0.05$, ε = 0.482, $h_p^2 = 0.127$). The interaction with ACP was attributable to larger N300 responses to related targets following sad primes than those following happy primes in the parietal region, and responses to unrelated targets following sad primes being generally more negative across the frontal and central regions than those following happy primes. The significant Lateralization/Midline interaction was due to the left lateralized N300 distribution in response to unrelated targets following happy and sad primes, and larger midline responses to unrelated targets following sad primes. Finally, the significant three-way Condition x ACP x Lateralization/Midline interaction reflected the N300's more left-lateralized distribution to unrelated targets primed by sad rather than happy musical excerpts; responses to unrelated happy primes showed particularly strong responses along the midline with minimal lateralization. This range of distributions across conditions is represented in Figure 3E-H.

3.2.1.2. P300

The Lateralization/Midline main effect (F(2, 34) = 19.705, $p < 0.001$, ε = 0.984, h_p^2 = 0.537) was attributable to the P300's predominantly midline distribution; an effect complemented by the Lateralization/Midline x ACP interaction (F(4, 68) = 5.357, $p < 0.01$, ε = 0.538, $h_p^2 = 0.24$) reflecting its midline distribution and slight right lateralization (Fig. 3 E-H).

3.2.1.3. N400

The N400 showed a main effect of Condition ($F(3, 51) = 10.236$, $p < 0.001$, $\varepsilon = 0.893$, $h_p^2 = 0.375$), that pair-wise comparisons revealed was due to: 1) Larger N400 responses to unrelated as compared to related targets following happy primes (*HappyHappy, HappySad*) ($t(17) = 3.661$, $p = 0.001$) (Fig. 3A); 2) Larger N400 responses to unrelated compared to related targets following sad primes (*SadSad, SadHappy*) ($t(17) = 2.683$, $p < 0.01$)(Fig. 3C); and 3) Larger N400 to unrelated targets following happy primes compared to related targets following sad primes (*SadSad, HappySad*) ($t(17) = 4.934$, $p < 0.001$)(Fig. 3D). This main effect is, however, best interpreted by also considering the ACP x Condition ($F(6, 102) = 2.978$, $p < 0.05$, $\varepsilon = 0.659$, $h_p^2 = 0.149$) was attributable to the larger N400 responses to unrelated targets primed by happy compared to sad music at the frontal and central regions (compare Fig. 3 E, H to Fig. 3 F, G). Finally, the N400 generally exhibited the classic right lateralized distribution as reflected by the Lateralization/Midline main effect ($F(2, 34) = 12.150$, $p < 0.05$, $\varepsilon = 0.922$, $h_p^2 = 0.239$)(Fig. 3 E-H).

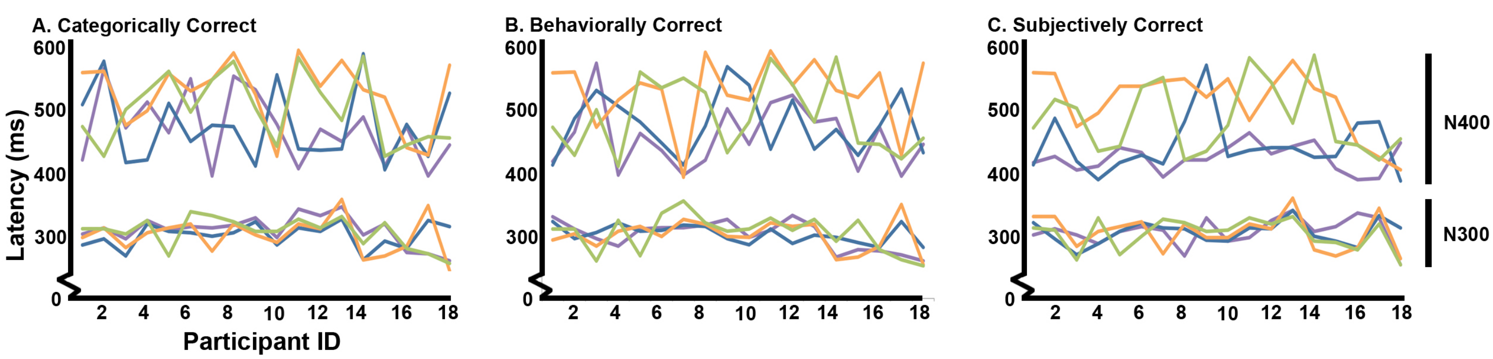

Figure 2. Peak latencies of the N300 and N400 (at Cz) in each of the 4 conditions. **A-C** represent each of the three analysis procedures (left to right: Categorically Correct, Behaviourally Correct and Subjectively Correct). Line colors representing word targets following HAPPY Music Primes are as follows: **Purple** lines depict Related word targets (*HappyHappy)* and **Orange** lines depict Unrelated word targets (*HappySad*). Line colors representing word targets following SAD Music Primes are as follows: **Blue** lines depict Related word targets (SadSad) and **Green** lines depict Unrelated word targets (*SadHappy*). Note that the N300 and N400 peaks occur in separate latency ranges, evidence that the N300 and N400 are distinct components.

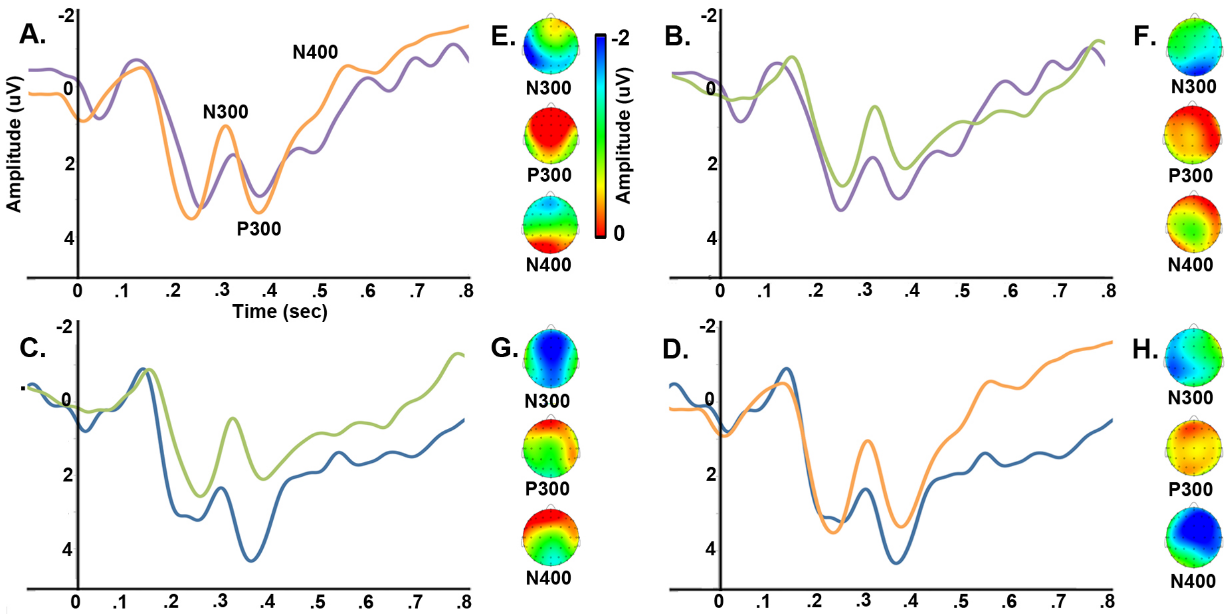

Figure 3. **A-D.** Grand average ERP waveforms (recorded at Cz) following the **Categorically Correct** analysis procedure. Waveforms for word targets following HAPPY Music Primes are as follows: **Purple** lines depict Related word targets (*HappyHappy*) and **Orange** lines depict Unrelated word targets (*HappySad*). Waveforms for word targets following SAD Music Primes are as follows: **Blue** lines depict Related word targets (*SadSad*) and **Green** lines depict Unrelated word targets (*SadHappy*). Condition comparisons are (A) *HappyHappy,* HappySad, (B) *HappyHappy, SadHappy,* (C) *SadSad, SadHappy,* and (D) *SadSad, HappySad.* **E-H.** The topographical maps show voltage differences between condition comparisons for the N300 (latency window: 250-375 ms), P300 (latency window: 300-450 ms), and N400 (latency window: 375-600 ms), of (E) *HappyHappy,* HappySad, (F) *HappyHappy, SadHappy,* (G) *SadSad, SadHappy,* and (H) *SadSad, HappySad.* Adjoining ERP and topographical plots correspond the adjoining waveform pair (**E** represents the difference values obtained from the waveforms shown in **A**, **F** represents **B**, **G** represents **C**, and **H** represents **D**).

