ERP RESPONSES TO MUSIC AS A MEASURE OF EMOTION

EVENT-RELATED POTENTIAL (ERP) RESPONSES TO MUSIC AS A MEASURE OF EMOTION

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ABSTRACT

This thesis examines how ERP responses to music provide an index of emotion in control, alexithymic, depressed and depressed alexithymic individuals using a musical affective priming task, with the objective being its clinical application to assess emotion in brain injured patients. Participants listened to pairs of music primes and music targets (music-music paradigm) and word targets (music-word paradigm) to mentally decide if they matched or not according to emotional valence (happy, sad). Responses manifested in the N300 (emotional categorization), P300 (emotional recognition) and N400 (emotional meaning) ERP components, with larger and more differentiated responses for the music-word paradigm indicating a less automatic nature than the music-music paradigm. Alexithymic individuals showed disrupted responses for all components for sad word targets, indicating a sequence of disconnects producing their decreased awareness of and difficulty with regulating emotion. Depressed participants displayed an emotional negativity bias for sad word targets in the P300 and N400, attributable to difficulty disengaging (cognitive rumination), reflecting how emotional deficits affect awareness. Disrupted P300 and N400 responses in the depressed alexithymic individuals were isolated to alexithymia rather than the emotional negativity bias. Specific processing deficits of happy music targets found only in depressed alexithymic individuals demonstrate how alexithymia increases the severity of depression. Although depression effects are more pervasive, alexithymia modifies depressive effects in emotional regulation. The

P300 was most reliably seen in depression, and alexithymia to a lesser extent. Therefore, ERP responses to music can effectively and covertly measure emotion and different levels of automaticity, alexithymia and depression. This thesis is the first to demonstrate: 1) how music conveys emotion in a pure musical context (music-music); 2) musical emotion perception in alexithymia, depression and depressed alexithymia; 3) an effective non-verbal measure of emotion for assessing emotional states in brain injured populations.

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LIST OF ABBREVIATIONS AND SYMBOLS

AIMS	Absorption in Music Scale
ANOVA	Analysis of variance
BC	Behaviourally correct analysis
BDI-II	Beck Depression Inventory-II
BDNF	Brain derived neurotrophic factor
BREQ	Brain Injury Rehabilitation Trust Regulation of Emotions Questionnaire
BVAQ-B	Bermond-Vorst Alexithymia Questionnaire Form-B
CC	Categorically correct analysis
dB	Decibels
DMN	Default mode network
DSM-IV	Diagnostic and Statistical Manual of Mental Disorders Fourth Edition
EEG	Electroencephalogram
e.g.	For example
EOG	Electro oculogram
ERPs	Event-related potentials
et al.	And others
fMRI	Functional magnetic resonance imaging
HH	Happy prime paired with happy target
HS	Happy prime paired with sad target
Hz	Hertz
i.e.	That is
ICD-10	International Classification of Diseases-10
ISI	Inter-stimulus interval

kΩ	Kilo Ohms
m	metre
M	Mean
MBEA	Montreal Battery of Evaluation of Amusia
MMN	Mismatch negativity
ms	Milliseconds
N	Number
N1	Negative ERP component occurring 100 ms post-stimulus
N2	Negative ERP component occurring 200 ms post-stimulus
N300	Negative ERP component occurring 300 ms post-stimulus
N400	Negative ERP component occurring 400ms post-stimulus
OMSI	Ollen Musical Sophistication Index
PANAS	Positive and Negative Affect Schedule
P300	Positive ERP component occurring 300 ms post-stimulus
P3a	Earlier portion of the P300
P3b	Later portion of the P300
SC	Subjectively correct analysis
SD	Standard deviation
SH	Sad prime paired with happy target
SS	Sad prime paired with sad target
TAS-20	Twenty-Item Toronto Alexithymia Scale
TBI	Traumatic brain injury
μV	Microvolts

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Chapter 1. Consciousness, emotion, brain injury and music: overview

"It is through a vague idea or through feeling that the mind judges the existence of creatures and that it knows its own existence."

(Nicolas Malebranche, (1678-79), cf. Damasio, 2000).

This thesis examines issues overlapping the four rapidly developing research domains of consciousness, emotion, brain injury and music. In this chapter, I will provide an overview of current perspectives in these areas and how they come together to enable music to reflect emotional states capable of being measured by event-related potentials (ERPs), to permit clinical application to brain injured populations.

To begin, consciousness will be discussed in relation to emotion, particularly their significance in brain injury. Alexithymia and depression will be introduced to elucidate the influence of emotional deficits on consciousness, especially as both are frequently present after brain injury. Music and emotion will then be explored to demonstrate music's suitability as a non-verbal reflection of emotion in healthy and clinical populations. Finally, the thesis experiments and objectives will be outlined to reveal how the research question will be tackled and how it benefits the current research field.

1.1 CONSCIOUSNESS

Consciousness has remained an elusive research target for disciplines from philosophy to psychology for centuries. Few would deny that higher levels of consciousness (e.g. self consciousness) constitute the very essence of humanity, compared to cognitive functions like language or memory. Research in consciousness has witnessed a resurgence of interest and progress in the last two decades due to substantial developments in neuroimaging and physiological recording techniques (electroencephalography/EEG, event-related brain potentials/ERPs and functional magnetic resonance imaging/fMRI), which enable the quantification of subjective experiences with objective neural activity. The resulting tangibility has also facilitated numerous theories of consciousness (see Lau & Rosenthal, 2011; Augustenborg, 2010 for reviews) as well as neural correlates of consciousness (see Aru, Bachmann, Singer & Melloni, 2012; Lau & Rosenthal, 2011 for reviews).

While it is beyond the scope of this thesis to appraise these various theories (featuring Baar's Global Workspace, Damasio's Biological Nature of consciousness and Tononi's Information Integrated theories among others), what each theory agrees upon is that consciousness is an emergent property resulting from a widespread neural system, comprised of various levels (e.g. Block's classification of phenomenal, monitoring, access and self-consciousness) and the distinction of cognitive from non-cognitive consciousness (e.g. gut feelings or intuitions), which has a strong, if not exclusive, emotional basis. It is important to note that the term "cognitive" encompasses all cognitive processes (e.g. appraisal) and not just language. Augusternborg (2010) has even advocated that non-cognitive consciousness be added and considered an individual element in

Block's taxonomy of consciousness, with Cleeremans (2008) explicitly citing the blatant exclusion of emotion in discussing consciousness, "Conscious experience would not exist without experiencers who *care* about their experiences!" (pg. 31).

These seemingly abstract issues on consciousness become pressingly real and critical with increased occurrences of severe brain injury worldwide. This has thrust ethical dilemmas surrounding disorders of consciousness (coma, vegetative state, minimally conscious state) into the limelight. Media sensationalization of these cases like the removal of Terry Schiavo's feeding tube and Terry Wallis's amazing recovery (see Fins, 2008) has further fueled research in this domain. In order to fully appreciate, intervene and improve the fate of these patients, the definitions of consciousness need to be rigorously probed and debated as a consensus still eludes the field. Details of these diagnoses and their implications will be elaborated further in Section 1.3.

Generally, consciousness is defined as a state or activity characterized by sensation, emotion, volition or thought (Gove, 1961). Clinically, consciousness is defined by its level (arousal/wakefulness – being awake or asleep) and content (awareness – being aware of an external/internal stimulus or not) on a continuous scale (Posner, Schaper, Schiff & Plum, 2007). Notably, both aspects of this definition agree that consciousness is an experience existing on a gradient. It is important not to lump 'consciousness' into a single entity, or equate it to 'self-consciousness' (Searle, 1998), a higher level of consciousness. Unfortunately, the interchangeable use of these terms and categorical view of consciousness is still commonplace between and across research fields (Augusternborg, 2010; Searle, 1998).

What follows is how one determines the point where consciousness begins in disorders of consciousness, or when it starts to matter. Is it cognition - the experience of memory or language? Or is it self-awareness – when one is aware of the self? To this end, simply consider how a brain injured patient, his/her family and medical staff prioritize or contemplate decisions, irrespective of the patient's fate. Any indication of the patient experiencing *something* – be it suffering, distress, pleasure – is sufficient. It warrants that they are conscious *enough* - adequate to reconsider treatment, diagnosis or euthanasia – and also sufficient enough to influence our moral attitudes towards them (Knobe & Prinz, 2008). That critical point and consciousness level (i.e., awareness), as this thesis will argue, is emotion.

1.2 EMOTION

While less ambiguous than consciousness, the definition of emotion also varies slightly across fields (LeDoux, 2012; Izard, 2009) and is often used interchangeably with terms such as feeling or affect (Taylor, Bagby & Parker, 1997). Emotion is most commonly defined as the neurophysiological and motor-expressive changes regulated by a particular neural system in response to a specific perception, object or event (Bechara & Damasio, 2005; Taylor, Bagby & Parker, 1997). Feeling is the subjective, cognitive-experiential domain of an emotion while affect is the overall state encompassing emotion and feeling, incorporated with other evaluative and valenced (range of positive or negative emotional value) elements like memories and preference (Juslin & Västfjäll, 2008; Taylor, Bagby & Parker, 1997). A closely related term, mood, is a less intensive, sustained state that lacks focus or an object (Juslin & Västfjäll, 2008). The relation and distinction between these commonly confused terms is nicely captured by Damasio (2000), "Affect is more general and can designate the whole subject matter we are discussing – emotion, mood, feeling. It is the thing you display (emote) or experience (feel) towards an object or situation, any day of your life whether you are moody or not." (p.342). Emotion remains the focus of this thesis.

Like consciousness, emotion exists on a continuum, and they both share an intricate relationship. Consider how emotions are dampened in drowsiness, and how consciousness is amplified in emotionally charged situations (Krystal, 1988). Darwin was the first to acknowledge the role of emotions in organizing behaviours that favour survival (Darwin, 1872, cf. Taylor, Bagby & Parker, 1997). Krystal (1988) notes how emotion is omnipresent and functions to preserve life, and several researchers have opined that emotions and consciousness are not separable (Izard, 2009; Tsuchiya & Adophs, 2007; Phelps, 2006; Russell, 2003; Damasio, 2000), unlike the more marked distinction between cognition and consciousness. These observations are consistent with the idea that emotions precede cognition, are more basic by nature, and are governed by more medial and ventral brain regions, thus designated as 'affective consciousness' (Panksepp, 2003). The recent discovery of emotion as a sign of consciousness in amniota (common ancestors of mammals, turtles, scaled reptiles, birds and dinosaurs) reflected in dopamine production, play behaviour, sensory pleasure in decision making and increased heart rate and body temperature due to emotion (Cabanac, Cabanac & Parent, 2009; see also Mashour & Alkire, 2013) further reflect the fundamental relation between emotion and consciousness.

The previous studies mentioned corroborate the prioritization and emergence of emotion before cognition in consciousness. In addition, events crucial for survival are also often emotionally laden (e.g. spider = threat), motivating us to move, act or feel. Emotional (e.g. spider) but not neutral (e.g. house) pictures were processed in the affected hemifield for spatial neglect and blindsight studies; subliminally presented emotional stimuli showed the amygdala to reliably distinguish between consciously unseen emotional and neutral targets, independent of ensuing attention in imaging studies (Dolan, 2002; see also Tamietto & de Gelder 2010 for review). This more inherent emotional response and its autonomy from cognition is also exemplified in the facilitation of conditioned fear responses to an emotional (e.g. spider) stimulus paired with an electric shock, a response persisting even during extinction; in contrast to decreased affinity and attenuated responses to a neutral (e.g. flower) stimulus (Mineka & Öhman, 2002; Öhman & Mineka, 2001). Following this, one can appreciate why emotion, not cognition, is the point of consciousness that matters when dealing with brain injured patients. As emotion is more innate, a brain injured patient may not know or remember an event (e.g. pain), but will still feel and experience it.

1.3 TRAUMATIC BRAIN INJURY (TBI)

TBI (head injuries caused by blunt, penetrating or acceleration-deceleration forces, contained within the skull) is an increasing global concern, constituting one of the leading causes of mortality and disability worldwide (Maas, Stocchetti & Bullock, 2008). Injuries arise from contusions (bruising, bleeding or lesions in brain gray matter) with frontal lobes being the most vulnerable, and diffuse axonal injury (nerve fibre lacerations in brain white matter). These structural injuries are often widespread (unlike stroke, which is more localized) and are key contributors to the subsequent behavioural, motor, cognitive and emotional deficits in these patients. They also trigger cascading neurochemical processes resulting in neural atrophy (Tate, 2012).

Recall that consciousness has two clinical aspects – wakefulness or arousal (level: from being awake to asleep) and awareness (content: from being aware of an internal/external stimulus to being unaware). TBI typically begins with coma/the comatose stage (a transient, unconscious state where patients are, as far as we know, unaware and unresponsive), resulting from extensive damage to both cerebral hemispheres and the ascending arousal or reticular activating system (Posner, Schaper, Schiff & Plum, 2007). Surviving patients may then transition to the vegetative state (recovery of rudimentary arousal denoted by eye opening and autonomic functions), minimally conscious state (adequate arousal with recovery of fluctuating awareness, denoted by volition and command following) or regain awareness. Recently, it has been suggested that the term ‘unresponsive wakefulness syndrome’ be adopted instead of ‘vegetative state’ due to the latter’s negative connotations (Laureys et al., 2010). As both refer to the same condition and for brevity, ‘vegetative state’ will be adopted for this thesis. Unlike coma, the vegetative and minimally conscious are not fleeting states and can be permanent (Posner, Schaper, Schiff & Plum, 2007). Collectively, the comatose, vegetative and minimally conscious states are known as disorders of consciousness (see Goldfine & Schiff, 2011 for a neurological review).

The threshold between the vegetative and minimally conscious state poses a crucial and strategic point with regard to consciousness in terms of the first manifestation of awareness. As the minimally conscious state has been formally defined only recently (Giacino et al., 2002), the distinction between both states remain subtle and rife with controversy, exemplified in the cases of Terry Schiavo (reported as comatose when she was permanently vegetative) and Terry Wallis (diagnosed as vegetative when he was minimally conscious) (Fins, 2008). When comparing the clinical diagnosis (the current gold standard in clinical behavioural assessment) and standardized neurobehavioural assessment (e.g. the JFK Coma Recovery Scale/CRS-R), 41% of minimally conscious patients were misdiagnosed as vegetative (Schnakers et al., 2009). Considering both methods are behaviourally based (dependant on patient exhibiting motor or verbal responses), this high misdiagnosis rate is not surprising as patients are often unable to respond due to motor, verbal and arousal deficits.

The use of painkillers for vegetative patients is still debated as these patients are not thought to be conscious or experience pain, unlike minimally conscious patients. This pattern extends to attitudes regarding end-of-life issues (Demertzi et al., 2012). More importantly, pain effectively highlights how critical emotion is to *experience* (i.e., awareness in consciousness). Pain is regulated by a sensory-discriminative/lateral network (e.g. stimulus detection) and an affective-motivational/medial network (e.g. stimulus unpleasantness) (Kulkarni et al., 2005; Villemure, Slotnick & Bushnell, 2003). The latter is of crucial importance in producing the experience of pain, as without it the presence of a stimulus is merely a numb sensation (Sklar, 2013), just as how an anaesthetic dampens pain.

What this means is that vegetative patients may detect but not *experience* pain as most studies have found their lateral pain network to be intact whilst the medial pain network was compromised, although Markl et al. (2012) noted some activity in the latter network in 30% of their vegetative patients, suggesting some pain experience or clinical misdiagnosis (i.e., patients were minimally conscious rather than vegetative). On the whole, emotion seems to be the determining factor in transcribing nociception (the neural process of processing noxious stimuli) into an *experience*, that of pain – another indication of emotion being the point of interest in consciousness.

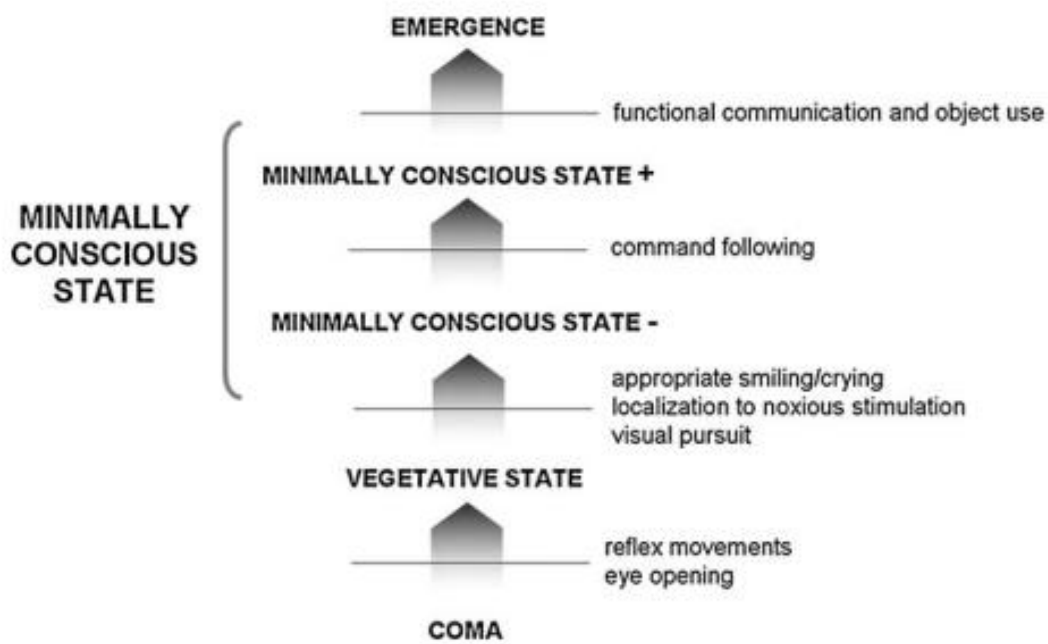

Figure 1.1 Clinical criteria in disorders of consciousness (Taken from Bruno et al., 2011).

Considering the subtle divisions, misdiagnosis rates, sedative complications and limitations of current diagnostic tools, navigating, let alone resolving this domain remains a challenge. Moreover, the minimally conscious state has only just been subdivided into minus and plus states, characterized by basic behavioural interaction (e.g. visual pursuit, localizing noxious stimuli) and command following respectively (Bruno et al., 2011). Neural structural differences between the plus and minus states have since been demonstrated (Fernández-Espejo et al, 2012; Bruno et al., 2011), with Figure 1.1 portraying the various discussed stages in disorders of consciousness.

Another issue pertains to the relative predominance of cognitive function in the clinical bedside examination, neuropsychological assessment and rehabilitation of these patients, which results in the neglect of their emotional function. The Brain Injury Rehabilitation Trust Regulation of Emotions Questionnaire (BREQ) has only been recently developed (Cattran, Oddy & Wood, 2011) and affective factors were found to better predict post-concussive symptoms (e.g. headaches, affective disturbances and cognitive problems) following mild TBI compared to neuropsychological test performances (Clarke, Genat & Anderson, 2012). Considering how emotional deficits (e.g. loss of motivation) can substantially depreciate a patient's cognition, recovery and social relationships (Ciurli et al., 2011; Hynes, Stone & Kelso, 2011; Särkämö et al., 2008), emotion assessment should be prioritized. The impact of emotion on cognition is well validated in post-traumatic stress disorder (see Hayes, VanElzakker & Shin, 2012 for review). The premise of affective factors better predicting post-concussive symptoms is extended to recovery in spinal cord injury patients. The emotional resiliency (e.g. lack of depression) of spinal cord injury patients is thought to account for their better response recovery (Hassanpour et al., 2011). As patients with similar but less severe injuries (e.g. whiplash) had higher rates of depression compared to spinal cord injury patients, the influence of injury severity or location being the predominant factor for recovery is minimized.

Nevertheless, neuroimaging and electrophysiological measures have markedly improved the clinical viability of clinical bedside examinations and neurobehavioural assessments (Harrison & Connolly, 2013; Wu & Yuan, 2012, Laureys & Schiff, 2011; Cruse & Owen, 2010; Gawryluk, D'Arcy, Connolly & Weaver, 2010; Laureys et al., 2006; Schiff, 2006; Connolly, Mate-Kole & Joyce, 1999) as they circumvent assessment complications caused by motor or verbal deficits. Many cognitive assessments have thus been incorporated into paradigms using these methods (Bardin et al., 2011; Goldfine et al., 2011; Boly et al., 2007; Neumann & Kotchoubey, 2004; Connolly & D'Arcy, 2000). In particular, ERPs have proven to be a highly suitable measure.

ERPs are a derivative of the brain's ongoing electrical activity (EEG) capable of reflecting volitional responses to a mental task. Because ERP amplitudes are about an order of magnitude smaller than that of the background EEG, ERP responses are obtained by averaging together responses to the repeated presentation of a stimulus. By summing these individual trials over time, the ERP response is revealed by virtue of its synchronization with the eliciting stimulus while the background EEG decreases in amplitude with increasing number of trials in the average due to its lack of a temporal relationship to the stimulus. This averaging process enables the extraction of time-locked ERP responses that would otherwise be buried in the temporally unrelated EEG because the averaging of random values tends towards a zero baseline, allowing synchronized values to emerge from the background.

ERPs are typically described by their polarity (positive or negative) and latency (timing after stimulus onset). For instance, the N300 is a negative-going waveform occurring 300 milliseconds (ms) after the stimulus was presented. With regard to brain injured and clinical patients, ERPs allow expeditious, efficient and economic bedside assessment, with relatively no patient stress (Connolly, D'Arcy, Newman & Kemps, 2000). They also yield a profile of neural events as they unfold in time, and are therefore appropriate for the assessment of patients' conscious and emotional states (Harrison & Connolly, 2013).

As mentioned, consciousness and emotion are closely intertwined. Thus, it is crucial to consider instances where deficiencies in one domain influence the other. The intricacies of complex systems are exposed and better appreciated during a system breakdown than during normal functioning (McCloskey, 2001, c.f. Peretz, Campod & Hyde, 2003). Being common outcomes of TBI (Rapoport, 2012; Henry et al., 2006; Koponen et al., 2005), the incidence of alexithymia and depression becomes especially pertinent. Furthermore, both alexithymia and depression are instances of impaired consciousness and emotion.

1.4 ALEXITHYMIA

Alexithymia describes a personality construct or condition marked by difficulty identifying, describing and distinguishing feelings from bodily sensations; with a limited imagination and an overdependence on externalization and reasoning (being aware of sensations rather than sentiments) (Nemiah & Sifneos, 1970). It has gained increased attention and research in the past four decades (see Taylor & Bagby, 2004 for a review) due to its relationship to a multitude of psychiatric, medical and social problems (Leweke, Leichsenring, Kruse & Hermes, 2012; Conrad et al., 2009; Willemsen, Roseeuw & Vanderlinden, 2008; Lumley, Neely & Burger, 2007; Sifneos, 2000).

As their emotion differentiation remains global and unresolved, alexithymics are unable to adapt or recognize their emotions. This suppressed expression of emotions in alexithymia finds an acceptable outlet in physical ailments, resulting in predispositions to psychiatric and medical conditions (e.g. somatisization) (Krystal, 1988). Alexithymics displayed an attentional bias to illness words (e.g. ache, pain, attack) compared to negative based emotional words (e.g. anxiety, rage, panic) in a Stroop interference task, being slower to name illness words than negative based emotional words (Lundh & Simonsson-Sarnecki, 2002). It is important to note that their difficulty with verbalizing emotion is not due to language deficiencies, as alexithymics process emotional language (i.e., semantics, prosody, associative emotional-learning) similarly as control individuals (Swart, Kortekaas & Aleman, 2009).

With a prevalence of 10 - 17% in healthy and 30 - 60% in patient populations (Parker, Keefer, Taylor & Bagby, 2008), alexithymia is normally distributed and single dimensional (one has different degrees of it). It has a higher incidence in males (Levant, Hall, Williams & Hasan, 2009; Kokkonen et al., 2001; Honkalampi et al., 2000; Salminen et al., 1999) and while its aetiology is still debated, theories support deficits/lesions in the anterior cingulate cortex, right hemisphere and corpus callosum (see Bermond, Vorst & Moorman, 2006; Larsen, Brand, Bermond & Hijman, 2003; Lane, Ahern, Schwartz & Kaszniak, 1997 for reviews). Recently, Walter, Montag, Markett & Reuter (2011) demonstrated that an interaction between transporters of two dopamine related genetic polymorphisms resulted in a reduced anterior cingulate cortex and higher levels of alexithymia. This contribution substantiates another prominent genetic study demonstrating alexithymia heritability of up to 33% in Danish twins (Jørgensen, Zachariae, Skytthe & Kyvik, 2007) and the stability of alexithymia as a personality trait, rather than an outcome of psychological distress (Taylor, Bagby & Parker, 1997).