3.2.2 *Behaviourally corrected* (**BC**) *analyses*

This analysis excluded all trials in which the participant provided a manual response that contradicted the experimental design, i.e. incorrect responses, and included only those trials in which the participant agreed with the experimental design, i.e. correct responses.

3.2.2.1. N300

There was a main effect of Condition ($F(3, 51) = 8.245$, $p < 0.001$, $\varepsilon = 0.736$, $h_p^2 = 0.327$), that subsequent pair-wise comparisons indicated was due to: 1) Larger N300 responses to unrelated compared to related target words following sad primes (*SadSad, SadHappy*) ($t(17) = 5.009$, $p < 0.001$)(Fig. 4C); 2) Larger N300 responses to unrelated target words following happy primes compared to related target words following sad primes (*SadSad, HappySad*) ($t(17) = 5.369$, $p < 0.001$)(Fig. 4D); and 3) Larger N300 responses to unrelated target words following sad primes compared to related targets following happy primes (*HappyHappy, SadHappy*) ($t(17) = 2.866$, $p < 0.01$)(Fig. 4B). Condition was found to interact with Lateralization/Midline ($F(6, 102) = 3.814$, $p = 0.005$, $\varepsilon = 0.579$, $h_p^2 = 0.183$) – an effect attributable to the contrast between the more left-lateralized responses to unrelated targets that followed happy primes and the more midline dominant and symmetrical responses to unrelated targets when primed by sad musical excerpts (compare Fig. 4 E, H with Fig. 4 F, G). Finally, N300 was characterized generally by a centroparietal distribution (ACP main effect: ($F(2, 34) = 4.785$, $p < 0.05$, $\varepsilon = 0.762$, $h_p^2 = 0.22$)(Fig. 4 E-H).

3.2.2.2. P300

There was a Condition main effect ($F(3, 51) = 3.297$, $p < 0.05$, $\varepsilon = 0.796$, $h_p^2 = 0.162$), that pair-wise comparisons revealed was due to a larger P300 to related as compared to unrelated targets following sad primes (*SadSad, SadHappy*) ($t(17) = 2.158$, $p = 0.01$)(Fig. 4D). The Condition x Lateralization/Midline interaction ($F(6, 102) = 2.305$, $p < 0.05$, $\varepsilon = 0.902$, $h_p^2 = 0.119$) was attributable to larger responses to unrelated targets following happy primes at the midline compared to the lateral sites (Fig. 4E). Finally, the main effect of Lateralization/Midline

($F(2, 34) = 20.26$, $p < 0.001$, $\varepsilon = 0.981$, $h_p^2 = 0.544$) must be interpreted in light of the fact that this factor interacted significantly with ACP ($F(2, 34) = 5.41$, $p < 0.01$, $\varepsilon = 0.542$, $h_p^2 = 0.241$), reflecting the midline maximal and right-lateralized distribution of the P300 (Fig. 4 E-H).

3.2.2.3. N400

The Condition main effect ($F(3, 51) = 5.432$, $p = 0.005$, $\varepsilon = 0.828$, $h_p^2 = 0.242$) was revealed by pair-wise comparisons to be due to: 1) A larger N400 response to unrelated compared to related targets following sad primes (*SadSad, SadHappy*) ($t(17) = 5.009$, $p < 0.005$)(Fig. 4C); 2) Larger N400 responses to unrelated targets following happy primes compared to related targets following sad primes (*SadSad, HappySad*) ($t(17) = 5.369$, $p = 0.001$)(Fig. 4D); 3) Larger N400 responses to unrelated targets following sad primes compared to related targets following happy primes was observed (*HappyHappy, SadHappy*) ($t(17) = 2.866$, $p < 0.01$)(Fig. 4B, note that the figure represents one site and does not reflect the statistical analysis involving all sites). This Condition effect should be interpreted within the context of the Condition x ACP interaction ($F(6, 102) = 2.937$, $p < 0.05$, $\varepsilon = 0.646$, $h_p^2 = 0.147$), which reflected the larger frontally distributed N400 observed to unrelated targets following happy primes that contrasted with the more parietally distributed N400 responses to unrelated targets following sad primes (compare Fig. 4 E, H with Fig. 4 F, G). The N400 exhibited the typical right lateralization (Lateralization/Midline: ($F(2, 34) = 3.747$, $p < 0.05$, $\varepsilon = 0.914$, $h_p^2 = 0.181$)) and a strong central distribution (Lateralization/Midline x ACP: ($F(4, 68) = 4.201$, p < 0.05, $\varepsilon = 0.528$, $h_p^2 = 0.198$))(Fig 4 E-H).

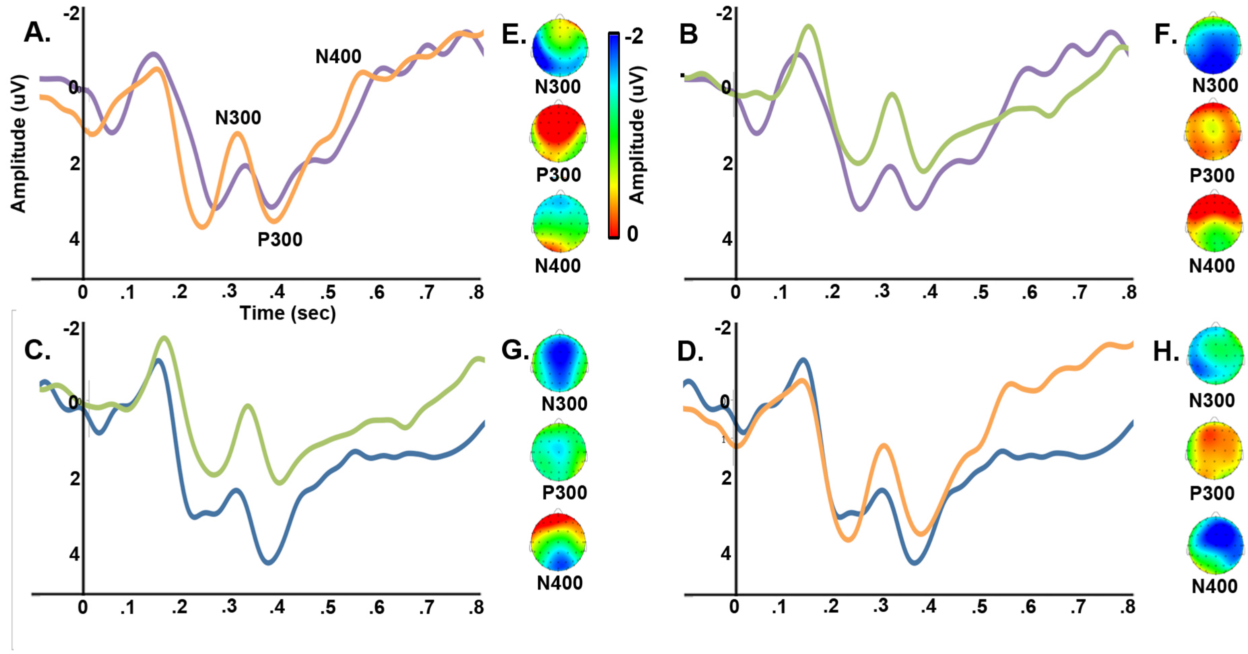

Figure 4. **A-D**. Grand average ERP waveforms (recorded at Cz) following the **Behaviourally Correct** analysis procedure. Condition comparisons are (A) *HappyHappy,* HappySad, (B) *HappyHappy, SadHappy,* (C) *SadSad, SadHappy,* and (D) *SadSad, HappySad.* **E-H.** The topographical maps show voltage differences between the condition comparisons of (E) *HappyHappy,* HappySad, (F) *HappyHappy, SadHappy,* (G) *SadSad, SadHappy,* and (H) *SadSad, HappySad.*

3.2.3. *Subjectively correct* **(SC)** *analyses*

The SC analysis was conducted in order to represent the responses of each individual participant's on a trial by trial basis.

3.2.3.1. N300

There was a main effect of Condition ($F(3, 51) = 13.083$, $p < 0.001$, $\varepsilon = 0.851$, $h_p^2 = 0.435$) that pair-wise comparisons revealed to be due to: 1) Larger N300 responses to unrelated compared to related targets following sad primes (*SadSad, SadHappy*) ($t(17) = 4.851$, $p > 0.001$)(Fig. 5C); 2) Larger N300 responses to unrelated targets following happy primes compared to related targets following sad primes (*SadSad, HappySad*) ($t(17) = 6.031$, $p >$

0.001)(Fig. 5D); and, 3) A larger N300 response to unrelated targets following sad primes compared to related targets following happy primes (*HappyHappy, SadHappy*) ($t(17) = 2.759$, $p < 0.01$). Although the N300 generally exhibited a parietal distribution (ACP ($F(2, 34) = 4.575$, $p < 0.05$, $\varepsilon = 0.708$, $h_p^2 = 0.212$)), this effect proved to be modulated by Condition (Condition x ACP: ($F(6, 102) = 2.728$, $p < 0.05$, $\varepsilon = 0.775$, $h_p^2 = 0.138$)) so that responses to related targets showed a frontal distribution while those to unrelated targets exhibited a parietal distribution – an effect most notable to unrelated responses following happy primes. Finally, the Condition x Lateralization/Midline interaction ($F(6, 102) = 3.76$, $p < 0.005$, $\varepsilon = 0.652$, $h_p^2 = 0.181$) reflected the left lateralization of the N300 to targets (related and unrelated) following happy primes, whereas unrelated targets following sad primes exhibited little or no lateralization (Fig. 5 A, C).

3.2.3.2. P300

The main effect of Condition ($F(3, 51) = 2.878$, $p < 0.05$, $\varepsilon = 0.818$, $h_p^2 = 0.145$) was revealed by pair-wise comparisons to reflect a larger P300 response to related compared to unrelated targets following sad primes (*SadSad, SadHappy*) ($t(17) = 2.378$, $p = 0.01$)(Fig. 5C). The main effect of Lateralization/Midline ($F(2, 34) = 18.133$, $p < 0.001$, $\varepsilon = 0.985$, $h_p^2 = 0.516$) is best understood by its interaction (Lateralization/Midline x ACP interaction ($F(4, 68) = 6.433$, $p < 0.005$, $\varepsilon = 0.563$, $h_p^2 = 0.275$) which indicated a slight centroparietal distribution with a slight left lateralization (Fig. 5 E-H).

3.2.3.3. N400

There was a main effect of Condition ($F(3, 51) = 9.089$, $p < 0.001$, $\varepsilon = 0.8$, $h_p^2 = 0.348$) that pair-wise comparisons indicated was due to: 1) Larger N400 responses to unrelated compared to related targets following happy primes (*HappyHappy, HappySad*) ($t(17) = 3.369$, $p < 0.005$)(Fig. 5A); and 2) Larger N400 responses to unrelated targets following happy primes compared to related targets following sad primes (*SadSad, HappySad*) ($t(17) = 3.725$, $p = 0.001$)(Fig. 5D). A significant Condition x ACP interaction ($F(6, 102) = 4.797$, $p < 0.005$, $\varepsilon = 0.592$, $h_p^2 = 0.22$) indicated that the larger N400s were observed to unrelated targets, especially those following happy primes in the frontal regions (Fig. E, H). The N400 in response to targets that were unrelated to their primes exhibited the classic right lateralization (Condition x Lateralization/Midline: ($F(6, 102) = 3.347$, $p < 0.05$, $\varepsilon = 0.645$, $h_p^2 = 0.165$). This lateralized distribution was further clarified by the ACP x Lateralization/Midline interaction ($F(4, 68) = 3.363$, $p < 0.05$, $\varepsilon = 0.592$, $h_p^2 = 0.165$) reflecting the right lateralization and frontocentral distribution of the N400.

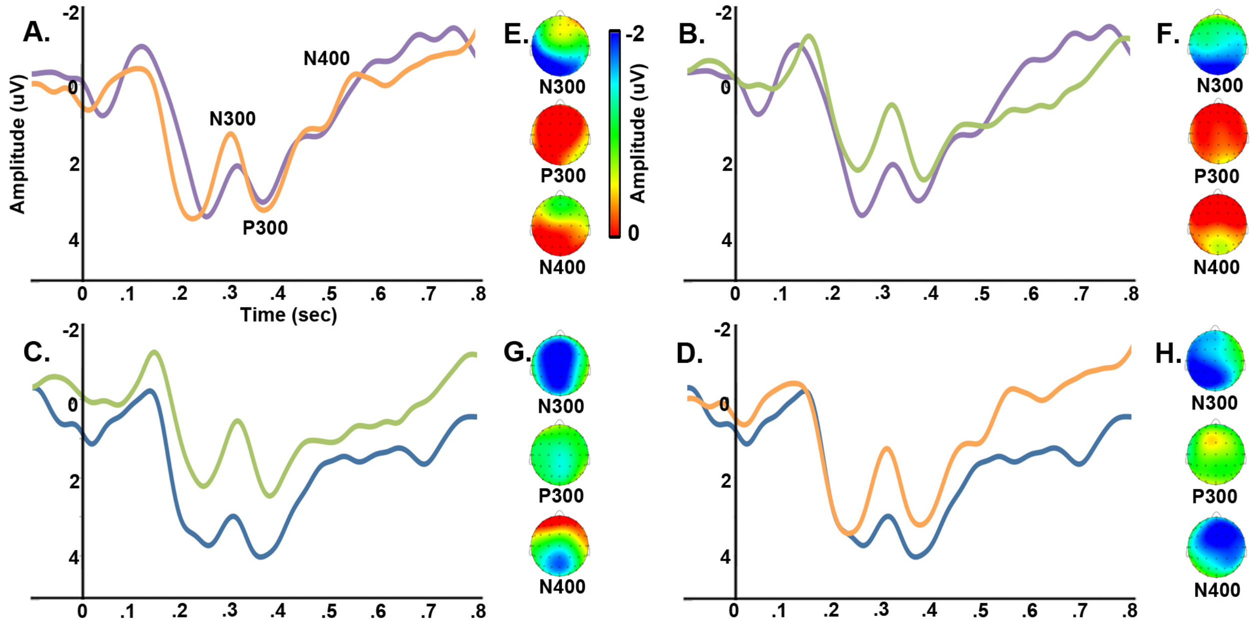

Figure 5. **A-D.** Grand average ERP waveforms (recorded at Cz) following the **Subjectively Correct** analysis procedure. Condition comparisons are (A) *HappyHappy,* HappySad, (B) *HappyHappy, SadHappy,* (C) *SadSad, SadHappy,* and (D) *SadSad, HappySad.* **E-H.** The topographical maps show voltage differences between the condition comparisons of (E) *HappyHappy,* HappySad, (F) *HappyHappy, SadHappy,* (G) *SadSad, SadHappy,* and (H) *SadSad, HappySad.*

4. Discussion

4.1 Introduction

The current study presents new insight into the communication of emotion concepts by music and language. Music that sounded both *happy* and *sad* was used to prime the target words "*happy*" and "*sad*". It was hypothesized that, if the emotion concepts were successfully communicated between music and language, affective priming would occur to pairs of music primes and target words that were related by emotion concept, such as *happy* sounding music followed by the word "*happy*", while no priming effect would be observed to music prime and target word pairs that were unrelated by emotion concept, such as *happy* sounding music followed by the word "*sad*". Affective priming was measured by larger N300 and N400 responses to word targets that were unrelated to the music prime, reflecting a disruption of conceptual categorization and integration processes, respectively (Kutas and Federmeier, 2011; Koelsch et al, 2004; Datrozzo and Schön, 2009; Franklin et al, 2007; Hamm et al, 2002). It was also thought that a larger P300 component would be observed in response to targets that were related to preceding primes, though this aspect of the hypothesis was not directly supported in the literature.

Our hypotheses were supported as evidenced by a priming effect in all condition comparisons, observed as greater N300 and N400 responses following unrelated targets. The N300 was elicited in condition comparisons that involved *sad* music as primes (*sad* music, related and unrelated word targets) while the N400 was elicited in the condition comparisons involving *happy* music primes (*happy* music, related and unrelated word targets). Our findings indicate that the emotion perceived in an excerpt of music can be interpreted to communicate emotion concepts in a manner that is comparable to spoken language comprehension. The remainder of this Discussion will note the novel contributions of this study and its relation to past research to the field of music, emotion and semantics. Next, the findings for the N300 and N400 will be interpreted including their relationship to each other. Results from the three analyses – CC, BC and SC – will be compared and their distinct contributions to data interpretation considered. Finally, conclusions from this study will be drawn, and avenues for future research will be proposed.

4.2 Novelties of the Current Study

The current study has several distinct and innovative features. It is the first to address the affective priming capacity of music on spoken words and to use ERP responses to assess this effect. Music and semantic research to date has been primarily cross modal, involving both the auditory and visual domains (Steinbeis & Koelsh, 2008; Koelsch et al, 2004; Daltrozzo & Schön, 2009). The current study was held exclusively in the auditory domain. Studies that have investigated the affective priming of music and language within the auditory domain have not employed ERP measures (March, 2010), nor have they focused on semantics: They have instead addressed acoustic properties, such as prosody and timbre (Painter & Koelsch, 2011; Goerlich, 2011). The current study addresses the interpretation of both music and spoken words for their conceptual emotion content, and as such is an important piece of the larger investigation of emotional meaning in music.