Alexithymia presents an intriguing perspective for a number of reasons. Lane, Ahern, Schwartz & Kasniak (1997) aptly termed it '*blindfeel*' as alexithymics process emotion without being fully aware of it. Frawley & Smith

(2001) likened it to a series of disconnects in the transfer of emotional information. The fundamental break seems to be where emotions interact with cognition to become feelings. Thus, alexithymia enables the examination of emotions in its purest form (Griffiths, 1997 c.f. Frawley & Smith, 2001) and illustrates how this disruption in emotional consciousness is a point of interest when dealing with brain injured patients.

Additionally, alexithymia is significantly higher in TBI populations (Koponen et al., 2005; Henry et al., 2006; Williams et al., 2001). This link warrants more scrutiny to determine if the incidence of alexithymia is an outcome of brain injury (organic), pre-existing neurobiological and genetic deficits (primary) or psychological traumas (secondary) (Sifneos, 1988 c.f. Becerra, Amos & Jongenelis, 2002). Disambiguating these causes is important to avoid inaccuracies in diagnosis, prognosis and rehabilitation; moreover, depression, alexithymia and dysexecutive syndrome (deficits in emotion and executive functioning) are often confused (Becerra, Amos & Jongenelis, 2002).

Strictly speaking, alexithymia should be viewed as more of a disruption of consciousness than emotion. Just as blindsight and conscious vision are both visual processes distinguished only by a difference in conscious awareness, alexithymia (blindfeel) and conscious emotion are both emotional processes that differ in their level of consciousness (Berridge & Winkielman, 2003).

1.5 DEPRESSION

Depression is a mental illness marked by persistent, recurrent and diminished mood and function. It is diagnosed according to a cluster of symptoms by the International Classification of Diseases-10 (ICD-10) and the American Diagnostic and Statistical Manual of Mental Disorders-IV (DSM-IV), where symptoms must persist for at least two weeks and include loss of interest or pleasure (anhedonia) in activities, diminished energy and cognition (Thalpar, Collishaw, Pine & Thalpar, 2012; Gotlib & Joormann, 2010). Like TBI, depression is one of the most disabling health problems worldwide (see Kupfer, Frank & Phillips, 2012; Gotlib & Joormann, 2010 for reviews) and is the most common psychiatric consequence of TBI, with a prevalence of up to 61% for major depression (see Rapoport, 2012 for review). As depression substantially impacts post-concussive symptoms in severe (Rapoport, 2012) and mild TBI (Herrmann et al., 2009; Rapoport, Kiss & Feinstein, 2006) and can affect disability up to 7 years post-injury (Whitnall, McMillan, Murray & Teasdale, 2006), it needs to be factored in when dealing with TBI patients.

Past psychiatric history, family dysfunction and frontal injuries/degeneration appear to predict the occurrence of depression after TBI quite consistently (Rapoport, 2012). Given that alexithymia is closely associated with depression (e.g. depressed individuals tend to be alexithymic and vice versa) and also widespread in TBI, it is important to note the contribution of both factors as they are distinct but overlapping conditions (Wood & Williams, 2007;

Honkalampi et al., 2000). Studies on psychiatric patients treated for depression resulted in decreased scores post-treatment, but alexithymia scores remained unchanged (Taylor, Bagby & Parker, 1997). The reduced awareness of feelings in alexithymia can compound depression in TBI patients, increasing suicide ideation (Wood, Williams & Lewis, 2010). Being able to tease alexithymia and depression apart would substantially facilitate treatment and therapeutic interventions, in addition to improving diagnostic accuracy.

While depression and alexithymia are closely related (Leweke, Leichsenring, Kruse & Hermes, 2012; Conrad et al., 2009; Honkalampi et al., 2000) they are dissimilar in some ways. Anti-depressants and/or psychotherapy (e.g. cognitive behavioural therapy) are considered most efficacious in treating depression (Kupfer, Frank & Phillips, 2012). Difficulties in self-reflection in alexithymia make psychotherapy ineffective (Ogrodniczuk, Piper & Joyce, 2010; Taylor, Bagby & Parker, 1997; Krystal, 1988) and it is not a condition resolved by medication. Disregarding TBI, depression is more common in females (Kupfer, Frank & Phillips, 2012) while alexithymia is more predominant in males (Levant, Hall, Williams & Hasan, 2009; Honkalampi et al., 2000). Depression impairs cognitive and executive function (Gotlib & Joormann, 2010), while alexithymics are typically unimpaired intellectually, often using their strong cognitive skills to compensate for their lack of emotional awareness (Krystal, 1988).

In short, alexithymia shows how a lack of consciousness affects emotion; depression reveals how emotional disruption affects consciousness. Investigating how they interact would provide informative clues on the relationship between emotion and consciousness in TBI.

1.6 MUSIC

Like consciousness, theories on musical origins and functions abound (Perlovsky, 2010; McDermott & Hauser, 2005; Huron, 2001; Trainor & Schmidt, 2003; Trainor, 2008), but it is undisputed that music and emotions are intricately bound together. Music automatically evokes emotions (Jäncke, 2008), and the endurance of music in civilization is due to its emotional roots (Peretz, Gagnon & Bouchard, 1998). Friedrich Nietzsche and Leonard Meyer famously declared music to epitomize emotional expression (Levitin & Tirovolas, 2009).

Compared to language, musical meaning is commonly not learned – it is generally innate, not domain specific (Peretz, 2006; Magee, 2005; McDermott & Hauser, 2005) and encompasses more brain areas than language (Peretz & Gagnon, 1999). Music appreciation is also immediate, requiring minimal effort or awareness (Molnar-Szakacs & Overy, 2006; Peretz, 2002). Therefore, music provides a non-verbal alternative to language for communicating concepts and meaning (e.g. language deficient populations like aphasics), in addition to being a fitting platform to assess emotion (Painter & Koelsch, 2011; see Koelsch, 2011 for examples of music conveying meaning without emotion, e.g. harmonic integration of musical units).

The intimate relation between music and emotion is closely associated with the role of music. Music is sometimes considered to have a cultural rather than evolutionary origin, with Pinker declaring music to be a pleasurable by-product of language with no evolutionary role and thus dispensable in life (Pinker, 1999, c.f. Allen, 2010); a view that could generously be referred to as myopic. Although no strict consensus has been reached, many theories appear to favour music as a product of biological evolution either directly or indirectly. As music is an 'honest signal' (the intentions and qualities of the source are clear and apparent to the recipient), it fosters coherence and interaction (Perlovsky, 2010), being less susceptible to feigned sincerity compared to language (Levitin, 2008). This social factor gives music an influential role in communication and bonding (Wallin, Merker & Brown, 2000; Trainor & Schmidt, 2003), which leads to increased survival (Huron, 2001; Trainor, 2008; Peretz, 2006).

Infant-directed singing and infant-related speech ('motherese') exemplify the earliest form of music and communication and occur prior to the development of language (Trainor & Corrigall, 2010). The effective emotional expression in 'motherese' proved to be the determining factor in regulating emotions in infants who are unable to do so themselves (Trainor, Austin & Desjardin, 2000; Trainor & Schmidt, 2003). Likewise, this observation is echoed in the predominance of music in social gatherings (e.g. dancing, singing), uniting and strengthening group ties through emotional contagion (i.e., instinctive tendency to mirror and match the actions of another, resulting in emotional connectedness) (Hatfield, Cacioppo

& Rapson, 1994, c.f. Peretz, 2006). Indeed, music cannot exist without movement (be it movements to produce the music or dance) (Levitin & Tirovolas, 2009), with Trainor (2008) advocating that how we move affects rhythm interpretation, not the other way around.

While music and language share many similarities and some overlap in neural correlates due to their auditory and social nature (see Koelsch, 2011; Patel, 2011; Milovanov & Tervaniemi, 2011 for reviews), there are studies showing how music and language are still distinct with dedicated networks (Peretz, in press) or at least, distinct in content (Patel, 2011). Jean-Baptiste Bouillaud was the first to report the dissociation of both functions as evidenced in the sparing of music but not language abilities in a brain damaged patient in 1865 (Peretz, Champod & Hyde, 2003). Alternatively, congenital and acquired amusia (tone deafness) occurs when individuals are deficient in musical but not language abilities (congenital being present from birth, acquired resulting from brain injury) (Peretz, in press).

In this view distinguishing music and language networks, pre-processed acoustic aspects of auditory signals are sent to both music and language domains to start, with differentiation occurring based on each domain's specialization for specific aspects of the signal (see Figure 1.2). The melodic (pitch) and temporal (timing) route represents the "what" and "when" events of auditory signals, and it is apparent how brain injury could affect one pathway and not the other, producing specific deficits. Amusia or tone deafness is caused by impaired

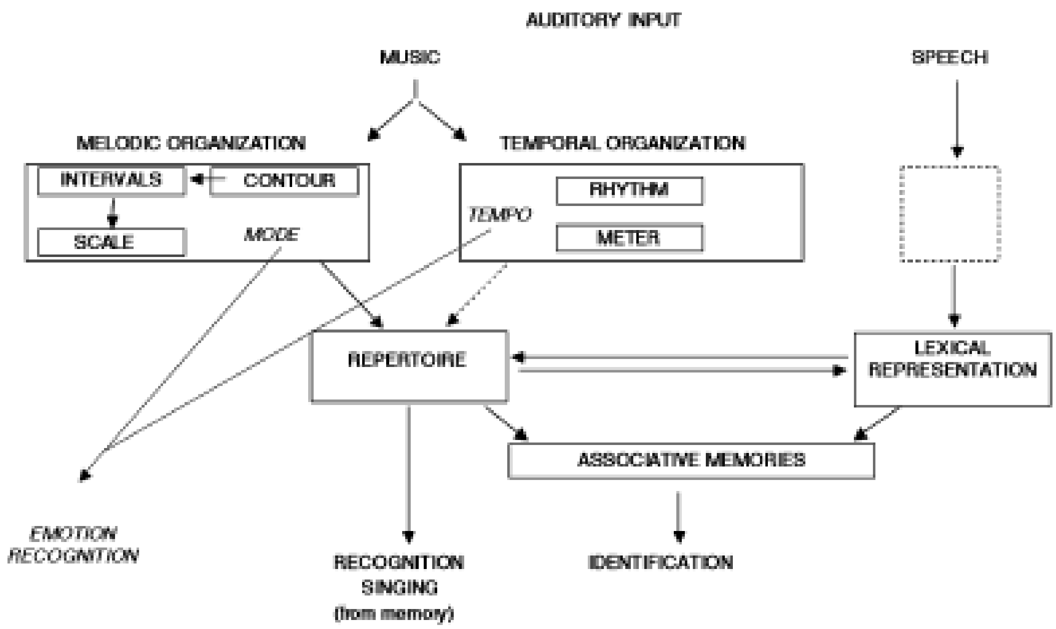

Figure 1.2 Musical recognition processes. The components involved in emotional recognition (mode and tempo) are in italics (Taken from Peretz, Champod & Hyde, 2003).

melodic processing in music (Peretz, Champod & Hyde, 2003); specifically pitch (Peretz, in press). However, brain damaged tone deaf patients were demonstrated to have normal emotional recognition (i.e., recognizing emotions expressed in music) for melodies, but deficient recognition for familiar and unfamiliar melodies (Peretz & Gagnon, 1999; Peretz, Gagnon & Bouchard, 1998; Peretz, 1996; Peretz et al. 1994). This dissociation shows the distinction between the cognitive (identification) and emotional (emotional evaluation) processing in music, with the emotional processing in music being more preserved and basic. Recently, Moreau, Jolicœr & Peretz (2013) also found pitch differences were detected at a pre-attentive (normal mismatch negativity (MMN) response indicating pre-conscious auditory processing) but not during a later, more conscious stage (absent P3b response indicating stimulus recognition) in tone deaf individuals.

Notably, mode or scale (melodic and harmonic combinations of pitch intervals in a musical fragment, e.g. major, minor) and tempo (beats per minute, e.g. fast, slow) are most commonly used for emotional recognition (Peretz, Gagnon & Bouchard, 1998; see also Figure 1.2). As seen in Moreau, Jolicœr & Peretz (2013), pitch accessibility is unconsciously processed in tone deaf individuals suggesting rudimentary processing via the emotional recognition route, although emotional recognition can also take place via the temporal domain. Emotional judgments are more basic and rapid compared to cognitive judgments, more indicative of an affective than cognitive system (Zajonc, 1980;

1984, c.f. Peretz, Gagnon & Bouchard, 1998), and can even influence cognitive performance unconsciously (Peretz et al., 1994 & Peretz, 1996).

Therefore, the emotional recognition stage of music presents a suitable and measurable platform for addressing the targeted level of emotional consciousness in TBI patients.

1.7. THESIS EXPERIMENTS AND OBJECTIVES

This thesis examines how music measures emotion using ERPs, by systematically comparing participant groups (differing in emotion and consciousness levels) who all perform the same experimental task. The ultimate objective of these experiments is its clinical application to examining emotion and consciousness in TBI patients.

In Chapter 2, a normative database of control individuals' brain responses is established as they perform a musical emotion perception task. The experimental task's reliability, accuracy and efficacy in reflecting musical emotion perception is measured by particular ERP components and validated by the behavioural experiment. This chapter serves to outline the *modus operandi* in tackling the experimental question, as well as being the baseline group to which each subsequent chapter/group is compared.

In Chapter 3, the performance of alexithymic individuals is examined in comparison to the baseline group. Hence, this chapter isolates the effects of alexithymia, enabling the nuances of decreased consciousness on emotion and its subsequent effects on musical emotion perception to be ascertained. The sensitivity of the experimental task in indicating alexithymia is also investigated.

Chapter 4 focuses on responses in individuals with depression. By comparing them with the baseline group, the effects of depression are isolated from that of the control group, revealing how impaired emotion influences consciousness and how these effects are reflected in musical emotion perception.

The combinations of both alexithymia and depression are examined in Chapter 5, where depressed alexithymic individuals are observed alongside the baseline group. This chapter probes the interaction, predominance and directionality of depression and alexithymia, and any conditional similarities/differences as they appear in combination or isolation (i.e., Chapter 3 and 4).

Having established normative ERP correlates and the influence of alexithymia and depression, Chapter 6 combines and considers these four participant groups together as a thesis participant database. The correlations of the behavioural scales with depression, alexithymia, mood and musical aptitudes are also examined. This chapter provides the frame to which condition and group differences are ascertained to determine alexithymia or depression’s role in the processing of musical emotion perception.

Finally, Chapter 7 will conclude the thesis by reviewing the thesis's main discoveries, novel aspects, significance and contributions to the current literature, as well as study limitations and future directions.

Chapter 2: Music as a measure of emotion: control individuals

"We judge by how we feel."

(Chung et al., 1996).

2.1 INTRODUCTION

2.1.1 *Basic emotion and emotional schemas*

While emotions have long been considered a part of human nature (Mashour & Alkire, 2013; Izard, 2012), the distinction between basic emotion and emotion schemas (emotional-cognition interactions) is important. Basic emotions (e.g. happiness, fear) develop earlier, constitute foundations for most emotional schemas, emphasize survival and initiate fast, often automatic reactions, unlike emotional schemas like jealousy. One does not learn to how to feel happy or angry, one just is – it is innate, although it can be influenced by the environment. Understandably, basic emotions are less frequently experienced in their "pure" entirety after early childhood as cognition assumes a more pervasive and dominant role in development (Izard, 2012; Krystal, 1988), colouring these experiences.

Alexithymia and emotional theories follow a similar trajectory in the increasing role of cognition and socializing in early childhood on emotional development. Cognition is required to effectively monitor and self-regulate emotions. Language acquisition permits the recognition of emotions as signals in guiding behaviour and forming strategies, enabling awareness of more complex emotional schemas (Taylor, Bagby & Parker, 1997). An inability to learn or form emotional-cognitive associations stunts emotional development and regulation, resulting in alexithymia, which will be further explored in Chapter 3.

A good example to illustrate this is remembering the attachment most of us had to a toy or object in childhood. The power of attachment is partly due to the symbolization of the object as a source of comfort and self-soothing (e.g. to sooth oneself after maternal separation), a crucial step in emotional development involving imagination and fantasy. Imaginary child play follows from this, and the inability to do so signals disrupted cognitive-emotional integration (Mayes & Cohen, 1992, c.f. Taylor, Bagby & Parker, 1997). Imagination also regulates emotion through dreams, in part through event organization and storage in long term memory (Chow et al., 2013; Taylor, Bagby & Parker, 1997) and impulse control and symbolic operations (Solms, 1995, c.f. Krystal, 1988). Impairment in imagination, fantasy and dreaming reflects deficient *internal* regulation of *sentiments* in alexithymia, who resort to *external* regulation of *sensations* (Krystal, 1988). In contrast, regular individuals effectively use cognition to regulate emotion and emotion to guide cognition in successful emotional regulation.

Hence, this thesis chose to study basic rather than complex emotions as they are more separable from cognition and involves a “purer” form of emotion. Although some may argue that basic emotions are stereotypical and completely unconscious due to the automaticity of their responses, the fact that basic emotions are to some extent (not completely) amendable to cognition shows they may be more conscious than previously thought. For instance, hearing a noise in a dark alley may trigger our fight-or-flight system, but we are able to laugh instead when we realize it was a racoon trapped in a dustbin. Moreover, one can laugh, yell or remain passive in response to a basic emotion like anger. If basic emotions were truly unconscious or automatic reflexes, these response variations and modifications would not be possible (Izard, 2012; LeDoux, 2012; Tsuchiya & Adolphs, 2007). Yet, the role of cognition is limited, as no amount of thought can eliminate the initiation of the fight-or-flight response.

Dreaming is a good example of the prevalence of emotion as a more primitive consciousness level, given the lack of external stimuli and cognitive regulation. The emotions experienced in dreams are often as or more intense than when awake due to the lack of cognitive inhibition and influence of the external environment on the affective system (although their conceptualization and goal-directed reference may differ), and this cortical suppression on primarily cognitive neural networks (Kirov et al., 2012, c.f. Linquist et al., 2012) may also account for the lack of dream recall. Taken together, studying basic emotion presents the best balance of minimal cognitive influence, yet is not a completely reflexive and unconscious process. This equilibrium makes basic emotion a valid measure of emotion and the point of consciousness (i.e. awareness) of most relevance in TBI patients.

2.1.2 *Musical perception*

Like language, music is capable of communicating meaning, but "meaning" does not translate directly in both domains. Obviously, we do not use music to deliver lectures. Jackendoff and Lerdahl (2006) posit that music is meaningful in that it produces an affective impression in the listener, and McDermott & Hauser (2005) states that music is more associated with pleasure than communication. Music may reinstate rather than represent the original experience (Taylor, Bagby & Parker, 1997), being typically approached in a different context, much like a framed picture. We can lose ourselves (e.g. singing in the shower) or remain detached (e.g. humming in class) when listening to music – either instances produce different emotional experiences, but the realization of the musical context or frame remains unchanged (Jackendoff & Lerdahl, 2006). This approach allows the distinction between musical emotion perception (perceiving emotions expressed in music) and induction (feeling the emotion induced by music), processes that are typically overlooked and confused in the literature (Juslin & Västfjäll, 2008; Gabrielsson & Juslin, 2003). It is entirely possible for one to perceive or recognize an emotion in music without necessarily feeling it (Juslin & Västfjäll, 2008; Kalinen & Ravaja, 2006).

This thesis focuses on musical emotion perception as it is more basic, quicker and less ethically binding than musical emotion induction (i.e., inducing positive or negative emotion in patients may not be considered acceptable) and can be more objectively examined. These factors become crucial when considering TBI patients, who fatigue easily and may not want to have emotions induced. Perception of musical emotion is relatively similar and accurate across age, culture and musical preferences (Hopyan, Laughlin & Dennis, 2010) and is less susceptible to individual differences. Perceiving emotions in music is naturalistic, being a primary reason why people listen to music (Peretz 1998; Lima, Garrett & Castro, 2013). Crucially, musical emotion perception was found to be preserved even in a tone deaf brain-injured patient (Peretz & Gagnon, 1999), thereby increasing the generalizability of this paradigm even in tone deaf individuals, or TBI patients who may have acquired tone deafness due to their injuries (see Peretz, Champod & Hyde, 2003). Moreover, the Montreal Battery of Evaluation of Amusia (MBEA) does not cover all musical perceptual aptitudes, particularly emotional appreciation (Peretz, Champod & Hyde, 2003).

Musical emotion perception can be examined using the affective priming paradigm, where an emotionally pleasant stimulus (prime) facilitates the recognition of a subsequently valenced stimulus (target) (see Schirmer, Kotz & Friederici, 2005 for review). Although conceptually comparable to semantic priming in language, affective priming taps emotion – particularly when paired with strategic instructions. Hence, it was decided that this thesis would utilize music-based affective priming measures to examine emotional processing.

2.1.3 *ERP affective priming: musical emotion perception*

ERP research in this domain has remained primarily cross-modal (visual-auditory), confined to healthy individuals and directed at semantic meaning rather than emotion (Painter & Koelsch, 2011; Steinbeis & Koelsch, 2009; Daltrozzo & Schön, 2009; Koelsch et al., 2004; Sollberger, Reber & Eckstein, 2003). Therefore, the focus has been on the N400 ERP component, which indexes semantic integration, being larger to semantic incongruence (Kutas & Federmeier, 2011). Still, emotions are most typically employed to convey musical meaning (Painter & Koelsch, 2011). The factor that fundamentally determines the transmission of musical meaning (e.g. cognition or emotion) is not the paradigm or stimuli, but rather the experimental instructions.

The vital role of instructions in influencing the nature of responses to music has been demonstrated in control and alexithymic individuals (Goerlich, Witteman, Aleman & Martens, 2011; Goerlich et al., 2012). As with other studies, participants heard music or prosodic (positive or negative pseudowords uttered in happy or sad prosody) primes followed by visual positive/negative word targets (and its reverse condition), but were specifically instructed to rapidly and precisely judge the valence (happy/sad) of the word/music/prosodic targets (affective categorization). Alexithymic individuals showed reduced sensitivity (smaller N400 amplitudes) to affective priming only to music/prosodic targets primed by visual words, but alexithymia did not influence N400 amplitudes when visual word targets were primed by music/prosodic primes. This observation is logical as alexithymics have difficulty identifying and verbalizing emotional information from non-lexical stimuli (music/prosodic targets), but not word targets as the emotion is already stated (Goerlich, Witteman, Aleman & Martens, 2011). Given this effect was not observed in control individuals in the same study, it demonstrates how strategic instructions can elicit and differentiate emotional from cognitive response in affective priming (Goerlich et al., 2012).

Two important points can be taken from Goerlich, Witteman, Aleman & Martens' (2011) study: 1. When instructions emphasize affective categorization rather than conceptual comprehension, the N400 may not be a suitable measure. 2. Visual examination of the waveforms of the musical and prosodic prime conditions revealed a distinct, earlier negative peak (350-400ms) before the N400, which was not evaluated or included in statistical analysis. This earlier peak is likely to be the N300, which has been linked to the evaluation of emotional prosody (Pinheiro et al., 2011; Kotchoubey et al., 2009; Bostanov & Kotchoubey, 2004) and categorization of similar and dissimilar musical patterns (Neuhaus, Knösche & Friederici, 2009) in the auditory domain.

One postulated function of the visual N300 is its sensitivity to affective valence (Carretié, Iglesias, Garcia & Ballesteros, 1996) and emotional facial expressions (Campanella, Vanhoolandt & Phillipot, 2005; Luo et al., 2010; Lu, Zhang, Hu & Luo, 2011), and its decreased susceptibility to cognitive modulation compared to the subsequent P300 (Carretié, Iglesias, Garcia & Ballesteros, 1996; Campanella, Vanhoolandt & Phillipot, 2005). Thus, it is our hypothesis that the

N300 reflects an emotional categorization process. Considering categorizing something makes it meaningful (Linquist et al., 2012), the observed susceptibility of the N300 to experimental instructions (Goerlich, Witteman, Aleman & Martens, 2011) and that the N300 precedes the P300 (a component thought to constitute the initial point of consciousness (Kouider et al., 2013)), the N300 likely constitute a semi-conscious component. The choice of this term reflects the continuum that is consciousness. The N300 is similar to the N400 in that it is larger to incongruence, as seen larger responses in the incongruent categorization of emotional valence in emotional word primes and prosody targets (Bostanov & Kotchoubey, 2004) and music primes and word targets (Morgan, Choy & Connolly, 2012) compared to congruent conditions.