The four condition comparisons in this study are unique, addressing effects inherent to both the primes and the targets. Two sets of comparisons were conducted: first, in order to compare the effect of the relatedness of the target word, conditions of related and unrelated targets were manipulated relative to a constant prime, as is standard practice (Anderson and Holcomb, 1995; Connolly and Phillips, 1994; Koelsch et al, 2004; Steinbeis and Koelsch, 2006, 2008, 2010; Daltrozzo et al, 2010). Second, to consider the effect of the music prime, conditions of related and unrelated primes were compared with the target held constant. Taken together, the four comparisons yield a thorough examination of the different contexts created by the primes and their effects on identical targets as well as the responses to different targets within identical contexts.

The present study is the first music-language affective priming work to measure the N300 as well as the N400. The N300 has been shown to correspond to categorical or superordinate concept processing while the N400 is a reliable indicator of complex conceptual integration processes (Hamm et al, 2002; Franklin et al, 2007; Kutas and Federmeier, 2011). Recent evidence suggests that the conceptual interpretation of music unfolds over time along a continuum of basic to elaborate analyses (Daltrozzo et al, 2010; Hamm et al, 2002). Therefore, attention to both the N300 and N400 in the same study affords a thorough investigation of the cognitive processes involved in the meaningful interpretation of emotion in music.

Finally, to most accurately assess participant performance, three analyses of the data were performed. The first analysis was based on this experiment's categorization of the music primes as sounding *happy* or *sad*, and is therefore called "Categorically Correct" (CC). The CC analysis assumed that the participant made a response that agreed with the experimentally defined categories of *happy* and *sad* meaning that no trials were excluded because the behavioural response was not categorically correct. This approach is not "standard practice" in ERP research currently because it allows for trials containing a false positive or false negative response to contaminate the data, skewing the results (see for example, Connolly et al., 1999). The inclusion of a CC analysis in the current study is motivated by our intent to apply certain ERP paradigms in the study of non-communicating patients who are often incapable of making reliable behavioural responses (e.g., Gawryluk et al., 2010). A CC analysis of the current data, corroborated by more discriminating analyses (described below), provides an indication of what the ERP data might look like in those individuals incapable of making externally observable responses.

The second analysis was the more traditional approach that considered the individual participant's response accuracy and only included for analysis those trials in which a correct response of related or unrelated was provided. This approach was referred to as the "Behaviourally Correct" analysis (BC). The BC analysis excludes the categorically incorrect responses and therefore provides a more accurate measure of participant intention and the corresponding ERP components (Painter and Koelsch, 2011).

The third analysis was motivated by the highly interpretive nature of emotion in music. Numerous subjective factors including evaluative conditioning, emotional contagion, visual imagery, episodic memory and musical expectancy – often assumed to be consistent across participants who share a common musical culture – influence the interpretation of music and its emotional impact (Juslin and Västfjäll, 2009; Koelsch, 2011a,b,c). In order to accommodate these individual differences in subjective responses to music, the third, "Subjective Response" analysis (SC) considered only the individual participant's subjective interpretation of the emotional content of each music prime. The SC procedure allowed the participant's behavioural response to determine what constituted a "correct" trial. That is, the behavioural response determined the emotion category (i.e., *happy* or *sad*) of each music excerpt and thus the relatedness of each prime-target pair, thus addressing the crux of ERP measures: access to subjective cognitive processes, regardless of the objective external environment. It could be argued that the findings of the SC analysis most accurately reflect the participants' intended responses, and as such, are those that will be of particular focus below.

4.3 The N300

The N300 has been seen in priming studies to between-category, but not within category, unrelatedness (Hamm et al, 2002) and targets that are straightforwardly unrelated, but not ambiguously unrelated, to their prime (Franklin et al, 2007). So far, the N300 has only drawn attention in linguistically based research (Painter and Koelsch, 2011; Franklin et al, 2008) but it is apparent in affective priming studies involving music and meaning (although not commented upon, the response is seen in Goerlich et al, 2011). The findings presented here, aligning with previous research, show the N300 was elicited by targets that are unrelated to their context by a categorical violation (Hamm et al, 2002; Franklin et al, 2007; Kutas and Federmeier, 2011). However, the categorical violation of unrelated targets reflected by the N300 was only detected in the condition of *sad* music primes (Table 1), a dissociation that suggests a difference in the how either emotion concept was inferred from the music primes.

There were several important methodological differences between the current study and previous investigations of the N300. First, the N300 has been elicited only by stimuli presented in the visual domain (Franklin et al, 2007; Hamm et al, 2002). Second, the nature of target stimuli used to elicit the N300 has varied: Franklin et al (2007) used written word primes and targets, while Hamm et al (2002) used written word primes and line drawing targets (Hamm et al, 2002). Here, the N300 was elicited using spoken words unrelated to the emotion context of a preceding musical prime, entirely in the auditory domain. Nonetheless, the N300 observed in response to auditory stimuli here is virtually identical to the response in the context of visual stimuli. The common ground among the studies described is the task requirement of semantic categorization, of words in the context of words (Franklin et al, 2007), pictures in the context of words (Hamm et al, 2002) and, presently, speech in the context of music. The similarity of the response across stimuli domains strengthens the conclusion that, despite its early latency, the N300 is a reflection of post-sensory cognitive processes.

The exact cognitive correlate of the N300 is unspecified by a lack of formal study, but some insight can be gleaned by considering the experimental tasks used to elicit the response. The task requirement of Franklin et al. (2007) was lexical decision, while Hamm et al. (2002) provided no explicit task requirement and measured passive responses, suggesting that the N300 reflects the engagement of implicit cognitive processes. The current study involved a relatively elaborate task: participants were required to interpret a musical context for its emotion content, then compare that emotion concept to a spoken target, either "*happy*" or "*sad*", and make a relatedness judgment. The consistency of the N300 response across tasks of varying complexity suggests that the mental categorization of stimuli – whether lexical, semantic or conceptual – is a basic process that is common to the meaningful interpretation of stimuli.

All studies of the N300 have been in a linguistic context, using written or spoken language as either a prime or a target. Therefore, it cannot be ruled out that the N300 corresponds to some component of linguistic access. A study of the N300 using non-linguistic stimuli, such as the line drawings from (Hamm et al., 2002) or the music of the current study, as the prime and target is the next step in a logical progression.

4.4 The N400

The N400 responses found here are compatible with prior research, indicating that we have replicated the affective priming of music on language entirely in the auditory domain. The N400 is elicited by disruptions in the cognitive integration of given stimuli, such as when the final word of a sentence has a low cloze probability (Connolly and Phillips, 1994), and in priming studies using to unrelated pairs of words, pictures, odors (Kutas and Federmeier, 2011) and music (Koelsch et al, 2004; Daltrozzo and Schön, 2009). In a replication of Koelsch et al (2004), Daltrozzo and Schön (2009) found larger N400 responses to target nouns and adjectives that did not describe a given music context. In the current study, the larger N400 reflects the participants' cognizance that the target word did not accurately describe the emotion concept communicated by the music prime. Therefore, the music excerpts used in this study were interpreted to communicate a specific emotion concept. However, the N400 was elicited only in the condition of *happy* primes followed by unrelated targets (*happy* primes, related and unrelated targets; *sad* primes followed by related targets and *happy* primes followed by unrelated targets), suggesting a difference in how *happy* and *sad* music excerpts were interpreted, an important detail that will be discussed below.

The N400 response of the current study is similar to a related component, the FN400. Like the FN400, the response observed here shows a fronto-centrally distribution, whereas the classic N400 is distributed over the parietal regions (Curran et al, 2006; Koelsch et al, 2004; Daltrozzo and Schön, 2009; Franklin et al, 2007; Kutas and Federmeier, 2011). The topographical distribution of the N400 varies according to the modality in which the stimuli are presented: parietal N400 responses are elicited when targets are presented visually, while a frontally distributed N400 responds to aurally presented targets (Kutas and Federmeier, 2011, Connolly & Phillips, 1994). Given that the current study is the first of its kind held exclusively in the auditory domain, it is reasonable to attribute the more frontal N400 response distribution, at least in part, to the use of auditory target words.

A frontally distributed N400 has been recently elicited in a priming paradigm based on affective categorization, when visual word targets were unrelated to the context of music and speech prosody (Goerlich et al, 2012). The anterior N400 was not observed in the distractor task, which was designed to prevent affective categorization. Therefore, it was concluded that the frontal N400 reflects an aspect of affectively based categorization of music and speech prosody. Furthermore, the frontal N4000-like component was interpreted to arise from mechanisms of Response Conflict, as opposed to ASA (Goerlich, 2012). The task-dependent modulation of the N400 indicated that the priming effect was not strictly automatic, but was contingent on participants' cognitive control at the level of deliberate response. While the current study did not specifically delineate the automaticity of priming, it can be concluded that the N400 reflects deliberate affective-based categorization of music excerpts and spoken words.

The frontal N400 may reflect the ambiguity of the *happy* music primes. A frontally distributed N400 response has been associated with processes of *familiarity* – the qualitative feeling of vague recognition of a stimulus as having been previously presented – which is distinct from processes of clear *recollection* as reflected by the parietal N400 (Curran et al, 2006). *Familiarity* and *recollection* are also umbrella terms used to cover, respectively, the processing of shallow as compared to deep, or nonlexical as compared to lexical stimuli (Rugg et al, 1998; Curran, 1999). Here, the frontal N400 was most clearly observed in the unrelated condition following *happy* primes (*happy* primes, related and unrelated targets; *sad* primes followed by related targets and *happy* primes followed by unrelated targets). It is possible that the N400 response here reflects the ambiguity of the *happy* music primes in the current paradigm elicited a *familiarity* response and, conversely, the clarity of the *sad* music primes was sufficient for responses similar to *recollection*. However, the paradigm was not designed to provoke old-new judgments and separate processes of *familiarity* and *recollection* or their corresponding ERP component responses.

4.5 N300 and N400 In Three Analyses

Results for the N300 across the CC, BC and SC analyses for all condition comparisons were identical, indicating that the component shows a robust effect (Table 1, Fig. 3, 4, 5). In measuring the N400, the conventional BC analysis agreed with the SC analysis in only one condition comparison, and with the CC analysis in only two condition comparisons. The anomalous results yielded by the BC analysis do not accurately depict the data, as shown by SC. The experiment paradigm was designed to be expeditious, and used an economic number of trials sufficient for priming effects to be observed: in some cases, as many as 10% of trials were excluded for in their inaccuracy. Therefore, the inconsistency of the BC analysis may likely be due to the exclusion of categorically incorrect trials, reducing statistical power and, in turn, producing false negative or false positive results. Note that the inclusion of categorically incorrect trials in the CC analysis does not necessarily invalidate the result.

The consistency of the N400 across the CC and SC analyses indicates that, despite the inclusion of trials containing categorically incorrect responses, the priming effects are robust. There is evidence, therefore, to support the use of the CC analysis, but not the BC analysis. The BC analysis involves the risk that discarding trials due to their categorical incorrectness will impoverish and skew the data. However, the CC and SC analyses were out of step in the condition of *sad* primes followed by related and unrelated targets: the CC analysis showed an N400 that was not found by the SC analysis. The contradictory N400 result between CC and SC analyses is attributable to a difference in the processing of *happy* and *sad* music excerpts, discussed below. It is therefore both more theoretically and practically sound to perform a CC analysis, corroborated by an SC analysis. The overall agreement of the CC and SC analyses establishes CC as a reliable analysis procedure that may be trusted even when no manual response is provided, such as in the clinical assessment of non-communicative patients.

4.6 Dissociation of the N300 and N400 According to Affective Content of Music Prime

In this study, the N300 is associated with the processing of *sad* music excerpts whereas the N400 is observed in the processing of *happy* music excerpts (Table 1). The dissociation of the N300 and N400 becomes interesting in light of our pre-experimental stimulus ranking survey, which indicated that the music excerpts used in the current study were interpreted with some variability: ratings of *happy* music excerpts were showed 10% more variance in ratings than those of *sad* music. The rating of *sad* music as more distinctive diverges from previous findings, which finds *happy* music to be more distinctive (Vieillard et al, 2008). Nonetheless, in the context of the current study, *sad* music excerpts were interpreted with greater clarity than *happy* music excerpts (see Appendix C). Therefore, the dissociation of the N300 and N400 is interpreted to correspond with the differentially ambiguous and clear categorization of *happy* and *sad* music excerpts, respectively.

There is no evidence to establish a link between either the N400 or N300 and a specific emotion. Therefore, the more parsimonious interpretation of the association of the N300 and N400 with *happy* and *sad* emotion concepts, respectively, is not as a response of emotion specificity, but instead as a reflection of processes rooted in the semantic interpretation of music.

It has been suggested that the semantic interpretation of music follows on a continuum of basic to elaborate processes (Koelsch, 2011a; Daltrozzo et al, 2010). One comprehensive model proposes that a music stimulus has been processed within the first 10 ms of sensation for basic qualities, including periodicity, location and timbre, followed by cognitive processes of feature extraction (10-100 ms), Gestalt grouping formation, echoic memory and interval analysis (100-200 ms), concurrent with structure building and analysis (200-600 ms) (Koelsch, 2011a). Electrophysiological readings that occur early in the course of processing correspond to basic processes, such as brainstem responses and the sensory ERP components (N1, P1, MMN), while later readings reflect more elaborate cognitive processes (Koelsch, 2011a). The model allows for the extraction and integration of semantic and emotional information at virtually any time from 250 ms onward throughout the processing continuum, and relates semantics and emotion information as highly interactive (Koelsch, 2011a).

It logically follows that music distinctly conveying features of a meaningful emotion - such as a certain timbre, interval, articulation rate (Steinbeis and Koelsch, 2010; Juslin and Västfjäll, 2008; Poon and Schutz, 2011) – would be processed as meaningful more quickly than would music that conveys an emotion concept ambiguously. It has been established that, in this study, the distinct perception of *sad* music excerpts and the ambiguous interpretation of *happy* music excerpts corresponds to the N300 and the N400, respectively. It is therefore proposed here both the N300 and the N400 represent different points on the continuum of the interpretation and categorization of music and spoken words. The N300 reflects early categorization of *sad* music excerpts, based on information clearly derived early in the processing stream - such as feature extraction, Gestalt grouping and interval analysis - while the N400 reflects the more deliberate analysis required for the interpretation of the ambiguous *happy* music excerpts, such as structural analysis and extra-musical integration (Koelsch, 2011). The association with an anterior N400-like component in an affective categorization task involving music and speech prosody with deliberate response, rather than relatively automatized conceptual processes (ASA), corroborates our interpretation of the current findings (Goerlich et al, 2012)[1]. Furthermore, our interpretation that the N300 is associated with clear affective categorization of *sad* music stimuli and the frontally distributed N400 reflects additional semantic processing required to interpret the ambiguous *happy* music stimuli is supported by the findings of previous semantic priming research (Hamm et al, 2002; Franklin et al, 2007; Curran et al, 2006).

4.7 Conclusion

In this study, the N400 and N300 are taken as reflecting different stages of the same cognitive process involved the interpretation of a spoken word target in the context of a music prime. Of course, the converse paradigm with spoken words as primes to music excerpts has yet to be employed, and is the topic of future research. The N300 corresponds to an early categorical decision, following the more distinctive *sad* music primes, while the N400 indicates more

[1] This current experiment measured manual responses for accuracy (rather than reaction time). Accuracy measures reflect the interpretation of a target relative to a prime following one-second of deliberation during EEG recording. Accuracy is therefore contingent on the distinctiveness with which an emotion is initially recognized in a given music primes. Accuracy was, on average, strong. However, the ambiguity of *happy* music primes does not square with the response accuracy ratings. The accuracy was highest for *happy* primes followed by related targets 91% (*SD* = 2.1), and closely followed by all other conditions, which were roughly equal. It seems that, though rated as least distinctive, *happy* music excerpts were conducive to the greatest response accuracy. However, it is possible that ambiguous and distinct music excerpts would be recognized with equal accuracy, even considering the role of Response Conflict. With deliberation (afforded by the 1000 ms of EEG recording time intervening between target presentation and response prompt), an ambiguous music excerpt can lead to a correct response, without affecting the ERP profile. This is especially likely following a target that serves to affirm the initially ambivalent interpretation (Nickerson, 1998). In this way, following deliberation and suggestion, response accuracy might not be affected by ambiguous music primes.

elaborate processes following ambiguous *happy* music primes (Hamm et al, 2002; Franklin et al, 2007; Daltrozzo et al, 2010). In the context of this experiment, *sad* music excerpts were more readily recognized for their emotion content than were *happy* music excerpts. Therefore, these findings suggest that the N300 is elicited when the relationship between the prime and target is clearly identified as unrelated while the N400 is elicited when discerning the relation requires more elaborate processing. The effect of music ambiguity in affective priming studies, and how this might influence both the N300 and N400, is an interesting detail of the current study that has not yet been fully investigated. When considering response to such highly interpretive stimuli as music, we feel that the results of CC and BC analysis procedures should be corroborated by an SC analysis. The appraisal of emotion in human is, so far as we know, a uniquely and universally human attribute, with deeply seeded personal and social importance (Perlovsky, 2010; Trainor, 2010). The presented findings support the application of music in a clinical setting, particularly for the assessment of emotion cognition in non-communicative patients.

Appendix A: Screening and Consent Forms

This information is strictly confidential and will not be shared.