2.1.4 *The N300, P300, N400: emotional processing gradient?*

ERP research on affective picture processing has found it to start early, span several processing stages, be relatively sustained and modulate component amplitudes rather than latencies (see Oloffson, Nordin, Sequeira & Polich, 2008 for review). Valence (e.g. positive, negative) primarily influences earlier and middle latency components (~200-400ms) while arousal (e.g. high, low) results in positive shifts in the middle and later components. Although these two properties typically interact, valence is processed before arousal (Lithari et al., 2010; Gianotti et al., 2008; Oloffson, Nordin, Sequeira & Polich, 2008). This interaction stage – particularly the arousal portion – is encapsulated in the P3b (i.e., the later component of the P300) which is associated with immediate memory, task relevance and decision making (Oloffson, Nordin, Sequeira & Polich, 2008; Delplanque et al., 2006). The P300 is larger to congruence as responses are larger to reoccurrences of an item (reflecting context updating and recognition) than new items (Polich, 2012), being sensitive to task relevance (Oloffson, Nordin, Sequeria & Polich, 2008). In this manner, the P300 differs from the N300 and N400 (which are larger to incongruence).

Taken together, the affective processing stages of interest can be traced from the N300 (emotional valence categorization) and the subsequent P300 (emotional recognition of stimuli). Reconciling with the previously mentioned music-based literature, the N400 would consequently reflect emotional meaning or integration. In the context of this thesis, the N400 would reflect extra-musical indexical meaning, where music points to the presence of an emotion (Koelsch, 2011). This gradient in affective processing also provides correspondence to increasing consciousness (i.e., awareness) and would be considerably more informative in reflecting different stages of emotional processes than studying a single component. For instance, three categories of concept communication in music have been proposed – notions from musical structure that are not verbalizable, concepts from emotions that can or cannot be verbalized, and notions from semantic associations that can be verbalized (Patel 2008, c.f. Daltrozzo, Tillmann, Platel & Schön, 2009).

As previously mentioned, all studies conducted thus far have been cross-modal. In developing a measure that ultimately will be used in brain injured or

TBI patients, we have pioneered a music-based ERP affective priming paradigm exclusively in the auditory domain and began the development of a normative database with control individuals (Morgan, Choy & Connolly, 2012 in preparation). Visual stimuli can be missed easily or ignored (e.g. by closing one's eyes) and visual deficits are common in TBI, in addition to problems detecting visual acuity in TBI patients. Audition is a more reliably assessed modality in TBI (Gustoff, 2002), and auditory stimuli are better than visual in being able to express emotion (Gabrielsson & Juslin, 2003). The merits and significance of the auditory modality in TBI will be further elaborated in Chapter 7.

Our normative study (Morgan, Choy & Connolly, 2012) used music primes (happy, sad) paired with word targets (spoken words "happy", "sad") that were either emotionally congruent (happy prime, happy target) or incongruent (happy prime, sad target). Participants were instructed to mentally decide if the music and word stimuli matched or not according to emotional valence. Happy and sad emotions were chosen as they are the most common and easily classified emotions in music (Mohn, Argstatter & Wiler, 2011; Vieillard et al., 2008), with this discrimination being demonstrated even in 9 month old babies (Flom, Gentile & Pick, 2008).

Both ERP and behavioural responses were recorded to investigate participant performance as thoroughly as possible (Morgan, Choy & Connolly, 2012). Typically, ERP data are examined only to those trials that the participant responds to correctly (as defined by a behavioural response such as a button press). This analysis procedure is based on the observation that certain cognitive ERP components (e.g. P3b) known to reflect correct identification of a stimulus, do not occur if the participant fails to recognize a stimulus as correct (Connolly, Major, Allen & D'Arcy, 1999; Connolly, Mate-Kole & Joyce, 1999). However, other research has demonstrated that additional insights on participant performance can be obtained by comparing these "accurate" ERPs to those ERPs that include inaccurate trials (see Connolly, Major, Allen & D'Arcy, 1999).

Therefore, data in Morgan, Choy & Connolly (2012) were analyzed according to three procedures so that ERPs were formed with trials that were 1) categorically correct (CC) as determined by experimental design irrespective of the participant's behavioural response; 2) behaviourally correct (BC) as determined by the participant's correct (based on the experimental design) behavioural response; and 3) subjectively correct (SC) as determined by trials the participant considered to be correct regardless of the experimental design. Thus, if a participant decided a prime-target pair matched in emotional valence, that trial would be considered a congruent trial even if that prime-target pair was experimentally assigned to be incongruent (see Painter & Koelsch, 2011). Simply put, the three analyses differ in their consideration of the participant's behavioural response and the experimental design in determining a correct response. CC analyses only considers the experimental design, BC considers both the participant's behavioural response in line with the experimental design and SC only looks at the participant's behavioural response.

Comparing these analyses was crucial because they reflect quite different measures of cognitive and behavioural processes during the task. The CC condition represented what ERPs would look like for patients incapable of responding behaviourally, BC depicts the usual ERP analysis method and SC would most closely reflect participants' intended response due to the highly subjective nature of music (e.g. one could more easily interpret a less intense sad musical stimulus as happy, but it would be considerably harder to interpret the word "sad" as "happy"). Ultimately, CC and SC was found to share good overall consensus and consistency, with BC being less consistent due to reduced signal-to-noise ratio power resulting from exclusion of categorically incorrect trials. This result (particularly the similarity of CC and SC analyses) enabled us to adopt the CC analysis strategy (recording ERP responses on each trial regardless of participant performance accuracy) in this thesis in establishing a more complete database that will be used for reliable and accurate comparisons with TBI patients.

2.1.5 *Film music, music-word and music-music paradigm*

In order to reduce the variability in musical emotional expression ratings, the current thesis focused on using film instead of classical music. Film music is created specifically to express emotions effectively, yet remain neutral in terms of musical genre, preferences and familiarity (Eerola & Vuoskoski, 2011; Vieillard et al., 2008). The selection of film music is a departure from the predominantly classical musical repertoire used in the field (Eerola & Vuoskoski, 2011) and would therefore have more ecological validity and generalizability.

As discussed, the essence of music is communicative but in a manner different from language. Cross (2008) notes the complementary role of language and music in the development of culture. While language facilitates information transfer due to its precision and specific goals, it can also aggravate conflicts for the very same reasons. On the other hand, music is less specific in its goals and capitalizes on social and shared intentions. Moreover, it is sometimes difficult to verbalize musical emotions and this margin of subjectivity is useful in reducing cultural conflict (Perlovsky, 2010). To account for and examine these subtle differences, the current thesis adopted two paradigms: music-word (as before and widely used in the literature) and music-music. Inclusion of both paradigms provides a gradual transition to an exclusively non-verbal musical paradigm.

To date, the music-music paradigm has not been investigated with ERPs or in an affective priming context, likely due to the predominant use of cross-modal paradigms in the literature. Painter and Koelsch (2011) employed a condition in a traditional cross-modal design when they studied musical/non-musical timbre sounds in one of their four experimental conditions (sound-sound, sound-word, word-sound, word-word). Even so, their study explicitly explored how basic sounds can activate meaningful concepts independent of musical context or emotional valence. Once again, we noted two significant observations from Painter and Koelsch's (2011) study: 1. All conditions resulted in similar meaningful processing of the target stimuli (reflected by the N400). 2. An earlier, negative-going peak preceding the N400 beginning at approximately 250ms (likely the N300) was noted on visual inspection but excluded from statistical analyses. Therefore, the results indicate that purely non-verbal (sound-sound) stimulus pairs convey meaning similar to verbal (word-word) or verbal-non-verbal (word-sound, sound-word) stimulus pairs, and the N300 is elicited in both domains. However, the *extent* of similarity between communication in both domains (i.e., music and language) remains to be seen, as evidenced by the studies below.

Despite neural overlap in language and musical syntax, differences in intracranial EEG activation strength and latency were observed, suggesting different degrees of automaticity and involvement of volitional processes (Sammler et al., 2012). In examining concurrent syntactic processing in music and language using ERPs, Maidhof and Koelsch (2011) found language syntactic processes to be less influenced by attention and were more automatic compared to music syntactic processes. As the focus was on pragmatic rather than emotional communication, it was not surprising for language processes to be less effortful given they operate similarly with the experimental context (e.g. comparing syntactically congruent and incongruent sentences/musical chords is more compatible with language processing than music) and our higher familiarity with language (Maidhof & Koelsch, 2011). In this case, musical stimuli would need to be modified to operate in a similar context, resulting in less automaticity.[1]

[1] I am grateful to Dr. Laurel Trainor for suggesting this.

Considering our focus on emotion conveyance and perception, a property more inherent and functional to music compared to language (Lima, Garrett & Castro, 2013); it is reasonable to surmise that the opposite pattern of automaticity would manifest with our affective priming paradigms. In other words, musical emotion perception in the music-music paradigm (within/intra domain) would be more automatic and facilitated compared to the music-word paradigm (between/inter domain), further enhanced by the nature of our task (prime-target association, as opposed to processing sentence/musical chord sequence).

2.1.6 *Study aim and hypotheses*

The objectives of this study are to: 1) Investigate music as an index of emotion using ERPs by examining musical emotion perception in affective priming of music-word and music-music paradigms with film music; 2) Examine any musical emotion perceptual differences between music-word and music-music paradigms by testing control individuals; and 3) Establish a database of normative brain responses for comparison with other groups (alexithymic, depressed, depressed alexithymic). By using ERPs and strategic instructions, the hypothesized stages involved in musical emotion perception (e.g. emotional categorization, recognition and meaning) would be reflected by the N300, P300 and N400 respectively, providing a corresponding, increasing gradient of consciousness. Participants will be instructed to decide on each trial if the emotion expressed by the preceding musical stimulus matches that of the following spoken word (music-word paradigm) or musical stimulus (music-music paradigm), which can either be emotionally congruent or not.

To ensure the effectiveness of both paradigms, a behavioural portion of the experiment was conducted separately from the ERP portion with different participants. The difference between the behavioural and ERP experiment was that the former had participants indicate stimulus emotion match/mismatches with a mouse click, while the latter experiment required they make judgements mentally. Although it could not be tested directly, it was expected that both paradigms would result in similar accuracy and priming rates (see Painter & Koelsch, 2011), with emotionally congruent trials being identified faster and more accurately than emotionally incongruent ones – the general finding in the priming literature.

The ERP study's hypotheses were generated after considering the previous literature (Morgan, Choy & Connolly, 2012; Goerlich, Witteman, Aleman & Martens, 2011; Painter & Koelsch, 2011). Although the N300 and N400 reflect different processes (emotional categorization and meaning respectively), it is expected that the experimental manipulation would affect them in a similar fashion. The first hypothesis is that larger N300 and N400 responses will be emitted to emotionally incongruent trials (reflecting ease of integration in emotional categorization and meaning respectively) and larger P300 responses will be found to emotionally congruent trials (reflecting emotional recognition). These responses would provide the ERP gradient of emotional processing.

The second hypothesis is that ERP and behavioural response differences between the music-word and music-music paradigms will be observed, with the music-music paradigm operating with a higher degree of automaticity (i.e., more similar ERP waveforms and amplitudes) than the music-word paradigm (i.e., more differentiated ERP waveforms and amplitudes) due to the emphasis on emotion perception and paradigm context that is more comparable to musical functions. These differences would provide further insight into the functions tapped, inter and intra-domain differences and how reliably they are represented.

2.2 METHODS

2.2.1 *Stimuli and materials*

The auditory affective priming paradigm was modified for use in TBI patients from Morgan, Choy & Connolly (2012). The original paradigm in Morgan, Choy & Connolly (2012) was modelled after Koelsch et al. (2004) and Goerlich, Witteman, Aleman & Martens (2011). The present study consisted of two separate paradigms: 1) music-word (music prime and spoken word target) and 2) music-music (music prime and target).

Stimuli consisted of 200 final samples of happy and sad musical orchestral excerpts (duration ~1000 milliseconds (ms) each) and spoken words “happy” and “sad” (~200 ms each) by a native Canadian male speaker using a neutral prosody. Music stimuli for the present study were sampled from an established set of instrumental film music excerpts, selected and rated by 12 expert musicologists for optimal emotion expression and controlled for familiarity (Eerola & Vuoskoski, 2011). Film period was constrained to the last 3 decades and ranged in genre to include sci-fi, comedy, romance, horror and drama (see Eerola & Vuoskoski, 2011 for details). Filler/neutral trials were omitted to avoid complicating the binary nature of the task (Schirmer & Kotz, 2003) for applicability in patient populations. Moreover, music is rarely emotionally neutral (Krumhansl, 1997; Peretz, Gagnon & Bouchard, 1998) and the term "neutral" does not constitute an absence of emotion, but rather the presence of an ambiguous few emotions (Dellacherie, Ehrlé & Samson, 2008).

Shorter music stimuli of 1000ms duration were sampled from the top rated tracks (10 to 30 seconds (s) each) in Eerola & Vuoskoski (2011) and rated separately again (to account for the shortened duration) for valence (i.e., how effectively they expressed happy and sad emotions). Ratings were done by a separate focus group of non-musicians (n = 8, 6 females, age range 19-30, M = 24 years). The final set of music stimuli was shortlisted based on high valence and accuracy scores. On a 5-point Likert scale (with 1 being very sad, 3 being ambiguous and 5 being very happy), happy music stimuli were rated 4.0 (SD = 0.38) and sad music stimuli were rated 2.0 (SD = 0.37) in valence respectively. Accuracy rates were 80.1% and 81.6% for happy (SD = 17.63) and sad (SD = 16.55) musical excerpts respectively. The 5-point scale was used (as opposed to 7-point or more) as it provides clearer and more reliable ratings (Eschrich, Münte

& Altenmüller, 2008). The complete list of musical stimuli details are listed in Appendix A.

For both paradigms, primes and targets were pseudo-randomly paired by valence (happy or sad) and congruency (match or mismatch) into 4 conditions (happy primes, happy targets [HH: happy]; happy primes, sad targets [HS]; sad primes, sad targets [SS]; sad primes, happy targets [SH]) of 50 prime-target pairings each. Two pseudo-randomized presentation orders were generated for each paradigm to counterbalance any order effects, although prime-target pairings remained unchanged. Musical excerpts were not repeated within a paradigm, and those from the same track or film (no more than 5 samples per track or film) were ensured not to appear successively or paired together. The same conditions did not occur more than twice in a row. Music primes and pairings were maintained for both paradigms, only substituting the word target for a similarly valenced (i.e., happy or sad) musical excerpt target in the music-music paradigm. For example, a happy music prime paired with a sad word target (HS condition) in the music-word paradigm would appear as the same happy music prime with a sad music target (HS condition) in the music-music paradigm.

All stimuli were edited using Audacity software (Version 1.3.12) (Boston, USA: Free Software Foundation, Inc.) where both channel input and volume were standardized. All musical excerpts had a 10 ms rise time applied at the start and end to prevent auditory startle and clicks. The inter-stimulus interval (ISI) between primes and targets was 800 ms, and the inter-trial interval was 4000 ms.

A white central fixation point (a plus sign) remained continuously on screen except during the 15 second (s) rest breaks, which occurred after every 40 trials. The stimuli were programmed and presented using Presentation software (Version 14.9) (Albany, CA: Neurobehavioural Systems, Inc.).

Participants were administered the lab's health questionnaire, Twenty-Item Toronto Alexithymia Scale (TAS-20) (Bagby, Parker & Taylor, 1994), Bermond-Vorst Alexithymia Questionnaire-B (BVAQ-B) (Vorst & Bermond, 2001) and Beck Depression Inventory II (BDI-II) (Beck, Brown & Steer, 1996), before the testing session. They filled out the Positive and Negative Affect Schedule (PANAS) (Watson, Clark & Tellegen, 1988) at the start and end of the testing session, and completed the Absorption in Music Scale (AIMS) (Sandstrom & Russo, 2011) and Ollen Musical Sophistication Index (OMSI) (Ollen, 2006) at the end of the experiment. Copies of most scales are listed in Appendix B.

2.2.1.1 *Alexithymia*. The TAS-20 is a 20-item self-report scale and the most established measure of alexithymia (Vermeulen, Toussant & Luminet, 2010; Taylor, Bagby & Parker, 2003). Items are grouped into three factors – difficulty identifying feelings, difficulty describing feelings and externally oriented thinking. Five items are negatively phrased (e.g. answers to questions are negative rather than affirmative). However, the TAS-20 does not distinguish between Type 1 (Affective, lack of emotional experience and regulation) and Type 2 (Cognitive, lack of emotion regulation) alexithymia as it excludes imaginative/daydreaming activities and only measures cognitive elements. The BVAQ-B was included to make this distinction, as well as to avoid using a sole measure of alexithymia (Taylor & Bagby, 2004; Kooiman, Spinhoven & Trijsburg, 2002).

While the complete BVAQ consists of the BVAQ (A+B) of 40 items, the BVAQ-B is more accurate than the BVAQ-A and sufficient in its own right without compromising the comprehensiveness of the complete BVAQ scale (Allen, 2010; Berthoz & Hill, 2005). It is also less susceptible to changes in emotional states compared to the TAS-20 (Deborde et al., 2004, cf. Allen, 2010). The BVAQ-B comprises a 20-item self-report scale with five subscales – poor verbalizing, fantasies, insight, emotional excitability abilities and concrete thinking abilities. Ten items are negatively phrased. The total scores for the verbalizing, insight and concrete thinking subscales corresponds to the cognitive elements (Type 1 alexithymia), which is comparable to the total score of the TAS-20 (Berthoz & Hill, 2005; Vorst & Bermond, 2001). The remaining subscales (fantasies, emotional excitability) constitute the affective dimensions (Type II alexithymia). Items in both the TAS-20 and BVAQ-B are rated on a five-point Likert Scale ranging from 1 (Strongly disagree) to 5 (Strongly agree). Total scores range from 20-100, with higher scores indicating high levels of alexithymia.

2.2.1.2 *Depression.* The BDI-II is an established 21 item self-report questionnaire indicating the presence and severity of depression in diagnosed patients and the normal population. Unlike its predecessors, the BDI-II includes the DSM-IV criteria for depression (Beck, Brown & Steer, 1996) and is demonstrably suited to identify depression after TBI (Homaifar, Brenner & Guitierre, 2009). Participants are asked to respond to statements based on how they feel over the past fortnight, where each statement corresponds to a depressive symptom. Items are rated on a four-point Likert Scale ranging from 0 (Absence) and 3 (Severe). Total scores range from 0-63, with higher scores indicating depression presence/severity.

2.2.1.3 *Mood.* The PANAS is a 20-item self-report scale and the most widely used scale to assess mood (Vermeulen, Toussant & Luminet, 2010). It correlates well with the BDI (Watson, Clark & Tellegen, 1988) and comprises of 10 positive and 10 negative emotional states statements. Items are rated on a five-point Likert Scale ranging from 1 (Not at all) to 5 (Extremely). Total scores range from 20 to 100, with higher scores indicating the predominant mood (positive or negative) at the start and end of the testing session.

2.2.1.4 *Responsiveness to musical emotion.* The AIMS is a 34-item self-report questionnaire specifically measuring and predicting an individual's emotional response to music regardless of musical training (Sandstrom & Russo, 2011). Items consist of statements on music and responses rated on a five-point Likert scale ranging from 1 (Strongly disagree) to 5 (Strongly agree). Total scores range from 34 to 170, high scores indicate strong emotional response to music.

2.2.1.5 *Musicality.* The OMSI is a 10-item self-report questionnaire consisting of a mix of short answer and multiple choice questions on musical sophistication. It assesses an individual's musical ability aside from musical training, which does not always satisfactorily classify musicians from non-musicians. Musical sophistication encompasses musical knowledge, instrument playing and singing aptitudes and musical activity, understanding, responsiveness and creation abilities (Ollen, 2006). Answers are scored according to a formula online (http://marcs-survey.uws.edu.au/OMSI/), where 500 was the cut-off score between a musician and non-musician.

2.2.2 *Participants*

28 healthy university students and staff participated in this McMaster University and Hamilton Health Sciences ethically approved study. Data from 4 participants were discarded due to excessive EEG drift, dependence on hearing aids and the inability to follow task instructions, leaving 24 participants (12 in the behavioural control group and 12 in the ERP control group). Recruitment was done through word of mouth, flyers, the university's student online forum and the lab and Linguistic Department's research participant databases, with selection based on eligibility for the aforementioned criteria and administered questionnaires. No participants reported any visual, hearing, neurological, psychiatric or cognitive problems, or any prescriptive medication use that would interfere with cognition and emotion as assessed by the lab's health questionnaire.

Participants self-reported abstaining from drugs and alcohol 24 hours preceding the experiment. All provided written consent and were either paid an hourly rate of $20 or received course credit for their participation. Non-musicians were tested as they constitute a majority of the population and perform musical perception on a more emotional level compared to musicians, who have a more technical focus (Peretz, Gaudreau & Bonnel, 1998; Eschrich, Münte & Altenmüller, 2008). The presence of alexithymia and depression were determined by the recommended cut-off points for the TAS-20, BVAQ-B and BDI-II scales respectively (Deborde et al., 2008 and Beck, Brown & Steer, 1996).

TAS-20:	Total score < 44	Non-alexithymic
	Total score > 56	Alexithymic
BVAQ-B:	Total score < 44	Non-alexithymic
	Total score > 53	Alexithymic
BDI-II:	Total score ≤13	Minimal depression
	Total score ≥ 14	Mild depression

The behavioural control group was meant to be a random sample of the population so was less stringent in its requirement of having non-alexithymic and non-depressed individuals as opposed to the controls for the ERP study. It did however have an equal number of control and alexithymic individuals, with 1 depressed and 1 depressed alexithymic (see Table 2.1). None of the controls for the ERP study were alexithymic or depressed.

Behavioural controls: Twelve participants (6 females), 11 whom were dextral (Edinburgh Handedness Inventory (Oldfield, 1971)) and 8 of whom were native

English speakers comprised this group (age range 20-29 years, M = 23.40). None were musicians (M = 125.58) as assessed by the OMSI scale, and all reported positive moods both at the beginning (M = 29.40/50) and 10 at the end (M = 24.08/50) of the experiment (2 females felt slightly negative and neutral respectively at the end of the experiment) according to the PANAS scale. Six were alexithymic as measured by BVAQ-B (M = 51.08) and/or TAS-20 (M = 50.75) scales, and 2 were depressed as measured by the BDI-II (M = 7.0) scale. One male and 1 female participant were less responsive to musical emotion (scoring less than 85 on the AIMS scale) compared to the rest (M = 105.30/170).

ERP controls: This subgroup consisted of 12 participants (6 females), 11 of whom were dextral and native English speakers. Ages ranged from 19 to 43 years old (M = 24.25). None were musicians according to the OMSI scale (M = 108.25) or depressed as measured by the BDI-II (M = 2.75). Their PANAS scores showed all had positive moods both at the beginning (M = 32.35/50) and end (M = 29.33/50) of the experiment. None were alexithymic according to the TAS-20 (M = 36.25) and BVAQ-B (M = 44.92) scales. Only three participants (2 males, 1 female) were less responsive to musical emotion compared to the rest as measured by the AIMS scale (M = 103.92/170). Table 2.1 lists the categorical scores for alexithymia and depression in the controls for the behavioural and ERP study.

2.2.3 *Task procedures*

Testing took place in the Language, Memory and Brain Laboratory in the Department of Linguistics and Languages. Participants were tested individually in a single session that took approximately 2 hours. Apart from the ERP control participants being fitted with an elastic cap containing electrodes (see Section 2.2.5 for details) before the testing session, all participants were seated comfortably in a chair approximately 1 metre (m) away from the computer screen.