Appendix A1: Personal Information

First name: ________________________________ Surname: ____________________________

Age: ___________ Years of Education: ____________

First language: ____________________________ Handedness: _______________

Appendix A2: Screening Form

Is your hearing normal? Yes No

Have you ever had any neurological or psychological problems? Yes No

If yes, please describe:

____

____

____

Have you ever had a head injury? Yes No

If yes, please describe:

____

____

____

Have you ever lost consciousness? Yes No

If yes, please describe (including duration): ____

____

____

Are you presently taking any medication? Yes No

If yes, please describe:

____

____

____

Have you recently taken any medication? Yes No

If yes, please describe:

____

____

____

Do you consume any of (please specify frequency of use):

Alcohol: ___________________________________

Cigarettes: ________________________________

Drugs: _____________________________________

Appendix A2: Screening Form (cont'd)

Have you consumed any alcohol or drugs in the last 24 hours? Yes No

If yes, please specify:

____

Have you consumed drugs in the last 7 days? Yes No

If yes, please specify:

____

Please rate your current state of alertness:

- 1 2 3 4 5 +

How many hours did you sleep last night?

____

Please rate your current mood:

-	1	2	3	4	5	+

Do you have any musical training? Yes No

Do you consider yourself a musician? Yes No

If yes, please describe:

____

Appendix A3: Edinburgh Handedness Inventory

Please indicate you preference in the use of hands in the following activities by putting + in the appropriate column. When the preference is so strong that you would never try to use the other hand unless absolutely forced to, put ++. If in any case you are really indifferent, put + in both columns.

Some of the activities require both hands. In these cases, the part of the task of object for which hand preference is wanted is indicated in brackets.

Please try to answer all the questions, and only leave a blank if you have no experience at all with the task.

Task	Left Hand	Right Hand
1. Writing		
2. Drawing		
3. Throwing		
4. Scissors		
5. Toothbrush		
6. Knife (without fork)		
7. Spoon		
8. Broom (upper hand)		
9. Striking match		
10. Opening box lid		

Score = (Total Left ___ + Total Right ___) x 100 = _______

Appendix A5: Debrief

Debrief Sheet for Study: ______________________________

Participant Code: ______________________________

Date: ______________________________

Personnel: ______________________________

Questions

1. How did you find the experiment? Difficulties? Discomforts?

2. Did you focus on the emotion (happy or sad) of the music? Did you have time to think clearly or were you rushed?

3. Walk me through what was going on in your mind over the course of a trial. Did you use any strategies?

4. Did you recognize any of the pieces?

5. What is your association to music? Do you have an emotional connection to music?

6. Are you generally emotional? Introspective of empathetic?

7. How might I improve the experiment?

Appendix A6: Consent Form

McMaster University
Inspiring Innovation and Discovery

Letter of Information and Consent Form

A Study of Music in the Brain

Principal Investigator: Dr. John Connolly, PhD.
Department of Linguistics and Languages
McMaster University
Hamilton, Ontario, Canada
(905) 525-9140 ext. 27095
jconnol@mcmaster.ca

Student/co-investigators: Jacob Morgan, B.A. (Hons) & Tsee Leng Choy, M.Sc.
Department of Linguistics and Languages & McMaster Institute
for Neuroscience Discovery & Study (MiNDS)
McMaster University

Hamilton, Ontario, Canada

(905) 525-9140 ext. 21675

morgaj5@mcmaster.ca & choytl@mcmaster.ca

Purpose of the Study

This is a study of emotion conveyed through music. More specifically, it is a study of your ability to appraise and compare the emotional content of musical excerpts. These comparisons, as match or mismatch, are distinctly reflected in your brain activity, which can be measured using an electroencephalogram (EEG). It is the profile of these brain responses that is of interest.

What will happen during the study?

You will be seated in a chair at a screen an computer mouse, fitted with ear-phones and an EEG recording electrodes. You will hear a brief musical excerpt. The excerpts have been selected to sound particularly **happy/positive** or **sad/negative**. Following the excerpt, you will hear a word, either **"happy"** or **"sad".**

It is your task to please appraise whether the pair of sounds are **related** (happy-happy, sad-sad) or **unrelated** (happy-sad, sad-happy) in their **emotional** content. You will be prompted by a visual or auditory cue to make your comparison. Please be sure to not only assess the excerpts as either happy/positive or sad/negative sounding, but also if the pair matches or does not match.

At the cue, please indicate your appraisal on the computer mouse, with a **left click for match** and **right click for mismatch**.

Your brain activity will be measured using an electroencephalogram (EGG), which is a non-invasive imaging device used to measure various biological responses. For the purposes of this study, the EEG will be fitted to a special sensor cap which will be placed on your scalp.

Caps will be secured to your head with the straps and additional sensors will be placed above and to the side (over the outer canthi) of one or both eyes in order to record eye movements including blinking. Recording the electro-oculogram (EOG) is important too when recording the EEG because blinking and other eye movements can interfere with and produce artifacts in the EEG signal. EOG recording enables the removal of such artifact. In order to obtain good quality EEG recordings it is important to lightly abrade the scalp and/or apply medical-grade alcohol at the recording site so that surface oils and associated skin conductivity do not interfere with the recordings. In addition, an electrolyte (an electrically conductive jelly-like substance) must be inserted under each electrode to enable good quality recording. Finally, surgical tape (i.e., tape that does not "pull" at the skin as much as regular tape) must be used to hold in place those sensors placed around the eyes. A trained experimenter will attach and remove all sensors and the cap.

In order to ensure the quality of the EEG recordings, you will first be asked to fill out a questionnaire of personal information. Certain neurological or psychiatric conditions, hearing problems, past head injuries, as well as medications that act on the central nervous system may prevent your participation in this study, since these factors may interfere with the data recorded.

You will receive three 10-second breaks.

The set-up for the experiment should last for no more than 45 minutes. The experiment itself should not last for more than 15 minutes.

Potential Harms, Risks or Discomforts:

The EEG recordings and behavioural tasks do not carry any risk. However, the placement of sensors requires the application of a conductive gel on the scalp, as well as cleaning of the areas of the face where sensors are applied. Cleaning of the skin is done with an alcohol pad and an abrasive paste. These procedures may cause a slight sensation of cold or very light scratching. Some of the conductive jelly will remain in your hair after the sensors have been removed. In addition, in order to obtain valid EEG recordings, many stimulus presentations are necessary. This requires you to sit still and pay attention for extended periods, which may cause some fatigue or discomfort. Stimulus presentation will be stopped at regular intervals in order to allow you to relax between parts of the experiment.

You may find the screening questions about your medical history and drug use to probe sensitive areas. We need to ask you these questions to find out whether you are eligible to take part in the study. The form will not have your name on it and will not be shared with anyone else.

Potential Benefits

Your participation will contribute to the understanding of the relation between music, emotion, and consciousness. There will be no direct benefits to you for participating in the study beyond the payment received. The results of this study could have application in determining the level of cognitive awareness in non-communicative minimally conscious patients.

Compensation:

Financial compensation at a rate of $20 per hour.

Confidentiality:

All personal information gathered during the experiment will be kept strictly confidential. You will only be identified by a number. Only the principal investigator and student investigator will have access to your name, as well as any other personal or identifying information that you provide. No publication or scientific communication resulting from the study will contain any identifying information. Personal data will be stored in a locked file cabinet or on a password-protected hard drive for a duration of 7 years, after which they will be destroyed. Data that has been made anonymous will be conserved indefinitely because they retain their scientific value and may be of use in analyses subsequent to the present study.

Participation:

Participation in this study is completely voluntary. You may choose to withdraw at any time without consequence or prejudice. You will not need to justify the decision to withdraw. If you withdraw, your data will be destroyed unless you indicate otherwise, but you will still receive prorated financial compensation or partial course credit.

Information About the Study Results:

You may obtain information about the results of the study by contacting either the principal investigator or the student investigator listed on the first page of this form.

Information about Participating as a Study Subject:

If you have questions or require more information about the study itself, please contact the principal investigator or the student investigator listed on the first page of this form.

This study has been reviewed and approved by the McMaster Research Ethics Board. If you have concerns or questions about your rights as a participant or about the way the study is conducted, you may contact:

McMaster Research Ethics Board Secretariat

Telephone: (905) 525-9140 ext. 23142

c/o Office of Research Services

E-mail: ethicsoffice@mcmaster.ca

CONSENT

A Study of Music in the Brain (Project # 2009 176)

I have read the information presented in the information letter about a study being conducted by Jacob Morgan & Tsee Leng Choy, supervised by Dr. John Connolly of McMaster University.

I have had the opportunity to ask questions about my involvement in this study, and to receive any additional details I wanted to know about the study.

I understand that I may withdraw from the study at any time, if I choose to do so, and I agree to participate in this study. I have been given a copy of this form.