Stimuli were presented binaurally through insert earphones adjusted to a comfortable hearing level (30-50 decibels (dB) sound pressure level) for the participants. Participants were instructed to listen to each stimulus pair and decide if the prime and target matched or not with regard to emotional valence (e.g. happy prime, happy target = match; happy prime, sad target = mismatch). This decision was indicated with a mouse click for the behavioural participants (hand order was counterbalanced) and done mentally for the ERP control participants. The administered order of the paradigms (music-word or music-music) was counterbalanced as well as the assigned randomized presentation order within each paradigm (music-word order 1, music-word order 2, music-music order 1, music-music order 2). The other unassigned randomized presentation order served as the practice trial for each participant, ending when the participant felt comfortable with the task. Upon completion of the first paradigm, participants had a brief break before starting the second paradigm. After the experiment, electrodes were removed (for the ERP controls) and participants were debriefed.

	Behavioural Controls (N = 12)	ERP Controls (N = 12)
TAS-20 non-alexithymic	6 (50%)	10 (83%)
TAS-20 intermediate	4 (33%)	2 (17%)
TAS-20 alexithymic	2 (17%)	-
BVAQ-B non-alexithymic	3 (25%)	5 (42%)
BVAQ-B intermediate	3 (25%)	7 (58%)
BVAQ-B alexithymic	6 (50%)	-
BDI-II minimal depression	11 (92%)	12 (100%)
BDI-II mild depression	1 (8%)	-

Table 2.1. Behavioural and ERP control group categorical scores for alexithymia and depression.

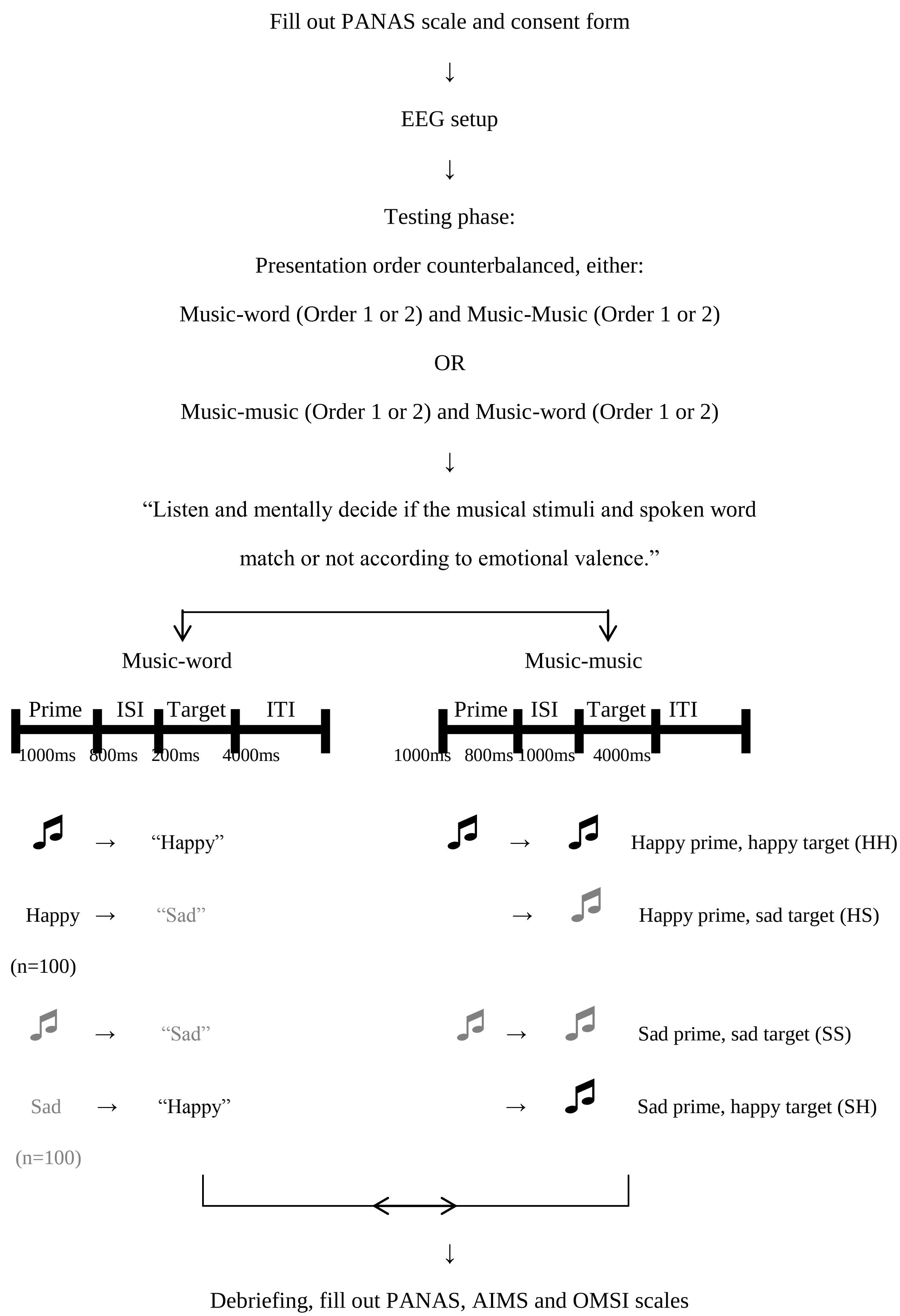

Figure 2.1. Thesis experimental design and procedure. Happy and sad stimuli are in black and grey respectively.

2.2.4. *Experimental design*

The experimental design of the behavioural and ERP study research was a 2 x 2 within subject auditory affective priming ERP study for the music-music and music-word paradigms. Independent variables were target valence (happy, sad) and prime-target congruency (congruent, incongruent). For the ERP study, the N300, P300 and N400 ERP components were analyzed separately. Figure 2.1 summarizes the experimental procedures and design.

2.2.5. *EEG acquisition and analysis*

Electroencephalography (EEG) was recorded using a BioSemi Headcap of 64 silver/silver chloride electrodes arranged according to the International 10-20 montage (http://www.biosemi.com/pics/cap_64_layout_medium.jpg), using the ActiView Active-Two amplifier system (Version 7.00) (Amsterdam, Netherlands: BioSemi). Additional electrodes were placed at the nose tip and mastoids for offline analyses. The electro-oculogram (EOG) was recorded from electrodes placed at the outer canthus (horizontal EOG) and above (vertical EOG) the left eye. The common mode sense (CMS) and driven right leg (DRL) electrodes (see above montage for electrode positions) served as the online reference and ground electrodes respectively (c.f. www.biosemi.com/faq/cms&drl.htm). Offsets were kept below 20 millivolts (mV). EEG and EOG were recorded with a band-pass of 0.01-100 Hertz (Hz) and a sampling rate of 512 Hz.

Data were digitally filtered offline between 0.1-30 Hz and referenced offline to the mastoids using Brain Vision Analyzer (Version 2) (Munich, Germany: Brain Products GmBH). EOG artefacts effects were corrected using the Gratton, Coles & Donchin method (Gratton, Coles & Donchin, 1983). EEG data were epoched from a baseline of 200 ms pre-stimulus to 1000 ms post stimulus target onset, with EEG deviations exceeding ± 100μV being excluded from analyses. ERP waveforms were generated by averaging epochs separately for each condition with the requirement that each condition had at least a 70% trial acceptance rate. Data from participants with lower trial acceptance rates were excluded from analyses. ERP components were quantified by calculating mean amplitudes across selected intervals. The N300 was scored as the most negative-going peak between 220-350ms, the P300 was scored as the most positive-going peak between 280-420ms and the N400 was scored as the most negative-going peak between 351-480ms (Duncan et al., 2009). The mean of data points within 70ms around that peak served as the amplitude measure for each component.

It was decided to address the thesis questions more precisely from a clinical perspective to prevent overwhelming the reader with information. Therefore, only selected analyses and comparisons will be presented and justified.

All reported results involve amplitude responses of three ERP components (N300, P300, N400) to the *target* stimuli after they had been primed by happy or sad music. Condition comparisons involving prime and target congruity (congruent, incongruent) and valence (happy, sad) are of interest. These condition comparisons are paired by holding either the prime or target constant to isolate the effect of target congruity effects with the context set by happy (HH/HS) and sad (SS/SH) music primes; or the effect of music prime/context congruity with happy (HH/SH) and sad (SS/HS) targets (see Section 2.3.2). Thus, HH and SS will be key comparators serving as baselines. For instance, when results for HH/HS are presented, the comparison involves the ERP components response to *happy* targets when primed by happy primes (H*H*) and the same component's response to the *sad* target when primed by happy primes (H*S*) – comparing responses while holding the prime constant to isolate and study the effects of target congruity.

The behavioural data will be presented first to demonstrate priming and accuracy effects. Statistical analyses were conducted using a 2 x 2 repeated measures analyses of variance (ANOVA) with condition congruence (congruent, incongruent) and valence (happy, sad) as factors, and when appropriate, the Greenhouse-Geisser correction accounted for violations of sphericity. Bivariate correlations were run using Pearson's correlation coefficient to examine correlations between accuracy and behavioural assessment scales.

ERP data were assessed in three stages. First, an overall sign test for the four conditions was carried out by visual assessment of each participant's individual waveforms for the N300, P300 and N400 components to determine the number of participants demonstrating the hypothesized response. This response included responses emitted in the correct, hypothesized condition regardless of whether or not it was statistically significant. In this way, the condition and component consistency can be ascertained, which is essential for comparison to a TBI patient on an individual case basis.

The 64 sites were grouped into 7 regions – left frontal (FP1, AF7, AF3, F1, F3, F5, F7), right frontal (FP2, AF8, AF4, F2, F4, F6, F8), left central (FT7, FC5, RC3, FC1, C1, C3, C5,T7, TP7, CP5, CP3, CP1), right central (FT8, FC6, FC4, FC2, C2, C4, C6, T8, TP8, CP6, CP4, CP2), left parietal (P1, P3, P5, P7, P9, PO3, PO7, O1), right parietal (P2, P4, P6, P8, P10, PO8, PO4, O2) and the midline (FPz, AFz, Fz, FCz, Cz, CPz, Pz, POz, Oz, Iz).

Second, statistical ANOVA analyses were conducted with condition (4 levels) and region (7 levels) as factors, with the Greenhouse-Geisser correction accounting for violations of sphericity in the ERP data when appropriate. Regional effects are of less importance than conditional effects as this thesis is more concerned with if, rather than where the response occurs. As we had specific hypotheses on conditional effects (i.e. the valence of the target and its congruency with the prime), additional 2 x 2 ANOVAs with the factors target condition valence (happy, sad) and congruency (congruent, incongruent) were run in the region where the component showed the highest mean amplitude (e.g. maximal distribution) after the initial omnibus ANOVA.

Finally, a paired samples t-test comparing the ERP grand averages for incongruent conditions (for the N300 and N400) and congruent conditions (for the

P300) with zero for each component was conducted to ensure component reliability and elimination from random noise.

2.3. RESULTS

2.3.1. *Behavioural*

Music-word paradigm: A main effect of congruence ($F(1, 11)=13.173$, $p=0.004$) showed priming occurred with responses occurring faster for congruent (1170.61ms) than incongruent targets (1251.6ms). Priming for happy targets (1165.7ms) were faster than sad targets (1256.6ms) as indicated by a main effect of valence ($F(1, 11)=33.839$, $p=0.0001$). The congruence x valence interaction ($F(1, 11)=6.54$, $p=0.027$) indicate priming occurred in happy targets only, as happy congruent targets (1033.49ms) were processed faster compared to happy incongruent targets (1298ms). Priming effects were more accurate for sad targets (90%) compared to happy targets (86.8%) as reflected by a main effect of valence ($F(1, 11)=21.35$, $p=0.001$). The congruence x valence interaction ($F(1, 11)=5.901$, $p=0.033$) show priming occurred in happy targets only, as happy congruent targets (92.8%) were more accurately identified than happy incongruent targets (80.8%). Mean accuracy and reaction time were 88.7% (SD=5.8) and 1216.5ms (SD=388.5) respectively, indicating high accuracy and task adherence. The fastest and most accurate conditions were happy-happy/HH and happy-sad/HS respectively. The slowest condition was sad-sad/SS and the least accurate condition was SH. Bivariate correlations run using Pearson's correlation coefficient did not find any significant correlations between accuracy scores and the behavioural assessment scales.

Music-music paradigm: A congruence x valence interaction ($F(1, 11)=6.771$, $p=0.025$) indicated priming occurred and was attributable to happy targets only, as happy congruent targets (1720.77ms) were processed faster than happy incongruent targets (1870.28ms). A main effect of congruence ($F(1, 11)=6.573$, $p=0.026$) show priming for congruent targets were more accurate (81.4%) than incongruent (75.6%) targets. Mean accuracy and reaction time was 79% (SD=6.6) and 1786.8ms (SD=474.5) respectively**,** also indicative of good accuracy and task adherence. HH was the fastest and most accurate condition. The slowest condition was SS and the least accurate condition was SH. As before, bivariate correlations run using Pearson's correlation coefficient did not find any significant correlations between accuracy scores and the behavioural assessment scales.

2.3.2. *ERP sign test*

The sign test compares two conditions by congruency to ascertain if component responses match the hypotheses. The term "condition comparisons" will be used to describe these evaluations (see page 56-57). The sign test determines the number of participants demonstrating the hypothesized response irrespective of its statistical significance. Thus, the condition and component consistency can be ascertained, which is essential for comparison to a TBI patient on an individual case basis. Data listed are based on site Pz, which best illustrates experimental effects in all the examined ERP components.

Music-word paradigm: Table 2.2a summarizes and lists the number of participants responding as hypothesized for each condition comparison and component for this paradigm. In almost all the controls, the N300 and N400 were larger to incongruent conditions and the P300 to congruent conditions in all comparisons as hypothesized except happy and sad word targets following happy music primes (HH/HS), where the N300 and P300 were uncharacteristically larger to congruent and incongruent conditions respectively. SS/SH was the condition comparison in which the greatest number of participants responded as hypothesized. HH/HS had the lowest number of participant responding as hypothesized. The N300 was the most reliably observed component by participant response numbers and the N400 in terms of participants responding as hypothesized; leaving the P300 component to be least reliably observed.

Music-music paradigm: Table 2.2b summarizes and lists the number of participants responding as hypothesized for each condition comparison and component for this paradigm. For most of the controls, the N300 and N400 were larger to incongruence and the P300 was larger to congruence as hypothesized only in happy music targets regardless of the music prime's valence (HH/SH) and happy and sad music targets primed by happy music (HH/HS). This dominance was reversed for sad music targets regardless of the music prime's valence

HH/SH			SS/HS			HH/HS			SS/SH		
N300 *	P300 **	N400 **	N300 **	P300	N400	N300	P300	N400	N300 ***	P300 *	N400 *
✓	✓	✓	✓	✓	✓			✓	✓	✓	✓
9/12	10/12	10/12	10/12	8/12	7/12	5/12	4/12	8/12	11/12	9/12	9/12

(a)

HH/SH			SS/HS			HH/HS			SS/SH		
N300	P300	N400	N300	P300	N400	N300 *	P300	N400 **	N300	P300	N400
✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
6/12	7/12	7/12	6/12	6/12	8/12	9/12	7/12	10/12	5/12	6/12	6/12

(b)

Table 2.2. Sign test results for ERP data for the control group in the (a) music-word and (b) music-music paradigms. Results matching (responses elicited in the correct direction, even if not statistically significant) and contrary to the hypotheses are marked ✓ and grey respectively, participant response numbers are listed in the bottom row and significance is indicated *p=0.073, ** p=0.019, *** p=0.003. Data listed are based on site Pz, which best illustrates experimental effects in all the examined ERP components.

(SS/HS) and both music targets primed by sad music (SS/SH), with the N300 and N400 being larger for congruent and the P300 larger for incongruent conditions. HH/HS was the condition comparison in which the most number of participants responded according to the hypotheses. SS/SH had the lowest number of participants responding as hypothesized. The N400 and N300 constituted the most and least reliably observed components respectively in terms of participant numbers responding as hypothesized.

2.3.3. *ERP statistics*

As we have specific hypotheses on conditional effects (i.e., the valence of the target and its congruency with the prime), additional 2 x 2 ANOVAs with the factors target condition valence (happy, sad) and congruency (congruent, incongruent) were run in the region where the component showed the highest mean amplitude (e.g. maximal distribution) after the initial omnibus ANOVA. Unless specified, all values reported assume sphericity criteria have been met by the data. The Greenhouse-Geisser correction is applied to account for violations of sphericity when appropriate.

Music-word paradigm

N300: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 53.78, p = 0.0001. Therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.37). A significant main effect for region found in the initial omnibus ANOVA

(*F*(2.24, 24.62)=7.17, *p*=0.003) reflected the left parietal distribution seen for this component (Figure 2.2a).

A condition x region interaction (*F*(18,198)=2.208, *p*=0.004) was found in the initial omnibus ANOVA. This interaction was analyzed further in a separate 2 (valence, happy vs. sad) x 2 (congruency, congruent vs. incongruent) ANOVA in the left parietal region. A main effect of congruence (*F*(1, 11)=8.165, *p*=0.0156) was found, reflecting a larger N300 to the incongruent versus congruent conditions (Figure 2.3a).

P300: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 47.12, *p* = 0.001. Therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.35). A main effect of region found in the initial omnibus ANOVA (*F*(2.07, 22.8)=4.471, *p*=0.022) was attributed primarily to increased amplitudes in the right central region (Figure 2.2b).

Further analyses were run in the right central region using a separate 2 (valence, happy vs. sad) x 2 (congruency, congruent vs. incongruent) ANOVA. A main effect of valence (*F*(1, 11)=6.19, *p*=0.0301) was found, reflecting a larger P300 to sad compared to happy valence target conditions (Figure 2.3b).

N400: Results did not reach statistical significance.

Music-music paradigm

N300: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 75.56, p = 0.0001. Therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.29). A significant main effect of region found in the initial omnibus ANOVA (F(1.76, 19.33)=10.267, p=0.001) reflected a predominantly left parietal distribution (Figure 2.4a).

P300: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 85.73, p = 0.0001. Therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.28). A main effect of region found in the initial omnibus ANOVA (F(1.65, 18.2)=8.281, p=0.004) reflected a predominantly right frontal distribution (Figure 2.4b).

Further analyses were run in the right frontal region using a separate 2 (valence, happy vs. sad) x 2 (congruency, congruent vs. incongruent) ANOVA. A valence x congruence trend (F(1, 11)=4.064, p=0.069) was found, attributable to a larger P300 to the happy congruent in comparison to the sad incongruent target conditions (Figure 2.3c).

N400: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 56.07, p = 0.0001. Therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.33). A main effect of region found in the initial omnibus ANOVA (F(1.97, 21.68)=6.712, p=0.006) was attributed primarily to a left parietal distribution (Figure 2.4c).

2.3.4. *Results summary*

The ERP sign test is a non-parametric test highlighting any median differences in two examined variables, showcasing the generalizability and reliability of the effect. The parametric ANOVA and corresponding contrast statistics deals with mean variances and if these variances are significantly different. Considering both methods enables a more comprehensive understanding of the results as both the average and median values are taken into account with the former providing an assessment of group behaviour and the latter an indication of the reliability of the measures at the individual subject level. Results were generally compatible between the ERP sign test and ANOVA statistics for all components and paradigms.

Music-word: The N300 was larger to incongruence than congruence across happy and sad word targets, indicating the music primes produced good priming effects regardless of valence in terms of emotional categorization. The P300 was larger to sad than happy valenced target words irrespective of congruency, suggesting sad target words are more readily identifiable than happy ones in terms of emotional recognition.

Music-music: The larger P300 response to happy congruent versus sad incongruent music target conditions suggests that congruency and happy valence specifically facilitate emotional recognition of music targets.

Figure 2.5a and 2.5b portrays the ERP responses for the music-word and music-music paradigms for the control group at site Pz. It is noteworthy that the statistical ANOVA results are based on regions where each component was maximally distributed, while the sign test and ERP figures are based on site Pz as it best illustrates experimental effects in all the examined ERP components and provides a standardized comparison measure across all participant groups.

2.3.5 *Paired samples t-test: component amplitude vs. zero comparisons*

Music-word

<u>N300:</u> A significant difference in N300 amplitude for incongruent (M= -1.91µV, SD=2.31) and baseline conditions was observed ($t(11) = -2.859$, $p = 0.016$).

<u>P300:</u> The P300 was significantly different in amplitude for congruent (M= 4.23 µV, SD=2.98) and baseline conditions ($t(11) = 4.927$, $p = 0.0001$).

<u>N400:</u> Results did not reach statistical significance.

Music-music:

<u>N300:</u> Results did not reach statistical significance.

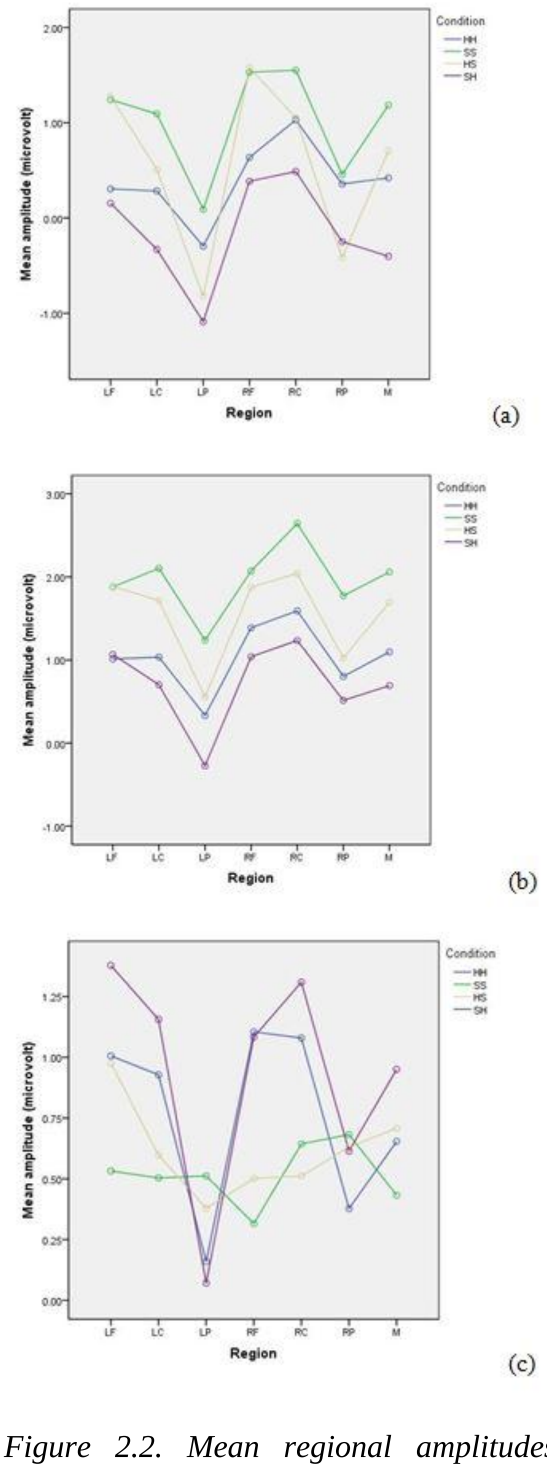

Figure 2.2. Mean regional amplitudes showing regions with the largest amplitudes in the music-word paradigm for the control group for (a) N300 (b) P300 (c) N400. Negative is plotted down. LF: left frontal, LC: left central, LP: left parietal, RF: right frontal, RC: right central, RP: right parietal, M: midline. Conditions Blue: HH, Green: SS, Yellow: HS, Purple: SH.

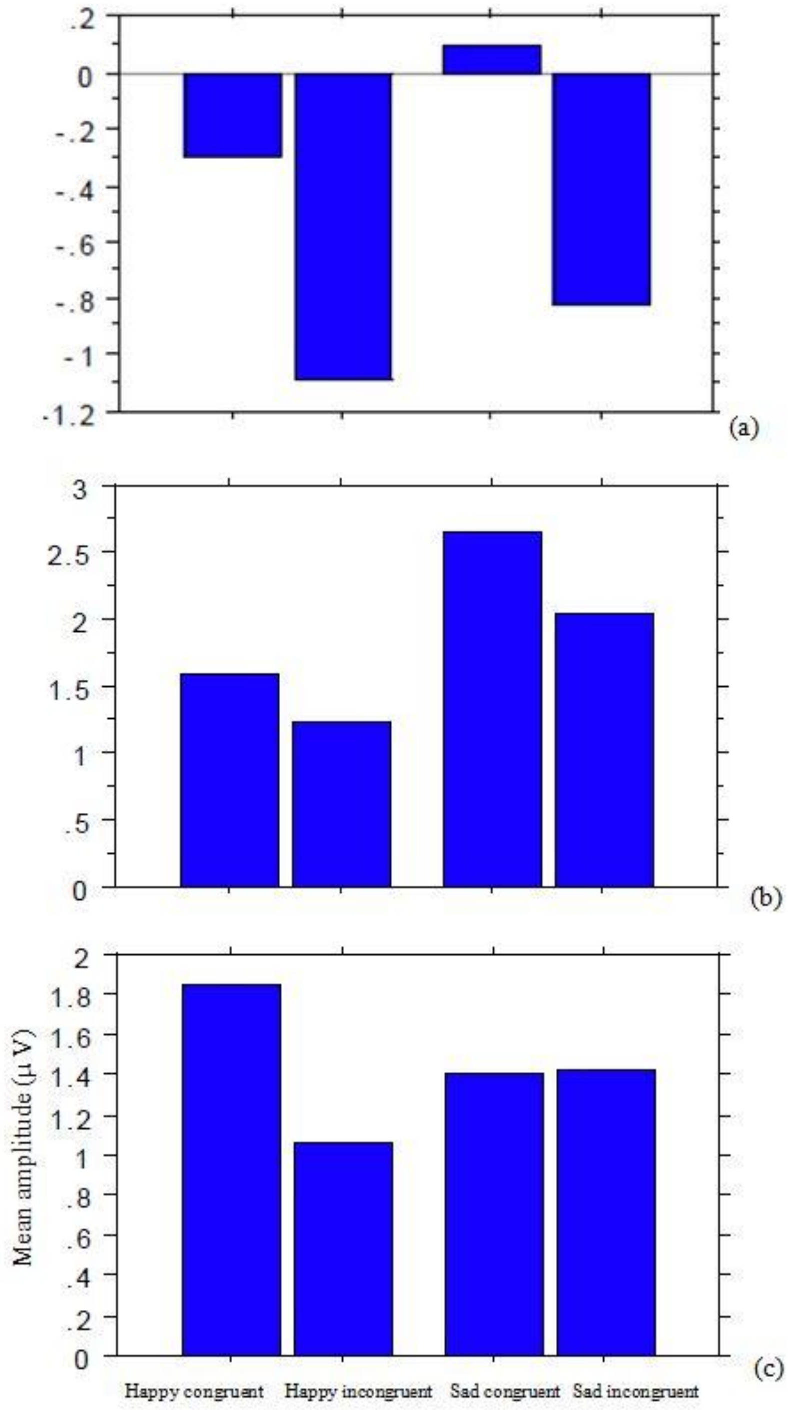

Figure 2.3 Control group interaction graphs in the music-word paradigm for (a) N300 condition congruence effect in the left parietal region (b) P300 condition valence effect in the right central region (c) Music-music paradigm P300 condition valence x congruence effect in the right frontal region.

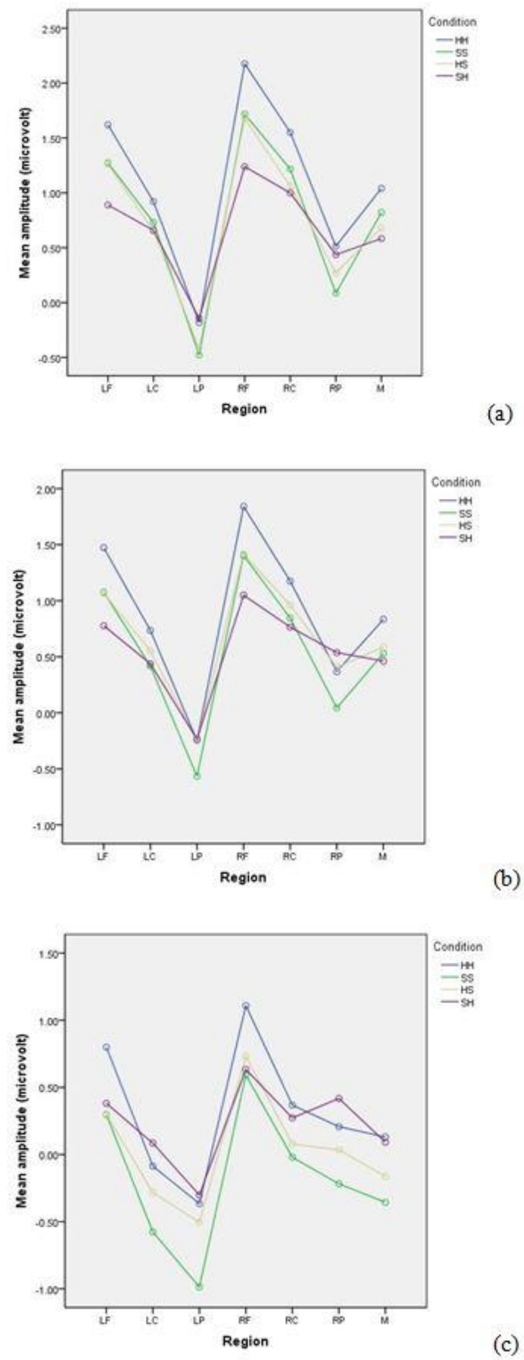

Figure 2.4. Mean regional amplitudes showing regions with the largest amplitudes in the music-music paradigm for the control group for (a) N300 (b) P300 (c) N400. Negative is plotted down. LF: left frontal, LC: left central, LP: left parietal, RF: right frontal, RC: right central, RP: right parietal, M: midline. Conditions Blue: HH, Green: SS, Yellow: HS, Purple: SH.

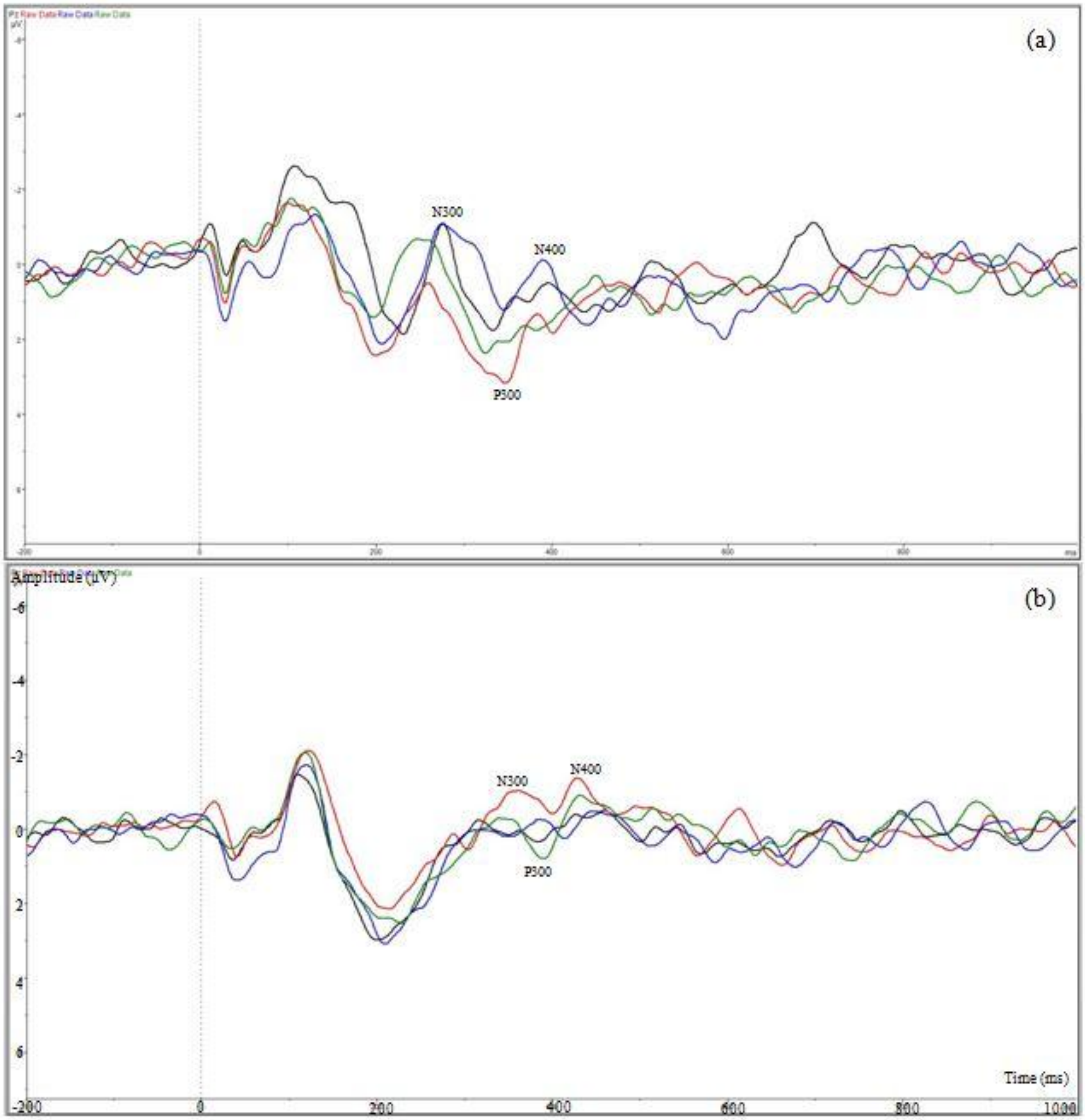

Figure 2.5. ERP responses in the control group for the (a) Music-word and (b) Music-music paradigm. Negative is plotted up. Lines - Black: HH, Red: SS, Blue: SH, Green: HS. Site shown: Pz, which best illustrates experimental effects in all examined ERP components.

P300: The P300 was significantly different in amplitude for congruent (M= 3.24 μV, SD=3.39) and baseline conditions ($t(11) = 3.312$, $p = 0.007$).

N400: Results did not reach statistical significance.

2.4 DISCUSSION

Behavioural findings

Behavioural priming was found in both the music-word and music-music paradigm, indicating the fundamental method was successful in generating the classic priming effects. Valence was found to modulate some of these effects. These priming effects showed participants understood the instructions and were able to perform the tasks well. Given the more subjective nature of music, responses and reaction times were more accurate and faster for the music-word (M = 88.7%, 1216.5ms) than music-music (M= 79%, 1786.8 ms) paradigm. These results applied across all behavioural controls (a random sample meant to reflect the general population) regardless of their alexithymic and depression scores, supporting the paradigms' generalizability and applicability characteristics. Both paradigms also supported literature findings that happy music was more quickly and easily recognized than sad music (Juslin & Laukka, 2003; Vieillard et al., 2008).

Congruency in both paradigms resulted in quicker decisions (i.e., faster reaction times), but this congruency was not necessarily associated with greater accuracy. Participants were more accurate in their responses to music prime and target pairs (music-music) when they were emotionally congruent, but more accurate in music prime word target pairs (music-word) when they were emotionally incongruent. This finding nicely illustrates the processing differences within and between the music and language domains (Sammler et al., 2012). When processing is contained *within* a domain (i.e., music-music), it makes sense for congruency to be more easily recognized and processed as the preceding stimulus has already primed the following target. For example, when asking people to quickly name the colour of snow, cotton and polar bears, then asking what cows drink, most will answer milk rather than water due to priming effects. Incongruence in this case becomes a stumbling block.

However, processing *between* domains (i.e., music-word) is different. Understandably, priming within rather than between domains is more efficient, as there would be additional processes involved in the latter due to switching domains, similar to switch costs in the task switching literature (Monsell, 2003). These additional processes may employ more effort or attention, for the purpose of making identification of differences rather than similarities easier. In turn, these extra resources result in a more controlled and conscious process (Vermeulen, Luminet & Corneille, 2006).

Besides elucidating why HH and HS were most accurately identified in music-music and music-word respectively, these priming differences also explain why SH was least accurately identified in both paradigms. If priming was compromised for the initial stimulus, it would affect the subsequent stimulus regardless of its domain or congruency. This observation indicates that sad music is less able to prime within (music) or between (word) domains compared to happy music, very likely due to its more ambiguous nature.

ERP findings

The results support our hypotheses of clear paradigm differences and the manifestation of emotional processing in the proposed ERP gradient (N300, P300 and N400). The more distinct and statistically significant ERP morphology and responses of the inter-domain music-word paradigm suggest a more challenging and controlled process (Figure 2.5a) compared to the tight overlap of the intra-domain music-music paradigm (Figure 2.5b), which was suggestive of a more automatic process. These results are the perfect contrast to those of Maidhof & Koelsch (2011), who focused on pragmatic communication and found ERP responses for music syntactic processes to be larger and less automatic than those of language; and support the observation of Lima, Garrett & Castro (2013) on emotional perception being a more intrinsic property of music than language. Thus, both paradigms can clearly be differentiated by automaticity levels and their basic operational framework (i.e., more emotion or pragmatic based).

The music priming effects on sad and happy targets should be comparable across both paradigms as only the target stimuli changes (from word to music or vice versa). Yet, word targets were primed more effectively than music targets in terms of emotional categorization (N300), by virtue of expectation caused by the instructions. This observation provides strong evidence for the influence of instructions on affective priming and indicates a conscious process that exerts its effects even before a target is presented. If this process were automatic, the effects would be similar across music and word targets. In addition, consideration of the ISI between prime and target is critical in evaluating priming effects. ISIs less than 250ms are isolated to automatic, conventional priming processes while longer ISIs result in more “controlled” (less automatic) priming (Bargh & Chartrand, 2000; c.f. LeMoult, Yoon & Joormann, 2012). As our ISI (800ms) exceeds 250ms, effects captured from the present study’s paradigms are likely to be less or partially automatic in that they can operate without awareness but can be influenced by attention (Hackley, 1993, c.f. Maidhof & Koelsch, 2011).

Compared to music, the effective emotional categorization (N300) of word targets based on congruity is likely due to our language dominance (Maidhof & Koelsch, 2011), their more objective nature (i.e., it is easier to emotionally categorize the word “sad” than sad music) and shorter duration (i.e., 200ms word targets compared to 1000 ms music targets). The fact that congruity was the main influence in modulating the N300 response shows that stimulus valence or saliency is less of an influence, although it is still processed with congruency. This is reflected in congruent conditions (HH and SS) being more easily processed compared to incongruent ones (HS and SH) irrespective of target valence. Thus, the N300 reflects a more basic, initial processing stage.

Valence began to exert an effect on the P300, where sad word targets were recognized more than happy word targets irrespective of congruity. This finding supports literature on motivational significance and valence influencing the P300 amplitude (see Olofsson, Nordin, Sequeria & Polich, 2008). Similarly, these results could be said to reflect the emotional negativity bias, where stimuli carrying a negative emotional valence are more readily attended to and processed due to their survival value (Cacciopo, Gardner & Bernston, 1999; Chen et al., 2008). As P300 amplitudes are also determined by task relevance (i.e., congruency) (Olofsson, Nordin, Sequeria & Polich, 2008), the observation of valence overriding congruency here alludes to the control group responses being more influenced by emotional factors. However, the effect could also be attributable to the shorter duration of sad compared to happy word targets rather than a pure valence effect. A similar observation would be noted in sad music targets if this was a pure valence effect (i.e., emotional negativity bias) as music engages emotion more readily than language (Lima, Garrett & Castro, 2013).

Interestingly, emotional recognition (P300) in the music-music paradigm was specific to happy congruent music and not to sad incongruent music target conditions, pointing to the interaction of valence and congruence rather than valence alone. This finding indicates that the shorter duration of “sad” versus “happy” word targets may have affected congruency effects for the P300 in music-word (Figure 2.3b). The minimal emotional recognition of sad music targets primed by happy music (Figure 2.3c) may have also resulted in the P300 in music-music manifesting as a strong trend (*p* = 0.069) rather than a significant effect. This process is further hampered by the more ambiguous nature of sad music compared to happy music (Juslin & Laukka, 2003; Vieillard et al., 2008), which affects emotion recognition of sad music targets despite successful priming. Although the P300 is generally resistant to stimulus properties due to its assumed endogenous (dependence on internal factors like participant expectancy rather than external factors like stimulus properties) nature (Luck, 2005), studies have shown differing P300 amplitude and latencies to changes in stimulus duration and complexity (Polich, 1989; Polich, Ellerson & Cohen 1996).

The apparent subordination or marginalization of emotional categorization (N300) to recognition (P300) in music-music is compatible with emotion recognition being more immediate in music compared to word targets (Lima, Garrett & Castro, 2013), perhaps rendering categorization less necessary (or at least to a minimal extent) than its lexical counterpart. While word targets may require categorization before emotion is recognized, music targets do not; which is also suggestive of the more automatic nature of the music-music paradigm and the difference in the general operations of music and language processing (Sammler et al., 2012; Maidhof & Koelsch, 2011). Thus, the differing N300 response between paradigms provides a useful index of automaticity levels.

An unexpected finding was the absence or rather the failure of the N400 (emotional meaning) response to reach statistical significance in both paradigms. It is possible that music emotion perception performance (or at least a majority of it) can be completed at the emotional recognition (P300) stage in the control group, requiring minimal integration for both music and word targets. Musical emotion perception is relatively basic (Juslin & Västfjäll, 2008) and considered innate by some (Peretz, 1998), so processing emotional meaning may not be apparent in an optimally functioning system (i.e., control group). The short duration of the musical excerpts may also contribute to the possible truncation[2] of emotional meaning (N400), and thus a more affective than semantic paradigm focus. It will be interesting to see if the N400 becomes more noticeable or modified in groups where emotion and awareness are impaired (Chapter 3, 4 and 5). The N400 sign test for happy and sad word targets assessed across controls lend support to this suggestion as more than 75% of participants exhibited the hypothesized N400 response, although the response magnitude was minimal and failed to achieve statistical significance (Table 2.2a).

Although the localization and topographical distribution of the ERP components are not the main focus of the present thesis, they do support findings from past research. The left parietal distribution of the N300 and right central dominant P300 was similarly distributed in our pilot study for the music-word paradigm (Morgan, Choy & Connolly, 2012). The topographical consistency of the N300 across both paradigms in the present study reflects basic, comparable emotional categorization. The right frontally dominant P300 in the music-music paradigm and its right central topography in the music-word paradigm

[2] I thank Dr. Laurel Trainor for highlighting this detail.

corresponds nicely with the respective fronto-central distribution of the P3a (earlier portion of the P300 signifying stimulus detection) and the centro-parietally dominant P3b (later portion of the P300 signifying stimulus recognition) (Polich, 2012). In other words, emotional recognition in the more automatic music-music paradigm is less extensive and suffices at a detection level, while the process is more elaborate in the music-word paradigm. Music also appears to initiate P3a more than P3b responses (Janata, 1995; Besson & Faita, 1995, c.f. Trainor, Desjardins & Rockel, 1999).

The left parietal distribution of the N400 in the present study for both paradigms differs from the fronto-central topography in Morgan, Choy & Connolly (2012). Morgan, Choy & Connolly (2012) grouped regions differently, which may have contributed to the differences between these two studies. Also, the inhibition of a behavioural response (i.e., responding only after an asterisk appeared on screen) in Morgan, Choy & Connolly (2012) may have affected the N400 distribution, as fronto-central positivities have been observed to precede motor inhibition (Diedrich et al., 1997, c.f. Delplanque et al., 2006) and thus could have influenced the appearance of the N400. However, as the N400 was not found to be dominant in the present experiment, this observation will remain to be investigated in the subsequent chapters where it may be more conspicuous.

2.5 CONCLUSION

The music-word and music-music paradigm were found to operate at different degrees of automaticity due to the inherent nature of each domain (music and language) and their differing levels of compatibility with the present study's emphasis on emotion perception. The adjustment of the more pragmatic operation of the music-word paradigm to a more emotionally focused operation resulted in a more controlled process compared to the music-music paradigm, which was inherently more emotionally based. These operational differences are manifested in the more differentiated and statistically significant ERP responses in the music-word paradigm, as opposed to the tight overlap and similar responses in the music-music paradigm. The ERP gradient of emotional processing also highlights these operational and automaticity differences, with the N300 (emotional categorization) and P300 (emotional recognition) being apparent in the music-word paradigm, and only the P300 in the music-music paradigm. The lack of the N400 (emotional meaning) in both paradigms is suggestive of minimal integration of emotional meaning in an optimal emotional processing system (control group) but remains to be investigated in the subsequent chapters.

Chapter 3: Music as a measure of emotion: alexithymic individuals

"The heart has its reasons that reason knows not of."

(Blaise Pascal (1662-1688), c.f. Taylor, Bagby & Parker, 1997).

3.1 INTRODUCTION

The ability to generate a representation of one's emotion is dependent on being able to experience and recognize them to begin with (Damasio et al., 2003; Northoff et al., 2006; c.f. Lieburg et al 2012). Alexithymia results from an inability to learn or form emotional-cognitive associations, inhibiting emotional development and regulation. Citing the previous chapter's example, the strong attachment to our favourite childhood toy is because the object symbolizes comfort (e.g. placating oneself after maternal separation), a crucial step in emotional development in the form of imagination, fantasy and dreams. Next, imaginary child play occurs, with failure reflecting disrupted emotional-cognitive integration or regulation. While regular individuals effectively use cognition to regulate emotion and emotion to guide cognition, alexithymics either rely heavily on cognition and ignore emotion, or ignore both and rely on unregulated affect (e.g. reflexes, heart palpitations). This theory explains the severe paucity in dreams/imagination and the overcompensation of external representations in alexithymics (Taylor, Bagby & Parker, 1997).

Recently, two notable fMRI studies provide further insights on the neural underpinnings of alexithymia. Liemburg et al. (2012) demonstrated that the default mode network's (DMN) resting state connectivity (intrinsic brain activity present in a select group of brain structures when the brain is at rest/baseline, implicated in self-referential activities like emotion) is different in alexithymics. They showed decreased activity in the medial frontal and temporal areas of the DMN (attributed to reduced emotional awareness, introspection and difficulties articulating), and increased connectivity in the sensorimotor and right lateral frontal cortex (reflecting their tendencies to be driven by external, somatic and action orientated stimuli and emotional suppression) compared to controls. This study is noteworthy as the intrinsic brain is examined at rest, with minimal influence from external stimuli; thus differences observed between control and alexithymic individuals are more likely to be attributable to alexithymia.

Moriguchi et al. (2009) examined the classic mirror neuron system (considered key in the development of empathy, imitation, language and introspection), where alexithymics were found to have more activation in the pre-motor and parietal areas than the control individuals. These areas were associated with decreased cognitive empathy and perspective, with the authors concluding these shallower processing characteristics result in inadequate self-other distinction abilities; rendering alexithymics more susceptible to the influences of other people (and adding to their externally orientated inclinations) and not being able to fully internally regulate their own emotions. This study further corroborates the legitimacy of alexithymia as a bona fide construct or condition rather than a language deficit (Swart, Kortekaas & Aleman, 2009) or an offshoot of depression or somatoform disorders (Marchesi, Brusamonti & Maggini, 2000; Parker, Bagby & Taylor, 1991). Indeed, alexithymia has been proposed to account for the lack of empathy (Bird et al., 2010) and emotional responsiveness to music (Allen, Davis & Hill, 2012) in autistic individuals, rather than autism itself.

In examining affective categorization using music/prosodic primes and visual word targets (and vice versa) in control and alexithymic individuals (Goerlich, Witteman, Aleman & Martens, 2011; Goerlich et al., 2012), the alexithymics were the only ones displaying reduced sensitivity to affective priming in music/prosodic targets, an outcome attributable to these targets being less explicit and verbalizable (non-lexical) compared to word targets (lexical) (Goerlich, Witteman, Aleman & Martens, 2011). Given their sensitivity to interdomain differences between music and language, including alexithymic individuals in the current research would lay out these distinctions nicely, in addition to providing further revelations on the interplay between emotion, awareness and cognition in comparison to control individuals (Chapter 2).

As with the control group and using the same paradigms in Chapter 2, it was hypothesized that alexithymics individuals would similarly display the ERP gradient of emotional processing. They would exhibit larger N300 and N400 responses (reflecting ease of emotional categorization and meaning respectively) for emotionally incongruent trials and larger P300 (emotional recognition) for emotionally congruent trials, but these conditional response differences would be decreased due to their immature emotional processing capabilities when considered alongside the control group.

In addition, the alexithymic individuals were hypothesized to be more impaired for the music-music than the music-word paradigm, owing to their particular difficulty processing emotional concepts in non-explicit stimuli like music compared to words. Contrasting these paradigm and group differences will further elucidate the interplay of emotion and consciousness in musical emotion perception, as alexithymia is theorized to illustrate how a lack of consciousness affects emotion (blind*feel*) (Lane, Ahern, Schwartz & Kaszniak 1997).