_______________________________	____________	_______________________
Name of Participant (printed)	Date	Signature

Appendix A: Screening and Consent Forms

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If yes, please describe:

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____

Have you ever lost consciousness? Yes No

If yes, please describe (including duration): ____

____

____

Are you presently taking any medication? Yes No

If yes, please describe:

____

____

____

Have you recently taken any medication? Yes No

If yes, please describe:

____

____

____

Do you consume any of (please specify frequency of use):

Alcohol: __________________________________

Cigarettes: ________________________________

Drugs: ____________________________________

Appendix A2: Screening Form (cont'd)

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If yes, please specify:

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Have you consumed drugs in the last 7 days? Yes No

If yes, please specify:

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Please rate your current state of alertness:

\- 1 2 3 4 5 +

How many hours did you sleep last night?

____

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\- 1 2 3 4 5 +

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Do you consider yourself a musician? Yes No

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8. Broom (upper hand)		
9. Striking match		
10. Opening box lid		

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Participant Code: ______________________________
Date: ______________________________
Personnel: ______________________________

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4. Did you recognize any of the pieces?

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6. Are you generally emotional? Introspective of empathetic?

7. How might I improve the experiment?

Appendix A6: Consent Form

Letter of Information and Consent Form

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Department of Linguistics and Languages & McMaster Institute for Neuroscience Discovery & Study (MiNDS)
McMaster University
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You will receive three 10-second breaks.

The set-up for the experiment should last for no more than 45 minutes. The experiment itself should not last for more than 15 minutes.

Potential Harms, Risks or Discomforts:

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You may find the screening questions about your medical history and drug use to probe sensitive areas. We need to ask you these questions to find out whether you are eligible to take part in the study. The form will not have your name on it and will not be shared with anyone else.

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Your participation will contribute to the understanding of the relation between music, emotion, and consciousness. There will be no direct benefits to you for participating in the study beyond the payment received. The results of this study could have application in determining the level of cognitive awareness in non-communicative minimally conscious patients.

Compensation:

Financial compensation at a rate of $20 per hour.

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All personal information gathered during the experiment will be kept strictly confidential. You will only be identified by a number. Only the principal investigator and student investigator will have access to your name, as well as any other personal or identifying information that you provide. No publication or scientific communication resulting from the study will contain any identifying information. Personal data will be stored in a locked file cabinet or on a password-protected hard drive for a duration of 7 years, after which they will be destroyed. Data that has been made anonymous will be conserved indefinitely because they retain their scientific value and may be of use in analyses subsequent to the present study.

Participation:

Participation in this study is completely voluntary. You may choose to withdraw at any time without consequence or prejudice. You will not need to justify the decision to withdraw. If you withdraw, your data will be destroyed unless you indicate otherwise, but you will still receive prorated financial compensation or partial course credit.

Information About the Study Results:

You may obtain information about the results of the study by contacting either the principal investigator or the student investigator listed on the first page of this form.

Information about Participating as a Study Subject:

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CONSENT
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____________________________ ___________ _____________________
Name of Participant (printed) Date Signature

Appendix B: Catalogue of Music Stimuli

	Piece Title	Composer	Excerpts	Instrumentation	Emotion
1	Brandenburg Concerto, No. 3	Bach, Johann Sebastian	5	Orchestra	Happy
2	Piano Concerto, no. 4	Beethoven, Ludwig van	8	Piano and Orchestra	Happy
3	Symphony, no.3, III (Eroica)		6	Orchestra	Happy
4	Symphony, no.6, III (Pastoral)		5	Orcestra	Happy
5	Peer Gynt Suite, no. 1, Op. 46 (Morning)	Grieg, Edvard	2	Orchestra	Happy
6	Choral: In Dich Hab Ich Gehoffet, Herr	Praetorius, Michael	2	Brass	Happy
7	Festival Overture, Op. 69	Schostakowitsch, Dimitri	1	Brass and Orchestra	Happy
8	La Boutique Fantasque, ballet after Rossini V. Cancan	Repighi, Ottornino	1	Orchestra	Happy
9	Egmont Overture, Op. 48	Beethoven, Ludwig van	1	Orchestra	Happy
10	Gott, Man Lobet Dich In Der Stille	Bach, Johann Sebastian	3	Orchestra	Happy
11	Mittsommerlied	Besch, Otto	1	String Quartet	Happy
12	Symphony, no. 2, Op. 16, IV (The Four Temperaments: Sanguine)	Nielsen, Carl	3	Orchestra	Happy
13	Loquasto International Film Festival	Mothersbaugh, Mark	4	Orchestra	Happy

Appendix B: Catalogue of Music Stimuli

	Piece Title	Composer	No. Excerpts	Instrumentation	Emotion
14	Eine Kleine Nachtmusik	Mozart, Amadeus	5	Orchestra	Happy
15	Die Zauberflote, Act 1, no. 2 (Papageno's Aria)		2	Orchestra	Happy
16	Symphony, no. 23, III		4	Orchestra	Happy
17	Piano Concerto, no. 23, II		2	Piano and Orchestra	Happy
18	Peter and the Wolf	Prokofiev, Sergei	4	Chamber Orchestra	Happy
19	Piano Concerto, no. 2	Rachmaninoff, Sergei	1	Piano and Orchestra	Happy
20	Le Tombeau De Couperin (Prelude)	Ravel, Maurice	1	Orchestra	Happy
21	Carnaval des Animaux (La Voliere)	Saint-Saens, Charles-Camille	4	Piano and Orchestra	Happy
22	Carnaval des Animaux (Finale)		6	Piano and Orchestra	Happy
23	Don Quixote, Op. 35, III (Variation)	Strauss, Richard	1	Orchestra	Happy
24	Concerto, no. 3, Op. 8 (The Four Seaons: Autumn, Danza Pastorale)	Vivaldi, Antonio	8	Strings and Orchestra	Happy
25	Adagio in G Minor	Albinoni, Tomaso	11	Orchestra	Sad
26	Passionmusik nad dem evangelisten Matthaus (St Matthew's Passion)	Bach, Johann Sebastian	5	Orchestra	Sad

27	Piano Concerto, no. 1, II	Brahms, Johannes	6	Piano and Orchestra	Sad

Appendix B: Catalogue of Music Stimuli

	Piece Title	Composer	No. Excerpts	Instrumentation	Emotion
28	Kol Nidrei, Op. 47	Bruch, Max	8	Double Bass and Organ	Sad
29	Nocturnes, Op. 27	Chopin, Frederic	4	Piano	Sad
30	Nocturnes, Op. 48		9	Piano	Sad
31	Nocturnes, Op. 9		5	Piano	Sad
32	Prelude: Das pas sur la Neige	Debussy, Claude	1	Piano	Sad
33	Peer Gynt Suite, No.2, Op. 55, II (Solveig's Lied)	Edvard, Grieg	5	Sad	Sad
34	Piano Concerto, no. 23, II	Mozart, Amadeus	4	Paino and Orchestra	Sad
35	Piano Concerto, no. 2	Rachmaninoff, Sergei	5	Piano and Orchestra	Sad
36	Prelude in C Minor		6	Piano	Sad
37	Concerto in G, II	Ravel, Maurice	1	Piano and Orchestra	Sad
38	Concerto de Arajuez (Adagio)	Rodrigo, Joaquin	7	Guitar	Sad

Appendix C: Affective Ratings of Stimuli

Number	File Name	Rating	Mode	Emotion
1	Bach Brand_1	3.0	4.0	Happy
2	Bach Brand_2	3.5	4.0	Happy
3	Bach Brand_3	3.5	4.0	Happy
4	Bach Brand_4	3.3	3.0	Happy
5	Bach Brand_5	3.2	4.0	Happy
6	Beethoven Piano Concerto 4_1	3.4	3.0	Happy
7	Beethoven Piano Concerto 4_2	3.0	3.0	Happy
8	Beethoven Piano Concerto 4_3	3.4	3.0	Happy
9	Beethoven Piano Concerto 4_4	3.7	4.0	Happy
10	Beethoven Piano Concerto 4_5	3.0	3.0	Happy
11	Beethoven Piano Concerto 4_6	2.9	3.0	Happy
12	Beethoven Piano Concerto 4_7	2.8	3.0	Happy
13	Beethoven Piano Concerto 4_8	2.9	3.0	Happy
14	Beethoven Symphony 3 III _1	3.0	4.0	Happy
15	Beethoven Symphony 3 III _2	3.6	4.0	Happy
16	Beethoven Symphony 3 III _3	3.8	4.0	Happy
17	Beethoven Symphony 3 III _4	3.0	3.0	Happy
18	Beethoven Symphony 3 III _5	3.0	3.0	Happy
19	Beethoven Symphony 3 III _6	3.0	3.0	Happy
20	Beethoven Symphony 6 _1	3.0	4.0	Happy
21	Beethoven Symphony 6 _2	3.0	3.0	Happy
22	Beethoven Symphony 6 _3	3.3	3.0	Happy
23	Beethoven Symphony 6 _4	3.1	4.0	Happy
24	Beethoven Symphony 6 _5	3.0	3.0	Happy
25	Besch _1	3.5	3.0	Happy
26	Greig Morning _1	3.0	3.0	Happy
27	Greig Morning _2	2.8	3.0	Happy
28	Praetorius _1	3.0	3.0	Happy
29	Praetorius _2	3.0	4.0	Happy
30	Schostakowitsch_1	3.7	4.0	Happy
31	Repighi_1	3.5	4.0	Happy
32	Beethoven Egmont_1	3.5	4.0	Happy
33	Bach Gott _1	3.7	4.0	Happy
34	Bach Gott _2	4.0	4.0	Happy
35	Bach Gott _3	3.5	4.0	Happy
36	Rachmaninoff Piano Concerto_1	3.4	1.0	Happy
37	Nielsen_1	3.0	4.0	Happy

Appendix C: Affective Ratings of Stimuli

Number	File Name	Rating	Mode	Emotion
38	Nielsen_2	3.0	4.0	Happy
39	Nielsen_3	3.8	4.0	Happy
40	Mothersbaugh_1	3.0	3.0	Happy
41	Mothersbaugh_2	3.0	3.0	Happy
42	Mothersbaugh_3	3.7	4.0	Happy
43	Mothersbaugh_4	3.6	4.0	Happy
44	Mothersbaugh_5	3.0	3.0	Happy
45	Mozart Eine _1	3.6	4.0	Happy
46	Mozart Eine _2	3.7	4.0	Happy
47	Mozart Eine _3	3.6	4.0	Happy
48	Mozart Eine _4	3.8	4.0	Happy
49	Mozart Eine _5	2.5	3.0	Happy
50	Mozart Zauberflote _1	4.0	4.0	Happy
51	Mozart Zauberflote _2	3.6	4.0	Happy
52	Mozart Symphony 23_1	2.5	3.0	Happy
53	Mozart Symphony 23_2	3.8	4.0	Happy
54	Mozart Symphony 23_3	3.3	4.0	Happy
55	Mozart Symphony 23_4	3.0	4.0	Happy
56	Mozart Piano Concerto 23 _1	2.0	4.0	Happy
57	Mozart Piano Concerto 23 _2	2.5	3.0	Happy
58	Prokofeiv _1	3.3	4.0	Happy
59	Prokofeiv _2	3.4	3.0	Happy
60	Prokofeiv _3	3.5	4.0	Happy
61	Prokofeiv _4	3.4	3.0	Happy
62	Ravel _1	3.0	3.0	Happy
63	Saint-Saens Voliere_1	3.5	4.0	Happy
64	Saint-Saens Voliere_2	3.5	3.0	Happy
65	Saint-Saens Voliere_3	3.5	4.0	Happy
66	Saint-Saens Voliere_4	3.4	4.0	Happy
67	Saint-Saens Finale _1	3.6	4.0	Happy
68	Saint-Saens Finale _2	3.6	4.0	Happy
69	Saint-Saens Finale _3	3.8	4.0	Happy
70	Saint-Saens Finale _4	3.9	4.0	Happy
71	Saint-Saens Finale _5	3.8	4.0	Happy
72	Saint-Saens Finale _6	3.4	4.0	Happy
73	Vivaldi _1	3.7	4.0	Happy

Appendix C: Affective Ratings of Stimuli

Number	File Name	Rating	Mode	Emotion
74	Vivaldi _2	3.8	4.0	Happy
75	Vivaldi _3	3.6	4.0	Happy
76	Vivaldi _4	3.0	3.0	Happy
77	Vivaldi _5	3.6	4.0	Happy
78	Vivaldi _6	2.5	4.0	Happy
79	Vivaldi _7	3.0	4.0	Happy
80	Vivaldi _8	3.7	4.0	Happy
81	Albinoni_1	2.2	2.0	Sad
82	Albinoni_2	2.1	2.0	Sad
83	Albinoni_3	1.6	2.0	Sad
84	Albinoni_4	1.6	1.0	Sad
85	Albinoni_5	1.3	1.0	Sad
86	Albinoni_6	1.7	2.0	Sad
87	Albinoni_7	1.8	1.0	Sad
88	Albinoni_8	1.8	1.0	Sad
89	Albinoni_9	1.8	1.0	Sad
90	Albinoni_10	1.1	1.0	Sad
91	Albinoni_11	1.5	1.0	Sad
92	Bach Passion_1	1.8	2.0	Sad
93	Bach Passion_2	1.4	1.0	Sad
94	Bach Passion_3	1.5	1.0	Sad
95	Bach Passion_4	1.9	2.0	Sad
96	Bach Passion_5	2.3	2.0	Sad
97	Brahms_1	1.4	1.0	Sad
98	Brahms_2	1.6	2.0	Sad
99	Brahms_3	1.4	1.0	Sad
100	Brahms_4	1.8	2.0	Sad
101	Brahms_5	1.5	2.0	Sad
102	Brahms_6	2.2	3.0	Sad
103	Bruch_1	1.7	1.0	Sad
104	Bruch_2	1.8	2.0	Sad
105	Bruch_3	1.8	2.0	Sad
106	Bruch_4	1.7	1.0	Sad
107	Bruch_5	1.3	1.0	Sad
108	Bruch_6	1.9	2.0	Sad
109	Bruch_7	1.9	1.0	Sad
110	Bruch_8	2.1	2.0	Sad
111	Chopin 27_1	1.8	2.0	Sad

Appendix C: Affective Ratings of Stimuli

Number	File Name	Rating	Mode	Emotion
112	Chopin 27_2	1.4	1.0	Sad
113	Chopin 27_3	1.8	1.0	Sad
114	Chopin 27_4	2.1	2.0	Sad
115	Chopin 48_1	1.3	1.0	Sad
116	Chopin 48_2	1.5	1.0	Sad
117	Chopin 48_3	1.6	1.0	Sad
118	Chopin 48_4	1.3	1.0	Sad
119	Chopin 48_5	2.2	2.0	Sad
120	Chopin 48_6	1.6	1.0	Sad
121	Chopin 48_7	2.2	2.0	Sad
122	Chopin 48_8	1.3	1.0	Sad
123	Chopin 48_9	1.6	2.0	Sad
124	Chopin 9_1	2.0	2.0	Sad
125	Chopin 9_2	1.3	1.0	Sad
126	Chopin 9_3	2.3	2.0	Sad
127	Chopin 9_4	1.3	1.0	Sad
128	Chopin 9_5	1.3	1.0	Sad
129	Debussy_1	1.5	1.0	Sad
130	Grieg Solveig's_1	1.7	1.0	Sad
131	Grieg Solveig's_2	1.8	1.0	Sad
132	Grieg Solveig's_3	2.6	2.0	Sad
133	Grieg Solveig's_4	1.5	1.0	Sad
134	Grieg Solveig's_5	2.4	2.0	Sad
135	Mozart Piano Concerto 23 II_1	2.0	2.0	Sad
136	Mozart Piano Concerto 23 II_2	2.4	1.0	Sad
137	Mozart Piano Concerto 23 II_3	2.4	2.0	Sad
138	Mozart Piano Concerto 23 II_4	1.6	2.0	Sad
139	Rachmaninoff Piano Concerto_1	1.8	1.0	Sad
140	Rachmaninoff Piano Concerto_2	1.6	2.0	Sad
141	Rachmaninoff Piano Concerto_3	1.5	2.0	Sad
142	Rachmaninoff Piano Concerto_4	1.5	1.0	Sad
143	Rachmaninoff Piano Concerto_5	1.8	1.0	Sad
144	Rachmaninoff Prelude_1	1.4	2.0	Sad
145	Rachmaninoff Prelude_2	1.5	1.0	Sad
146	Rachmaninoff Prelude_3	1.5	1.0	Sad
147	Rachmaninoff Prelude_7	1.7	2.0	Sad
148	Rachmaninoff Prelude_8	1.6	2.0	Sad
149	Rachmaninoff Prelude_9	1.5	1.0	Sad

Appendix C: Affective Ratings of Stimuli

Number	File Name	Rating	Mode	Emotion
150	Ravel Concerto_1	2.0	2.0	Sad
151	Rodrigo_1	1.5	2.0	Sad
152	Rodrigo_2	2.0	2.0	Sad
153	Rodrigo_3	1.5	1.0	Sad
154	Rodrigo_5	1.5	1.0	Sad
155	Rodrigo_6	2.0	2.0	Sad
156	Rodrigo_7	1.5	1.0	Sad
157	Rodrigo_8	1.7	2.0	Sad
158	Saint-Saens Cynge_1	1.8	1.0	Sad
159	Saint-Saens Cynge_2	1.8	1.0	Sad
160	Saint-Saens Cynge_3	1.5	1.0	Sad

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