3.2 METHODS

All stimuli, methods, materials, eligibility, recruitment and procedures are identical to Chapter 2.

Participants: Sixteen healthy university students were tested, but data from 4 participants were discarded due to excessive drift and inability to follow task instructions, leaving 12 participants (6 females). Ten were dextral and 8 were native English speakers (age range 19-32 years, M = 23.50). None were musicians according to the OMSI scale (M = 126.17) or depressed (M = 8.92) as measured by the BDI-II scale, and their PANAS scores showed all of them had positive moods both at the beginning (M = 30.67/50) and end (M = 27.58/50) of the experiment. All were alexithymic as measured by BVAQ-B (M = 56.50) and

TAS-20 (M = 52.58) scales except 1 male (P43) who was not considered alexithymic according to the TAS-20. However, as his TAS-20 score was very much borderline (a point short of being alexithymic) in comparison to high scores in the BVAQ-B, he was included in the alexithymic group. The BVAQ-B further categorized all alexithymics as Type II alexithymics (lack of emotional regulation). Only 1 female participant was slightly less responsive to musical emotion compared to the rest according to the AIMS scale (M = 106.42/170). Table 3.1 lists the categorical scores for alexithymia and depression for the alexithymic individuals.

EEG acquisition and analysis: Data acquisition and analyses were similar to Chapter 2, with the same requirement that each condition had at least a 70% trial acceptance rate. To compare the alexithymic and control groups, group (control, alexithymic) was added as a between subject factor in the initial omnibus ANOVA, on top of the initial condition (4 levels) and region (7 levels) factors. As we have specific hypotheses on conditional effects (i.e., the valence of the target and its congruency with the prime), subsequent 2 x 2 ANOVAs for target valence (happy, sad) and congruency (congruent, incongruent) were run separately for the alexithymic group in the region showing the largest amplitudes for each component after the initial omnibus ANOVA. Figures for these regions will not be displayed unless they differed from the regions illustrated by the control group in Chapter 2.

	Alexithymic individuals (N = 12)
TAS-20 non-alexithymic	1 (8%)
TAS-20 intermediate	7 (58%)
TAS-20 alexithymic	4 (33%)
BVAQ-B non-alexithymic	-
BVAQ-B intermediate	1 (8%)
BVAQ-B alexithymic	11 (92%)
BDI-II minimal depression	12 (100%)
BDI-II mild depression	-

Table 3.1. Alexithymic group categorical scores for alexithymia and depression.

3.3 RESULTS

3.3.1. *ERP sign test*

As the sign test compares two conditions by congruency to ascertain if component responses match the hypotheses, the term "condition comparisons" will be used to describe these evaluations (see page 56-57). The sign test determines the number of participants demonstrating the hypothesized response irrespective of its statistical significance. Thus, the condition and component consistency can be ascertained, which is essential for comparison to a TBI patient on an individual case basis. Data listed are for site Pz, which best illustrates the experimental effect in all the examined ERP components.

Music-word paradigm: Table 3.2a summarizes and lists the number of participants responding as hypothesized for each condition comparison and component for this paradigm. In contrast to the larger hypothesized N300 and N400 to incongruence and larger P300 responses to congruence in controls, the majority of the alexithymics displayed atypically larger N300 and N400 to congruence and a larger P300 response to incongruence for sad word targets regardless of music prime valence (SS/HS). SS/HS was the condition comparison with the lowest number of participants responding as hypothesized for the alexithymic group, compared to HH/HS in controls.

Otherwise, both groups had similar results. Almost all controls and alexithymics had a larger N300 and N400 to incongruence and a larger P300 to congruence in all condition comparisons as hypothesized except for both word targets primed by happy music (HH/HS), where both groups had atypically larger N300 responses to congruence and a larger P300 to incongruence. Both groups had SS/SH as the condition comparison with the highest number of participants responding as hypothesized. The N300 and N400 were the most reliably observed components in terms of participant numbers responding as hypothesized, with the P300 being the least reliably observed component in both groups.

Music-music paradigm: Table 3.2b summarizes and lists the number of participants responding as hypothesized for each condition comparison and component for this paradigm. In contrast to the atypically larger N300 and N400 to congruence in controls, the majority of alexithymics displayed the larger hypothesized N300 response to incongruence for both music targets primed by sad music (SS/SH). SS/HS was the condition comparison with the lowest number of participants responding as hypothesized for the alexithymic group, compared to SS/SH in the controls. The P300 was the least reliably observed component in terms of participant numbers responding as hypothesized for the alexithymics, compared to the N300 in controls.

Otherwise, both groups had similar results. The majority of controls and alexithymics elicited larger N300 and N400 responses to incongruence and larger P300 responses to congruence in all condition comparisons as hypothesized. Both groups had HH/HS as the condition comparison with the highest number of participants responding as hypothesized. The N400 was most reliably observed

HH/SH			SS/HS			HH/HS			SS/SH		
N300 **	P300	N400 *	N300	P300	N400	N300	P300	N400	N300 ***	P300 **	N400 *
✓	✓	✓						✓	✓	✓	✓
10/12	8/12	9/12	5/12	4/12	3/12	5/12	4/12	8/12	11/12	10/12	9/12

(a)

HH/SH			SS/HS			HH/HS			SS/SH		
N300	P300	N400	N300	P300	N400	N300 *	P300	N400 *	N300	P300	N400 *
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
8/12	7/12	8/12	8/12	7/12	7/12	9/12	8/12	9/12	8/12	7/12	9/12

(b)

Table 3.2. Sign test results for ERP data for alexithymic group for the (a) music-word and (b) music-music paradigm. Results matching (responses elicited in the correct direction, even if not statistically significant) and contrary to the hypotheses are marked ✓ and grey respectively, participant response numbers are listed in the bottom row and significance is indicated *p=0.073, ** p=0.019, *** p=0.003. Data listed are based on site Pz, which best illustrates experimental effects in all the examined ERP components.

with the highest number of participants responding as hypothesized for both groups, although the N300 was equally reliable by the same criteria only for the alexithymics.

3.3.2. *ERP statistics*

ANOVA statistics for the control and alexithymic groups are presented first, followed by those for just the alexithymic group for each component. As we have specific hypotheses on conditional effects (i.e., the valence of the target and its congruency with the prime), additional 2 x 2 ANOVAs with the factors target condition valence (happy, sad) and congruency (congruent, incongruent) were run in the region where the component showed the highest mean amplitude (e.g. maximal distribution) after the initial omnibus ANOVA. As before, unless specified, all values reported assume sphericity criteria have been met by the data. The Greenhouse-Geisser correction is applied to account for violations of sphericity when appropriate.

Music-word paradigm

N300

Control and alexithymic groups: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 111.33, p = 0.0001. Therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε =0.31). A significant main effect for region found in the initial omnibus ANOVA (*F*(1.88, 41.27)=7.03, *p*=0.003) reflected the left parietal distribution seen for this response.

A significant condition main effect (*F*(3,66)=4.261, *p*=0.008) was found in the initial omnibus ANOVA. The results were further analyzed in the left parietal region in separate 2 (valence, happy vs. sad) x 2 (congruence, congruent vs. incongruent) x 2 (group, control vs. alexithymic) ANOVAs. Main effects of valence (*F*(1,22)=5.419, *p*=0.003) and congruence (*F*(1,22)=6.865, *p*=0.016) were found. These reflected a larger N300 to happy over sad valence target conditions, and incongruent over congruent target conditions (Figure 3.1a). These factors did not interact with each other or with group.

Alexithymic group: When analyzed separately, the alexithymic group showed a condition trend (*F*(3,33)=2.705, *p*=0.061) in the initial omnibus ANOVA. This was further analyzed in the left parietal region in a separate 2 (valence, happy vs. sad) x 2 (congruence, congruent vs. incongruent) ANOVA. A main effect of valence was found, reflecting a larger N300 to happy versus sad valence target conditions (*F*(1,11)=5.228, *p*=0.043) (Figure 3.2a).

P300

Control and alexithymic groups: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 115.88, *p* = 0.0001. Therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε =0.31). A significant main effect for region found in the initial omnibus ANOVA ($F(1.86, 40.82)=4.762$, $p=0.016$) was attributed to primarily increased amplitudes in the right central region.

A significant main effect of condition ($F(3,66)=8.173$, $p=0.0001$) was found in the initial omnibus ANOVA. Further analyses were run with a separate 2 (valence, happy vs. sad) x 2 (congruence, congruent vs. incongruent) x 2 (group, control vs. alexithymic) ANOVA in the right central region. A main effect of valence ($F(1,22)=16.475$, $p=0.0005$) was found. As valence was observed to interact with congruence ($F(1,22)=4.135$, $p=0.054$) and group ($F(1,22)=5.747$, $p=0.025$), it must be interpreted in relation to these interactions.

A significant condition x region x group interaction ($F(18,396)=1.653$, $p=0.045$) was found in the initial omnibus ANOVA. Further analyses were run in the right central region using a separate 2 (valence, happy vs. sad) x 2 (congruence, congruent vs. incongruent) x 2 (group, control vs. alexithymic) ANOVA. A valence x congruence x group interaction was found ($F(1,22)=5.747$, $p=0.025$), reflected by alexithymic individuals emitting an atypically larger P300 to the sad incongruent condition compared to responses in the happy congruent condition in the controls (Figure 3.1b).

Alexithymic group: When analyzed separately, the alexithymic group showed a main effect of condition ($F(3,33)=7.553$, $p=0.001$) in the initial omnibus ANOVA. This was further analyzed in the right central region using a separate 2 (valence, happy vs. sad) x 2 (congruence, congruent vs. incongruent) ANOVA. A main effect of valence (*F*(1, 11)=10.351, *p*=0.008) and a valence x congruence interaction (*F*(1,11)=6.735, *p*=0.025) was found. Thus, the valence x congruence condition interaction is reflected by an atypically larger P300 in the sad incongruent versus the happy congruent and happy incongruent condition (Figure 3.2b).

N400

Control and alexithymic groups: A main effect of condition (*F*(3,66)=2.813, *p*=0.046) was found in the initial omnibus ANOVA. Further analyses were run using a separate 2 (valence, happy vs. sad) x 2 (congruence, congruent vs. incongruent) x 2 (group, control vs. alexithymic) ANOVA in the left parietal region. A main effect of valence (*F*(1,22)=6.190, *p*=0.021) was found. As valence was observed to interact with congruence (*F*(1,22)=5.327, *p*=0.031) and group (*F*(1,22)=5.746, *p*=0.026), it will be interpreted in relation to these interactions.

A significant interaction for condition x group (*F*(3,66)=3.017, *p*=0.036) was found in the initial omnibus ANOVA. Further analyses were run in the left parietal region with a separate 2 (valence, happy vs. sad) x 2 (congruence, congruent vs. incongruent) x 2 (group, control vs. alexithymic) ANOVA. A valence x congruence x group interaction was found (*F*(1,22)=5.746, *p*=0.0255), reflected by alexithymics eliciting an atypically smaller N400 to the sad incongruent in comparison to the happy congruent condition in the controls (Figure 3.1c).

Alexithymic group: When analyzed separately, the alexithymic group showed a main effect of condition ($F(3,33)=4.468$, $p=0.01$) in the initial omnibus ANOVA. This factor was observed to interact with region ($F(18,198)=2.716$, $p=0.0001$). Further analyses using a separate 2 (valence, happy vs. sad) x 2 (congruence, congruent vs. incongruent) ANOVA in the left parietal region found a main effect of valence ($F(1,11)=8.264$, $p=0.0151$) and a valence x congruence interaction ($F(1,11)=8.264$, $p=0.0151$). Thus, the valence x congruence condition interaction is reflected by an atypically larger N400 in the happy congruent versus the sad incongruent condition (Figure 3.2c).

Music-music paradigm

<u>N300</u>

Control and alexithymic groups: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region $\chi^2(20) = 85.85$, $p = 0.0001$. Therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.48$). A significant main effect for region found in the initial omnibus ANOVA ($F(2.87, 63.1)=17.889$, $p=0.0001$) reflected a primarily left parietal distribution.

Alexithymic group: When the alexithymic group was analyzed separately, Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region $\chi^2(20) = 47.17$, $p = 0.001$. Therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.48$). A main effect of region found in the initial omnibus ANOVA (*F*(2.86, 31.42)=8.523, *p*=0.0001) reflected a left parietal distribution for the N300.

P300

Control and alexithymic groups: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 87.87, *p* = 0.0001. Therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε =0.45). A significant main effect for region found in the initial omnibus ANOVA (*F*(2.72, 59.94)=14.427, *p*=0.0001) was attributed to primarily increased amplitudes in the right frontal region.

Alexithymic group: When the alexithymic group was analyzed separately, Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 45.73, *p* = 0.001. Therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε =0.50). A main effect of region found in the initial omnibus ANOVA (*F*(2.99, 32.9) =6.891, *p*=0.001) reflected a right frontal distribution for this response.

N400

Control and alexithymic groups: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 81.35, *p* = 0.0001. Therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε =0.52). A significant main effect for region found in the initial omnibus ANOVA ($F(3.11, 68.44)=9.040$, $p=0.0001$) was attributed to primarily increased amplitudes in the left parietal region.

Alexithymic group: When the alexithymic group was analyzed separately, Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 43.27, p = 0.003. Therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε =0.46). A main effect of region found in the initial omnibus ANOVA ($F(2.78, 30.61)=4.246$, $p=0.014$) reflected a left parietal distribution for the N400.

3.3.3. *Results summary*

The ERP sign test is a non-parametric test highlighting any median differences in two examined variables, showcasing the generalizability and reliability of the effect. The parametric ANOVA and corresponding contrast statistics deals with mean variances and if these variances are significantly different. Considering both methods enables a more comprehensive understanding of the results as both the average and median values are taken into account with the former providing an assessment of group behaviour and the latter an indication of the reliability of the measures at the individual subject level. As before, results are generally compatible between the ERP sign test and ANOVA statistics in the alexithymic group.

Music-word: The larger N300 response to incongruent and happy target conditions in both control and alexithymic groups suggest intact emotional categorization of word targets. The main effect of congruency indicates happy and sad music were successful primes, while the main effect of valence showed happy targets are inherently more salient regardless of what primes it. Still, valence had a larger influence than congruence in alexithymic individuals, as happy word targets were more effectively categorized emotionally than sad word targets. In contrast to controls, the alexithymic group displayed an atypically larger P300 and smaller N400 to sad incongruent compared to happy congruent target conditions, reflecting a specific impairment in the emotional recognition of sad word targets primed by happy music.

Music-music: Results did not reach statistical significance.

Figure 3.3a and 3.3b portrays the ERP responses for the music-word and music-music paradigms for the alexithymic group at site Pz. It is noteworthy that the statistical ANOVA results are based on regions where each component is maximally distributed while the sign test and ERP figures are based on site Pz, which best illustrates experimental effects in all the examined ERP components and provides a standardized comparison measure across all participant groups.

3.3.4 *Paired samples t-test: component amplitude vs. zero comparisons*

Music-word

<u>N300:</u> A trend in N300 amplitude for incongruent (M= -1.89µV, SD=3.55) and baseline conditions was observed ($t(11) = -1.847$, $p = 0.092$).

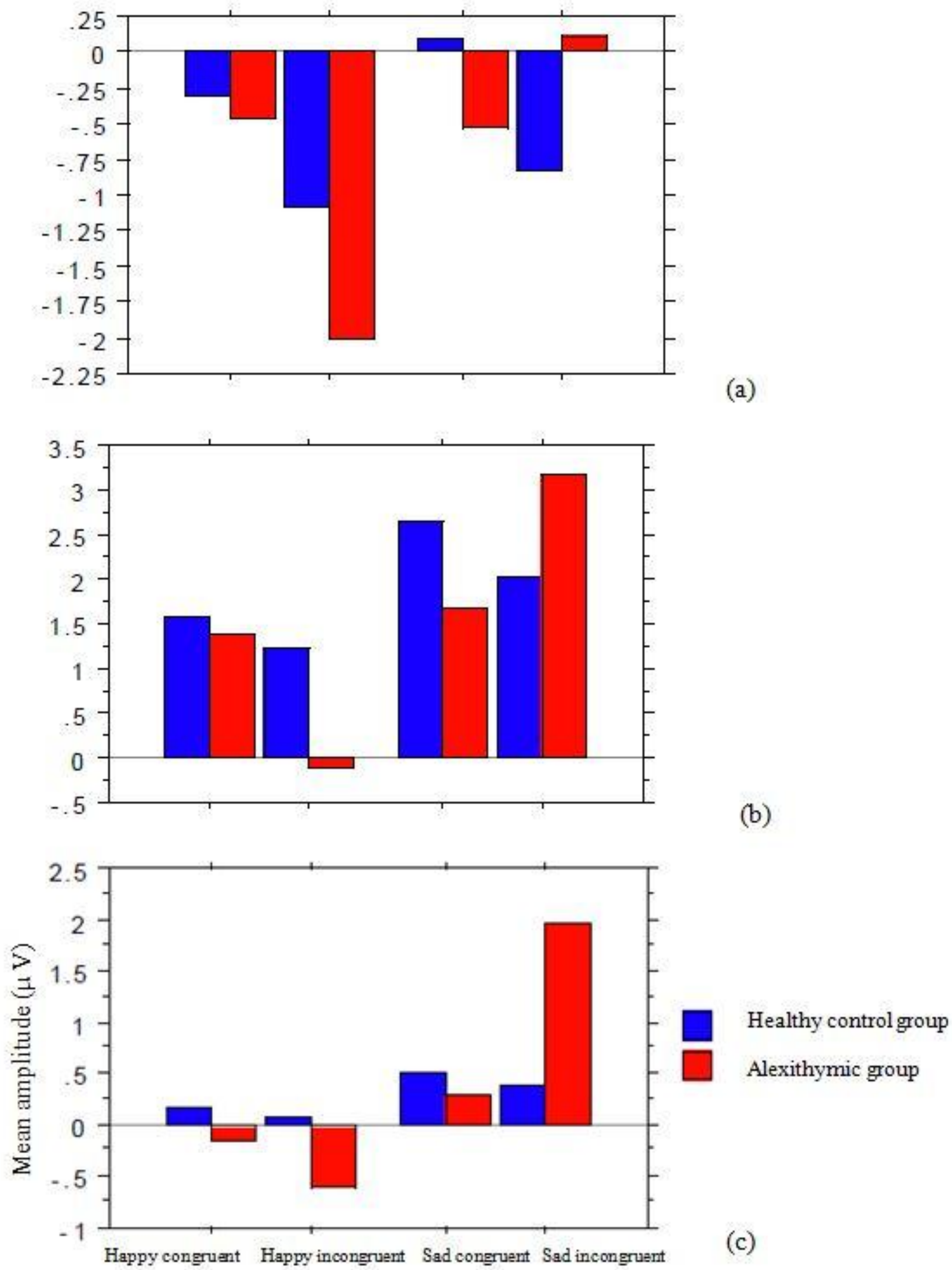

Figure 3.1. Control and alexithymic group interaction graphs in the music-word paradigm for (a) N300 condition valence and congruence effect in the left parietal region (b) P300 condition valence x congruence x group effect in the right central region (c) N400 Condition valence x congruence x group effect in the left parietal region.

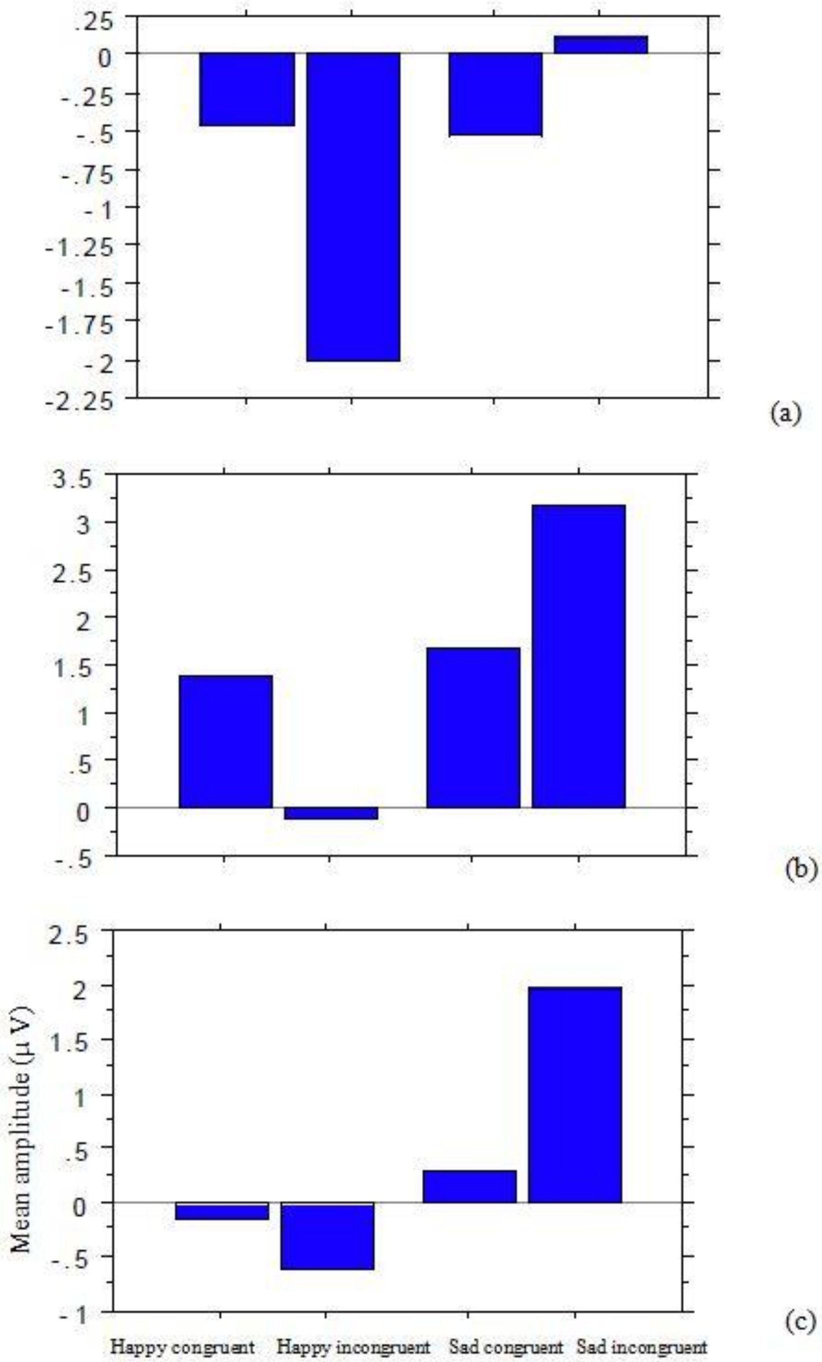

Figure 3.2. Alexithymic group interaction graphs in the music-word paradigm for (a) N300 condition valence effect in the left parietal region (b) P300 condition valence x congruence effect in the right central region (c) N400 condition valence x congruence effect in the left parietal region.

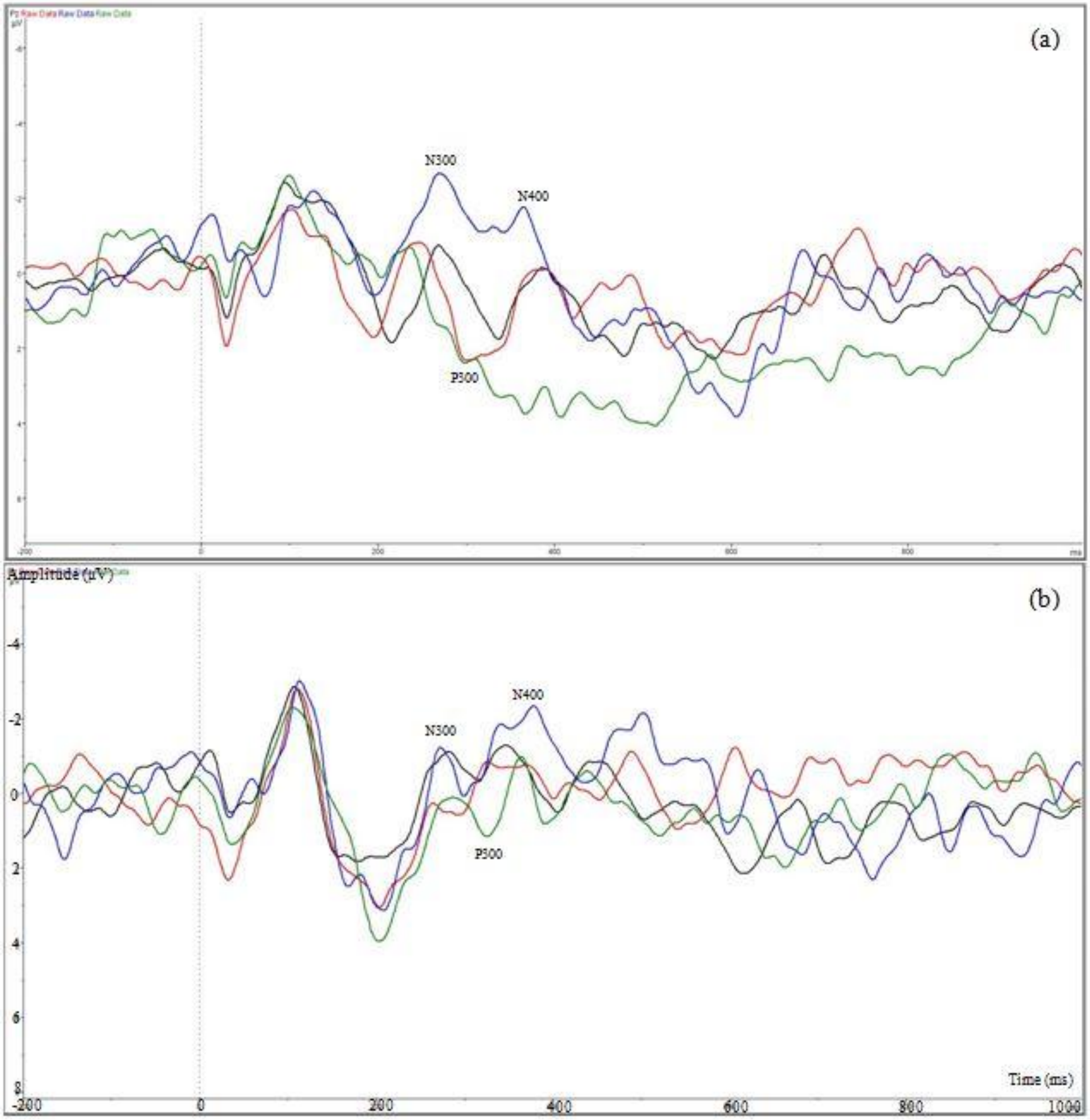

Figure 3.3. ERP responses in the alexithymic group for the (a) Music-word and (b) Music-music paradigm. Negative is plotted up. Lines - Black: HH, Red: SS, Blue: SH, Green: HS. Site shown: Pz, which best illustrates experimental effects in all examined ERP components.

P300: The P300 was significantly different in amplitude for congruent (M= 3.07 μV, SD=4.91) and baseline conditions ($t(11) = 2.166$, $p = 0.05$).

N400: Results did not reach statistical significance.

Music-music:

N300: A significant difference in N300 amplitude for incongruent (M= -1.84, SD= 2.65) and baseline conditions was found ($t(11) = -2.401$, $p = 0.035$).

P300: The P300 was significantly different in amplitude for congruent (M= 2.14 μV, SD=3.4) and baseline conditions ($t(11) = 2.184$, $p = 0.05$).

N400: Results did not reach statistical significance.

3.4 DISCUSSION

Alexithymic participants displayed decreased conditional response differences in the ERP gradient of emotional processing compared to controls, confirming our first hypothesis. The paradigm differences observed in the controls were replicated – a more differentiated ERP morphology for the music- word (Figure 3.3a) compared to the close overlap of the music-music paradigm (Figure 3.3b). Both groups also had identical dominant regional distributions for the N300, P300 and N400. Unlike the controls however, alexithymics was observed to be specifically impaired in the processing of sad word targets preceded by happy music primes. This result was contrary to that of Goerlich, Witteman, Aleman & Martens (2011), to be addressed later in the discussion. For the most part, the focus of this discussion will be on the music-word paradigm as results for the music-music paradigm were not statistically significant, which did not permit direct confirmation of our second hypothesis.

The main effects of congruence and valence in the emotional categorization (N300) of word targets reveals that although both groups had larger responses for happy incongruent than happy congruent target conditions as hypothesized, the control group’s response pattern was linked to congruence (i.e., responses were identical for sad targets) more than stimulus valence. In contrast, the alexithymics’ N300 responsiveness was affected by valence (i.e., responses were reversed for sad targets) rather than congruence (Figure 3.1a). In particular, alexithymics were impaired in their processing of sad word targets that were preceded by happy music prime conditions. Disruption in this specific condition continued for emotional recognition (P300) and emotional meaning (N400) for the alexithymics, a pattern that contrasted to that of the controls. While both groups displayed hypothesized P300 and N400 responses for happy target conditions, responses from the alexithymics were larger in amplitude and influenced by both target congruence and valence (Figure 3.2b & 3.2c). Conversely, controls were driven by target valence for the P300 and had only modest differences in the N400 across conditions.

Thus, alexithymia seems to specifically impinge on the processing of sad word targets that were primed by *happy* music at the earliest processing point measured in this research (emotional categorization). The absence of this impairment in the processing of sad word targets preceded by *sad* music primes suggest happy music cued sad word targets less effectively compared to sad music. These results complement that of Vermeulen, Toussaint & Luminet (2010), who found alexithymics were particularly influenced by music when determining congruency between music and words, especially for happy music (i.e., N300 valence effect in the present study). They recognized more happy words when happy music was played in the background (i.e., normal processing of happy word targets in the present study). Conversely, angry words were observed to be less affected by this interaction between music and alexithymia, although more angry than happy words were identified when angry music was played. That is, normal processing of sad word targets occurred *only* when preceded by sad music in the present study.

Although anger is a different emotion from sadness, both emotions are negatively valenced and are comparable in that sense. The interaction of valence and congruence influences in the P300 and N400 in alexithymics (in contrast to valence being the key modulator in the controls) also points to allocation of additional processing resources in alexithymics, suggestive of a less automatic response. This interpretation corresponds with their larger ERP responses – an unexpected result which will be discussed next.

While alexithymics displayed larger ERP responses (i.e., larger amplitudes in general) compared to controls in the present study, it is important to note that this pattern does not automatically translate to larger ERP *conditional response* *differences* (i.e., amplitude differences between conditions). Indeed, it is our observation that larger conditional response differences in alexithymics only applies if task performance is *successful* (see Figure 3.1 to compare the performance of happy word target conditions between alexithymic and control groups, also Figure 3.3a and Figure 2.5a). This aspect substantiates our earlier observation of a minimal N400 (emotional meaning) in controls compared to a larger N400 in the alexithymic group for the same task, an effect attributed to the additional effort required to process the targets' emotional meaning in the alexithymic group.

The N400 sign test (Table 3.2a) supports this premise as fewer alexithymics emitted the hypothesized responses compared to the controls (Table 2.2a), yet alexithymic responses were statistically significant while those of the controls were not. This means that out of the few alexithymics that can perform the task, they exert considerably more effort (statistically significant responses) than controls despite both groups emitting the same hypothesized response. Conversely, if alexithymics have difficulty performing the task (i.e., emotional processing of sad music targets following happy music primes), they display smaller conditional response differences than controls as predicted by our hypothesis.

The current findings can be integrated into the alexithymic literature suggesting that emotions remain undifferentiated in alexithymics leading to their inability to recognize or learn from emotions and subsequently adjust or adapt their behaviour accordingly. For example, while alexithymics may perform comparably with controls in processing aversive pictures, they exert more effort (larger P2 and P300), suggestive of less efficient emotional function (Franz et al., 2004). Thus, they overcompensate by augmenting responses to avoid ignoring potentially harmful or useful stimuli (Morrison & Pihl, 1990). This theory corroborates alexithymics displaying more controlled than automatic processing of emotion (Vermeulen, Luminet & Corneille, 2006). Taken together, emotional processing for alexithymics is less automatic than controls due to additional effort (i.e., larger ERP responses in general) and reflected by larger ERP conditional response differences *only* in successful task performance.

The dissimilarity of our results from that of Goerlich, Witteman, Aleman & Martens (2011) is likely due to a combination of task automaticity and difficulty. Goerlich et al. (2011) employed an ISI of 200ms, indicative of a more automatic paradigm than the present study, which had an ISI of 800ms. Unlike the present study, Goerlich et al. (2011) had a ceiling effect in task performance which may have enhanced automatic rather than controlled processing due to low task difficulty. Moreover, our alexithymic group were all Type II alexithymics, reflecting difficulties in emotion regulation rather than lack of both emotional experience and regulation (Type I). This aspect aligns with the current disparity in results as difficulties for Type II alexithymics may manifest in more controlled rather than more automatic processes (Vorst & Bermond, 2001). As Goerlich et al. (2011) did not formally measure and differentiate between Type I and II alexithymia, this aspect remains to be investigated.

If anything, the failure of the music-music paradigm to reach statistical significance for the alexithymic group can be linked to our earlier observation of the music-music paradigm generating a more automatic process due to music's inherent emotional nature. This premise is supported by music's compatibility with the present study's focus on affective priming and reflected by the music-music paradigms' close condition ERP response overlap in both control and alexithymic groups. Alexithymics may thus be able to intuitively integrate music (music-music), but struggle when it crosses domains (music-word) and becomes less automatic. This observation ties in well with alexithymics not necessarily being *devoid* of feeling, but just having trouble identifying, verbalizing and recognizing it (i.e., regulation).

3.5 CONCLUSION

The paradigm differences and regional dominance for the ERP gradient of emotional processing (N300, P300, N400) seen in controls were replicated. Alexithymics had larger ERP waveform amplitudes than controls owing to their response amplification tendencies, but ERP conditional responses were different. Alexithymics were specifically impaired in all (categorization, recognition, meaning) aspects of emotional processing for sad word targets following happy music primes, reflected by reversed and reduced conditional response differences in the N300, P300 and N400. In happy word target conditions where both groups performed similarly, alexithymics showed larger ERP conditional response differences than the controls. Moreover, the additional processing effort exerted by the alexithymics resulted in emotional processing being a more controlled process for them compared to the controls. The lack of statistical significance in the music-music paradigm suggests a more automatic paradigm and a possibly preserved emotional process for alexithymics, but this remains to be examined further. Based on the more controlled music-word paradigm, the ERP gradient of emotional processing indicates a breakdown from the early (categorization) stages. In this matter, the present results do not support Lane, Ahern, Schwartz & Kaszniak's (1997) theory of alexithymia as a type of blind*feel* (i.e., a lack of consciousness affecting emotion) as processing is disrupted from the start, rather than just the later stages of emotional processing.

Chapter 4: Music as a measure of emotion: depressed individuals

"Complex systems often reveal their inner workings more clearly when they are malfunctioning than when they are running smoothly."

(Micheal McCloskey (2001), c.f. Peretz, Champod & Hyde, 2003).

4.1 INTRODUCTION

Given that almost 1 in 5 people will be go through depression in their lifetime (Kessler et al., 2003; c.f. Aan het Rot et al., 2009), the depressed population should be taken into account when establishing any measure of emotion. Furthermore, considering the strong ties depression has with alexithymia (Picardi et al., 2011; Honkalampi et al., 2000); the dynamics of this association needs to be explored further. Genetic variations or polymorphisms have been uncovered that have been linked to increased depression risks (Aan het Rot et al., 2009), and recent studies have associated the onset of depression with the serotonin transporter gene (Gotlib & Joormann, 2010). Furthermore, two genetic polymorphisms, the brain derived neurotrophic factor (BDNF) and ANKK1 gene are of interest, as they have been implicated in alexithymia (Walter, Montag, Markett & Reuter, 2011) and recovery from TBI (Weaver, Chau, Portelli & Grafman, 2012) also. This observation shows the intricate overlap between depression, alexithymia and TBI and alludes to the importance of emotional function in recovery from TBI. The relationship between depression and alexithymia will be elaborated in Chapter 5.

Depression is defined as “a low mood and/or inability to experience pleasure lasting for more than two weeks, along with distress and impaired vegetative and cognitive symptoms” (American Psychiatric Association, 1994). Interestingly, depression can slow responses in TBI patients, making them appear seemingly vegetative when injuries are severe (Gillett, 2010). Considerable affective priming research have also shown depressed individuals to show preferential processing of emotionally negative stimuli (i.e., emotional negativity bias) and deficits in processing emotionally positive material (LeMoult, Yoon & Joormann, 2012). Chung et al. (1996) fittingly observes how the clinical depression literature provides the best evidence of the impact of emotion on cognition, and indirectly, consciousness (i.e., awareness).

As mentioned, affective priming occurs when an emotionally valenced prime (e.g. happy music) facilitates processing of an emotionally congruent (i.e., happy) target due to the activation of similarly valenced information (Fazio et al., 1986). Neely (1991) and Bargh et al. (1996) noted how prime presentation is sufficient to influence feelings, thoughts and action tendencies (LeMoult, Yoon & Joormann, 2012). This affective expectancy is more primitive and pervasive than semantic cognition (Tucker et al. 1990; c.f. Chung et al., 1996). However, a reverse priming effect was observed in healthy individuals in an affective priming task of categorizing emotional faces (LeMoult, Yoon & Joormann, 2012). Paradoxically, these individuals took longer to process a happy face target after a happy face prime. The authors reasoned that difficulty disengaging from positive material may account for their resiliency against negative affect, as depressed participants did not exhibit the same effect, or enhanced processing of negative faces. This finding is notable as it suggests that happy and sad stimuli do not *by themselves* determine preferential processing, but rather the individual's *disposition or emotional state*. As Chung et al. (1996) puts it, "We judge by how we feel." (p. 219). Hence, this paradigm provides a suitable platform to access depressed states in individuals.

Research in the related field of post-traumatic stress disorder corroborates the disconnection problem aspect. Two dominant models postulate these effects are due to either patients having an attentional bias or difficulty detaching from trauma-related information; with growing evidence for the latter although there is still no consensus on this issue (see Hayes, VanElzakker & Shin, 2012). Studies have shown larger P300s to threat related stimuli in these patients, although data on latencies are less frequently reported (see Javanbakht et al., 2011). Moreover, participants' subjective expectancies influence the P300 more than objective stimulus probability (Donchin & Coles, 1991; c.f. Chung et al. 1996). P300 amplitudes have been shown to be sensitive to the emotional negativity bias, reflected by larger responses to negatively valenced stimuli (Delplanque et al., 2006). Taken together, the emotional negativity bias could potentially be first manifested and measured in the P300. Investigating subsequent processing (i.e., N400) and its relationship to the P300 may then elucidate if the emotional negativity bias is due to attentional bias or problems disconnecting from the negative valenced stimuli.

The attentional bias and difficulty disengaging element also correspond well with emotional inertia (reliance of one's present affective state to the previous) and rumination (passive rehashing of depressive symptoms) respectively, two aspects correlating with each other while independently predicting depression severity (Koval, Kuppens, Allen & Sheeber, 2012). Although both these aspects reflect inflexibility and resistance to change, the authors point out that emotional inertia and rumination are akin to being "cognitively and affectively stuck" (p. 1413). Thus, further scrutiny of these effects would be useful in understanding the cause and treatment for depression.

Another central point concerns the automaticity of this emotional negativity bias. Human predispositions can be so ingrained that they are predominantly if not completely unconscious, which is not necessarily uninformative. For instance, severely depressed individuals are not aware of their negative bias – it has become so deeply entrenched that there is no other view in their bleak world, exacerbating their feelings of helplessness and hopelessness (Chung et al., 1996). In this vein, one would expect effects to surface in the earlier ERP components before the P300 (i.e., N300), in accordance with Chen et al.'s (2008) claim that every processing step is influenced by the emotional negativity bias. The bias may also manifest in overall smaller ERP responses, due to general response attenuation (Gillett, 2010) and anhedonia characteristic of depression.

The extent of how and which earlier component is affected would elucidate the nature of the effect and its consequences on the subsequent ERP components.

As with the controls and using the same paradigms as described in Chapter 2, it is hypothesized that depressed participants would show an ERP gradient of emotional processing with larger N300 and N400 responses (reflecting ease of emotional categorization and meaning respectively) for emotionally incongruent trials and a larger P300 (emotional recognition) for emotionally congruent trials. However, it is hypothesized further that responses and the gradient changes will be reduced due to general response attenuation characteristic of depression. This gradient will, however, be modified by the emotional negativity bias, another depressive trademark, manifested in a larger P300 to sad stimuli. Whether the appearance and impact of the emotional negativity bias is seen before or after the P300 will reflect its degree of automaticity and whether it is due to attentional bias (early stages) or difficulty disengaging (later stages). It is hypothesized that expected differences between the music-word and music-music paradigms will reflect this bias differently as both paradigms differ in automaticity. These observations will thus reveal how emotional disruption (depression) affects consciousness (i.e., awareness).

4.2 METHODS

All stimuli, methods, materials, eligibility, recruitment and procedures are identical to that of Chapter 2. None of the depressed participants were medicated.

Participants: Fourteen individuals were tested, but data from 2 participants were discarded due to excessive drift, leaving 12 participants (6 females). All participants were dextral, 9 of whom were native English speakers (ages range 19-30 years, M = 21.67) and none were musicians according to the OMSI scale (M = 137.42). All were depressed according to the BDI-II scale (M = 22.33) and their PANAS scores reported positive moods both at the beginning (M = 29.83/50) and end (M = 25.16/50) of the experiment. None were alexithymic according to the BVAQ-B scale (M = 43), 2 female participants (P54 and P57) were considered alexithymic according to the TAS-20 scale (M = 48.67). As their TAS-20 scores were very much borderline (just meeting the alexithymic score threshold) compared to low scores in the BVAQ-B, they were not considered alexithymic and included in the depressed group. All participants were responsive to musical emotion according to the AIMS scale (M = 115.75/170). Table 4.1 lists the categorical scores for alexithymia and depression for the depressed group.

EEG acquisition and analysis: Data acquisition and analyses were identical to Chapter 2. To compare control and depressed groups, group (control, depressed) was added as a between subject factor in the initial omnibus ANOVA besides the initial condition (4 levels) and region (7 levels) factors. Each condition had at least a 56% trial acceptance rate. This lower rate was due to EEG drifts in one particular participant (P44) tested in the summer, whose responses otherwise matched the hypotheses based on his sign test results. As we have specific hypotheses on conditional effects (i.e., the valence of the target and its congruence

	Depressed individuals (N = 12)
TAS-20 non-alexithymic	3 (25%)
TAS-20 intermediate	7 (58%)
TAS-20 alexithymic	2 (17%)
BVAQ-B non-alexithymic	6 (50%)
BVAQ-B intermediate	6 (50%)
BVAQ-B alexithymic	-
BDI-II minimal depression	-
BDI-II mild depression	12 (100%)

Table 4.1. Depressed group categorical scores for alexithymia and depression.

with the prime), subsequent 2 x 2 ANOVAs for target valence (happy, sad) and congruency (congruent, incongruent) were run separately for the depressed group in the region displaying the maximal amplitudes for each component after the initial omnibus ANOVA. Figures for these regions will not be displayed unless they differed from those by the controls in Chapter 2.

4.3 RESULTS

4.3.1. *ERP sign test*

As the sign test compares two conditions by congruency to ascertain if component responses match the hypotheses, the term "condition comparisons" will be used to describe these evaluations (see page 56-57). The sign test determines the number of participants demonstrating the hypothesized response irrespective of its statistical significance. Thus, the condition and component consistency can be ascertained, which is essential for comparison to a TBI patient on an individual case basis. Data listed are based on site Pz, which best illustrates experimental effects in all the examined ERP components.

Music-word paradigm: Table 4.2a summarizes and lists the number of participants responding as hypothesized for each condition comparison and component for this paradigm. In contrast to the atypically larger N300 response to congruence in the controls, the majority of depressed individuals displayed the hypothesized larger N300 to incongruence for both word targets primed by happy music (HH/HS). Most of the depressed group also showed atypically larger P300 responses to incongruence for sad word targets regardless of music prime valence (SS/HS), compared to the hypothesized larger P300 to congruence in controls.

Otherwise, both groups showed similar results. For the majority of the control and depressed groups, the N300 and N400 were larger to incongruence and the P300 larger to congruence in all condition comparisons as hypothesized, except for both word targets primed by happy music (HH/HS), where both groups had atypically larger P300 responses to incongruence. For both groups, SS/SH and HH/HS were the condition comparisons with the highest and lowest number of participants responding as hypothesized. Likewise, the N300 and P300 were the most and least reliably observed components for control and depressed individuals in terms of participant numbers responding as hypothesized.

Music-music paradigm: Table 4.2b summarizes and lists the number of participants responding as hypothesized for each condition comparison and component for this paradigm. In contrast to the larger hypothesized P300 response to congruence in the controls, most depressed individuals showed an atypically larger P300 to incongruence for happy music targets regardless of music prime valence (HH/SH) and both music targets primed by sad music (SS/SH).

Otherwise, both groups had similar results. For the majority of control and depressed individuals, the N400 and N300 were larger to incongruence and the P300 larger to congruence for all condition comparisons as hypothesized except

HH/SH			SS/HS			HH/HS			SS/SH		
N300 **	P300 *	N400 *	N300	P300	N400	N300	P300	N400	N300 **	P300 **	N400 *
✓	✓	✓	✓		✓	✓		✓	✓	✓	✓
10/12	9/12	9/12	8/12	5/12	6/12	6/12	5/12	7/12	10/12	10/12	9/12

(a)

HH/SH			SS/HS			HH/HS			SS/SH		
N300	P300	N400	N300	P300	N400	N300	P300 *	N400	N300	P300	N400
✓		✓	✓	✓	✓	✓	✓	✓			✓
7/12	4/12	6/12	7/12	7/12	8/12	7/12	9/12	8/12	5/12	4/12	6/12

(b)

Table 4.2. Sign test results for ERP data for the depressed group for the (a) music-word and (b) music-music paradigm. Results matching (responses elicited in the correct direction, even if not statistically significant) and contrary to the hypotheses are marked ✓ and grey respectively, participant response numbers are listed in the bottom row and significance is indicated *p=0.073, ** p=0.019, *** p=0.003. Data listed are for site Pz, which best illustrates experimental effects in all the examined ERP components.

both music targets primed by sad music (SS/SH), where the N300 was atypically larger to congruence in both groups. HH/HS and SS/SH were the condition comparisons with the highest and lowest number of participants responding as hypothesized respectively for both control and depressed groups. Similarly, the N400 and P300 were the most and least reliably observed components in both groups in terms of participant numbers responding as hypothesized.

4.3.2. *ERP statistics*

ANOVA statistics for the control and depressed groups are presented first, followed by those for just the depressed group for each component. As we have specific hypotheses on conditional effects (i.e., the valence of the target and its congruency with the prime), additional 2 x 2 ANOVAs with the factors target condition valence (happy, sad) and congruency (congruent, incongruent) were run in the region where the component showed the highest mean amplitude (e.g. maximal distribution) after the initial omnibus ANOVA. As before, unless specified, all values reported assume sphericity criteria have been met by the data. The Greenhouse-Geisser correction is applied to account for violations of sphericity when appropriate.

Music-word paradigm

<u>N300</u>

Control and depressed groups: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 114, p = 0.0001 and the interaction between condition and region χ^2 (170) = 406.64, p = 0.0001. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.34 for the main effect of region and 0.26 for the interaction between condition and region). A main effect of region found in the initial omnibus ANOVA (F(2.01,44.21)=13.694, p=0.0001) reflected a left parietal distribution seen for this response.

A significant main effect of condition (F(3,66)=4.137, p=0.009) was present in the initial omnibus ANOVA . This factor was observed to interact with region (F(4.66, 102.61)=3.086, p=0.014). Further analyses were run in the left parietal region using a separate 2 (valence, happy vs. sad) x 2 (congruence, congruent vs. incongruent) x 2 (group, control vs. depressed) ANOVA. A main effect of congruence was found, reflecting a larger N300 to incongruence versus congruence (F(1, 22)=4.310, p=0.0498) (Figure 4.1a).

Depressed group: When the depressed group was analyzed separately, Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 64.85, p = 0.0001. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.29). A main effect of region found in the initial omnibus ANOVA (F(1.75, 19.21)=7.239, p=0.006) reflected primarily increased amplitudes in the left parietal region.

<u>P300</u>

Control and depressed groups: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 102.75, p = 0.0001. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.35). A main effect of region found in the initial omnibus ANOVA (F(2.08, 45.77)=10.262, p=0.0001) revealed a right central distribution seen for this component.

A significant main effect of condition (F(3,66)=5.029, p=0.003) was found in the initial omnibus ANOVA. The results were further analyzed in the right central region using a separate 2 (valence, happy vs. sad) x 2 (congruence, congruent vs. incongruent) x 2 (group, control vs. depressed) ANOVA. A main effect of valence (F(1, 22)=10.768, p=0.034) was found, reflecting a larger P300 to sad over happy valence target conditions (Figure 4.1b).

Depressed group: When the depressed group was analyzed separately, Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 66.15, p = 0.0001. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.33). A main effect of region found in the initial omnibus ANOVA (F(1.97, 21.63)=6.199, p=0.008) reflected primarily increased amplitudes in the right central region.

A condition trend (F(3, 33)=2.675, p=0.063) was observed in the initial omnibus ANOVA. This was further analyzed in the right central region using a separate 2 (valence, happy vs. sad) x 2 (congruence, congruent vs. incongruent) ANOVA. A main effect of valence ($F(1, 11)=5.284$, $p=0.042$) was found, attributable to a larger response to sad versus happy valence target conditions (Figure 4.2a).

N400

Control and depressed groups: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 95.19, p = 0.0001 and the interaction between condition and region χ^2 (170) = 439.85, p = 0.0001. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.38 for the main effect of region and 0.23 for the interaction between condition and region). A significant main effect of region found in the initial omnibus ANOVA ($F(2.27, 49.83)=3.52$, $p=0.032$) reflected a left parietal distribution for the N400.

A condition x region interaction ($F(4.19, 92.23)=2.447$, $p=0.049$) was found in the initial omnibus ANOVA. Further analyses were run in the left parietal region using a separate 2 (valence, happy vs. sad) x 2 (congruence, congruent vs. incongruent) x 2 (group, control vs. depressed) ANOVA. A main effect of valence was found ($F(1, 22)=6.6$, $p=0.018$), attributable to the larger responses to happy versus sad valence targets (Figure 4.1c).

Depressed group: When the depressed group was analyzed separately, Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 51.12, p = 0.0001. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.36). A region trend observed in the initial omnibus ANOVA (F(2.18, 23.99)=2.932, p=0.069) reflected primarily increased amplitudes in the left parietal region.

Further analyses were run in the left parietal region with a separate 2 (valence, happy vs. sad) x 2 (congruence, congruent vs. incongruent) ANOVA. A main of valence was found (F(1, 11)=4.962, p=0.048), attributable to larger N400 responses to happy compared to sad valence target conditions (Figure 4.2b).

Music-music paradigm

<u>N300</u>

Control and depressed groups: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 125.96, p = 0.0001. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.34). A significant main effect of region found in the initial omnibus ANOVA (F(2.03, 44.69)=14.692, p=0.0001) reflected a left parietal distribution seen for this response.

Depressed group: When the depressed group was analyzed separately, Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 61.28, p = 0.0001. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.34). A main effect of region found in the initial omnibus ANOVA (F(2.03, 22.36)=6.156, p=0.007) reflected primarily increased amplitudes in the left parietal region.

P300

Control and depressed groups: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 115.81, p = 0.0001. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.33). A main effect of region found in the initial omnibus ANOVA (F(1.99, 43.83)=10.469, p=0.0001) was primarily attributable to increased amplitudes in the right frontal region.

Depressed group: When the depressed group was analyzed separately, Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 54.82, p = 0.0001. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.35). A main effect of region found in the initial omnibus ANOVA (F(2.08, 22.9)=3.599, p=0.042) reflected primarily increased amplitudes in the right frontal region.

N400

Control and depressed groups: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 99.33, p = 0.0001. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.36). A main effect of region found in the initial omnibus

ANOVA (F(2.14, 47.09)=5.938, p=0.004) reflected a left parietal distribution seen for this response.

Depressed group: Results were not statistically significant.

4.3.3 *Results summary*

The ERP sign test is a non-parametric test highlighting any median differences in two examined variables, showcasing effect generalizability and reliability. The parametric ANOVA and corresponding contrast statistics deals with mean variances and if these variances are significantly different. Considering both methods enables a more comprehensive understanding of the results as both the average and median values are taken into account with the former providing an assessment of group behaviour and the latter an indication of the reliability of the measures at the individual subject level. Results are generally compatible between the ERP sign test and ANOVA statistics in the depressed group.

Music-word: The larger N300 responses to incongruent over congruent target conditions in control and depressed groups indicate intact emotional categorization of word targets irrespective of valence. This effect is primarily due to the controls. Valence had strong effects on emotional recognition (P300) as both groups showed larger responses to sad versus happy target conditions, with slightly enhanced amplitudes from depressed controls compared to the control group. This valence predominance extends to emotional meaning (N400), reflected by a larger N400 to happy over sad target conditions in both groups, but an effect driven by the depressed group.

Music-music: Results did not reach statistical significance.

Figure 4.3a and 4.3b portrays the ERP responses for the music-word and music-music paradigms in the depressed group at site Pz. It is noteworthy that the statistical ANOVA results are based on regions where each component were maximally distributed while the sign test and ERP figures are based on site Pz, as it best illustrates experimental effects in all the examined ERP components and provides a standardized comparison measure across all participant groups.

4.3.4 *Paired samples t-test: component amplitude vs. zero comparisons*

Music-word

<u>N300:</u> Results did not reach statistical significance.

<u>P300:</u> The P300 was significantly different in amplitude for congruent (M= 5.47 μV, SD=3.58) and baseline conditions ($t(11) = 5.295$, $p = 0.0001$).

<u>N400:</u> Results did not reach statistical significance.

Music-music:

<u>N300:</u> Results did not reach significance.

<u>P300:</u> The P300 was significantly different in amplitude for congruent (M= 3.16 μV, SD=2.67) and baseline conditions ($t(11) = 4.112$, $p = 0.002$).

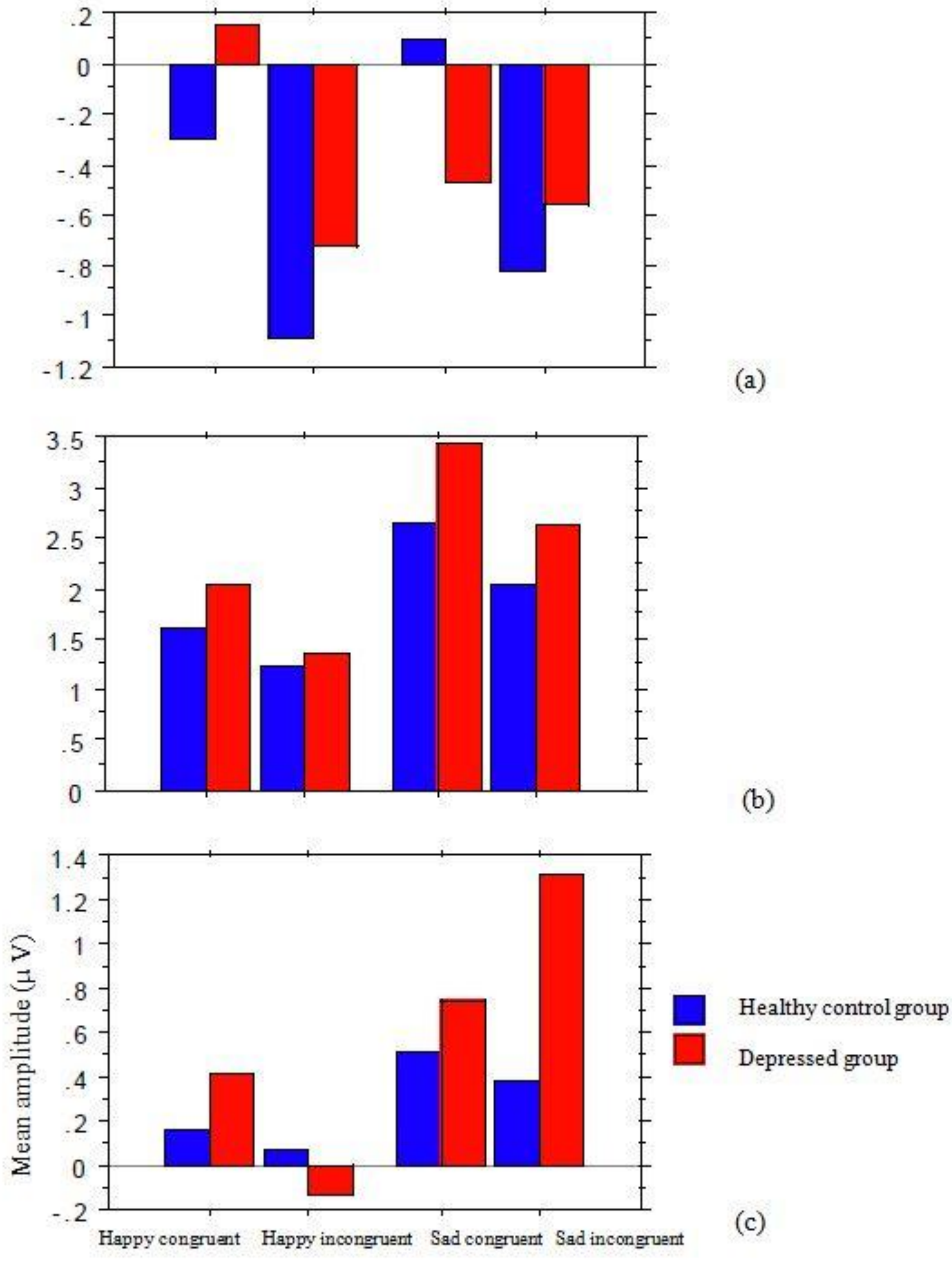

Figure 4.1. Control and depressed group interaction graphs in the music-word paradigm for (a) N300 condition congruence effect in the left parietal region (b) P300 condition valence effect in the right central region (c) N400 condition valence effect in the left parietal region.

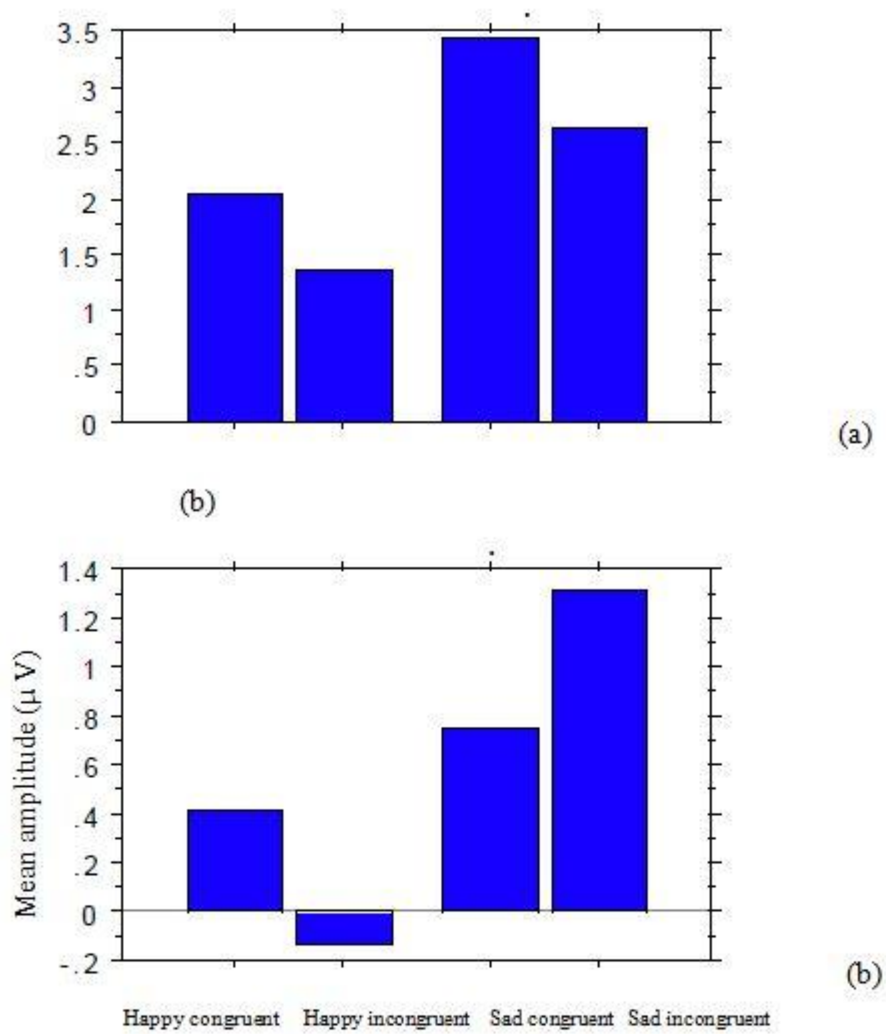

Figure 4.2. Depressed group interaction graphs in the music-word paradigm for (a) P300 condition valence effect in the right central region (b) N400 condition valence effect in the left parietal region.

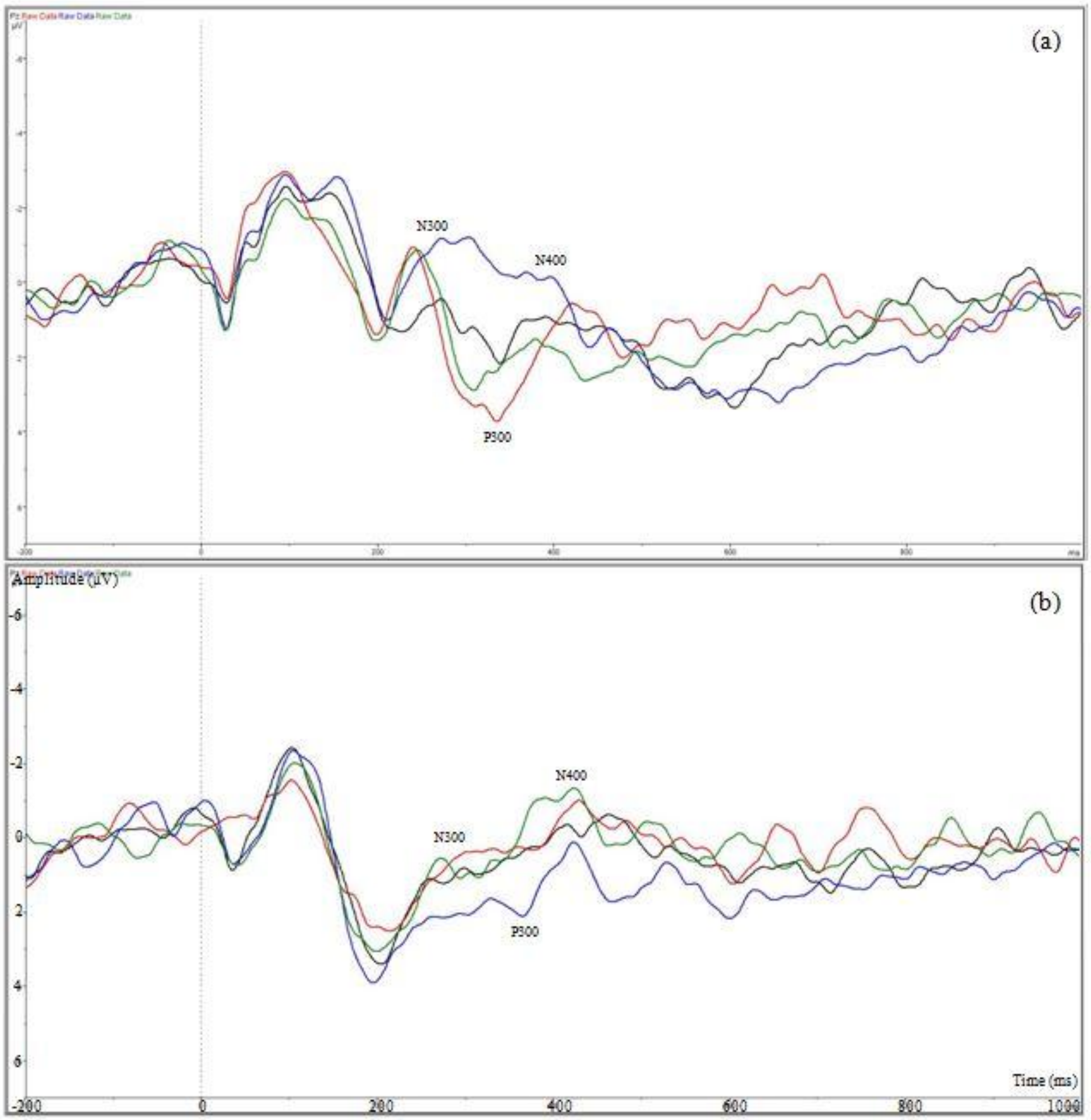

Figure 4.3. ERP responses in the depressed group for the (a) Music-word and (b) Music-music paradigm. Negative is plotted up. Lines - Black: HH, Red: SS, Blue: SH, Green: HS. Site shown: Pz, which best illustrates experimental effects in all examined ERP components.

N400: Results did not reach statistical significance.

4.4 DISCUSSION

Our results were generally compatible with our hypotheses. Depressed participants displayed similar but smaller responses compared to the controls in the ERP gradient of emotional processing for emotional categorization (N300), but showed larger conditional response differences for the P300 (emotional recognition) and N400 (emotional meaning) for the music-word paradigm. While responses in the N300 were influenced by congruence, the P300 and N400 were primarily driven by valence. The paradigm differences reflected in the more distinctive ERP morphology for the music-word (Figure 4.3a) over the more similar music-music paradigm (Figure 4.3b) are replicated in depressed individuals. Both groups showed the same regional distribution for the N300, P300 and N400. As results did not reach statistical significance for the music-music paradigm, the discussion will focus on results for the music-word paradigm.

Although the larger N300 to incongruent versus congruent target conditions in both groups were largely driven by the controls, this finding suggests emotional categorization is relatively preserved and less influenced by valence in depressed participants, though to a smaller extent than the controls. Conversely, depressed individuals primarily influenced the larger responses to emotional recognition (P300) of sad word target conditions and emotional meaning (N400) of happy word target conditions in both groups. These valence-driven effects are interesting as they are indicative of the emotional negativity bias (Cacciopo, Gardner & Bernston, 1999; Chen et al., 2008) manifesting at the later stages of emotional processing rather than the initial stages, a finding that supports those of LeMoult, Yoon & Joormann (2012) and the current consensus in the depression literature (Gotlib & Joormann, 2010).

In emotional recognition, both groups show preferential processing in the form of a larger P300 to sad versus happy word target conditions. As noted in Chapter 2, this effect in controls is more likely attributed to the shorter duration of the word “sad” compared to “happy” rather than a pure valence effect, as subsequent processing in emotional meaning (N400) is intact (i.e., larger response to incongruent versus congruent conditions). In contrast, depressed participants show disrupted integration specifically for sad word target conditions (i.e., atypically larger N400 to sad congruent versus sad incongruent target conditions) with normal performances for happy word targets (Figure 4.1b & c). Although not statistically significant, this detail is indicative of the emotional negativity bias in the depressed group starting from the emotional recognition stage (P300), primarily due to difficulty disengaging from the sad targets (subsequently impaired N400 response) and indicative of the rumination (i.e., “cognitively stuck”) aspect of depression rather than an attentional bias (i.e., “affectively stuck”, emotional inertia) (Koval, Kuppens, Allen & Sheeber, 2012).

While our results are compatible with the enhanced processing of negatively valenced stimuli (Chung et al., 1996; Chen et al., 2008) and the correlation of the emotional negativity bias with depression in music emotion perception (Bodner et al., 2007; Punkanen, Eerola & Errkilä, 2011; Chen et al., 2008), it does not support past studies on the disrupted processing of positively valenced emotion (LeMoult, Yoon & Joormann, 2012; Bodner et al., 2007; Punkanen, Eerola & Errkilä, 2011), as the depressed group exhibited comparable performances with the controls. This factor can be attributed to methodological and modality differences, as all of these studies are visual/cross modal, behavioural (LeMoult, Yoon & Joormann, 2012; Bodner et al., 2007; Punkanen, Eerola & Errkilä, 2011) involve mood induction (Chung et al., 1996; Chen et al., 2008) and clinically depressed patients who were medicated and not excluded from alexithymia (Bodner et al., 2007; Punkanen, Eerola & Errkilä, 2011). If these methodological discrepancies are resolved in future studies and the same effect is replicated, it could be potentially useful to help make depression treatments more effective by focusing on rectifying depressed individuals' processing of negative stimuli rather than positive ones.

Despite the lack of a statistically significant result in the music-music paradigm in the previous chapters, it was somewhat surprising that this finding remain unchanged for the depressed group as their ERP response pattern across conditions was more differentiated (Figure 4.3b) compared to the controls (Figure 2.5b). Moreover, the depressed group constituted the most responsive subgroup to musical emotion (based on their AIMS scores) and depressed individuals have been observed to respond more favourably to music (Bodner et al., 2007; Punkanen, Eerola & Errkilä, 2011) due to its non-verbal and non-judgemental nature. While this lack of statistical significance may again allude to the more automatic and thus, unimpaired processing of the music-music paradigm, it may very likely indicate that more participants are needed to highlight the more subtle effects of this paradigm.

4.5 CONCLUSION

Results for the depressed group replicate the paradigm differences, regional dominance and response pattern in the ERP gradient of emotional processing (N300, P300, N400) observed in the controls. Depressed participants showed similar but decreased N300 response amplitudes for emotional categorization of incongruent word target conditions; but slightly larger responses for emotional recognition (P300) for sad word targets and emotional meaning (N400) of happy word targets than the controls. The specific disruption of the integration of sad word targets (N400) following the preferential recognition of sad word targets (P300) in the depressed group is indicative of the emotional negativity bias manifesting at the later stages of emotional processing, likely due to difficulty disengaging (i.e., cognitive rumination) rather than attentional bias to sad word targets. The lack of statistical significance in the music-music paradigm is again suggestive of a more automatic and intact process for depressed individuals, but remains to be pursued, particularly as the depressed group comprised the most responsive group to musical emotion and showed more response differentiation in this paradigm than the controls. Results based on the music-word paradigm show a breakdown at a later (recognition) stage of emotional processing, showing how disrupted emotion can affect consciousness.

Chapter 5: Music as a measure of emotion: depressed alexithymic individuals

"If feelings cannot be processed, then the feelings as ***signifier*** *of internal states automatically become the* ***signified*** *horror that it would normally signal."*

(Taylor, Bagby & Parker, 1997)

5.1 INTRODUCTION

The ability to perceive and recognize emotion, be it through music, vocal prosody or facial expression; is crucial in non-verbal communication, social relations and aesthetic satisfaction (Saenze et al., 2012). Indeed, it is these very aspects that are compromised in depression (e.g. anhedonia) and alexithymia (e.g. inability to identify emotional and social cues). There has been some skepticism on whether alexithymia is a bona fide condition or if it merely forms some aspects of depression due to their close association (Campanella et al. 2012; Picardi et al., 2011; Bankier, Aigner & Bach, 2001; Honkalampi et al., 2000), but alexithymia levels have been reliably demonstrated to remain unchanged in depressed psychiatric patients while depression levels decreased (Luminet, Bagby & Taylor, 2001; Saarijärvi, Salminen & Toikka, 2006). Marchesi, Brusamonti & Maggini (2000) and Parker, Bagby & Taylor (1991) have also established that depression and alexithymia are separate conditions. So, although depression does not directly cause alexithymia or vice versa (Bankier, Aigner & Bach, 2001), some researchers advocate for alexithymia and depression to be accounted for when considering sex effects in studies on visual emotion recognition (Campanella et al.

2012), or when studying each condition on its own (Honkalampi et al., 2000; Leweke, Leichsenring, Kruse & Hermes, 2012).

In examining the intricate bond alexithymia shares with various DSM-IV disorders like somatoform disorder, panic disorder, obsessive-compulsive disorder and depression, Bankier, Aigner & Bach (2001) found alexithymia to be distinct and its strong ties with these disorders was due to its multidimensional nature. From subscales measuring alexithymia in the TAS-20, difficulty identifying feelings was significantly related with depression (see also Saarijärvi, Salminen & Toikka, 2001) and somatoform disorder; difficulty expressing feelings with depression (see also Saarijärvi, Salminen & Toikka, 2001); and externally oriented thinking with obsessive-compulsive disorder.

This finding makes perfect sense when one considers the characteristics of each disorder, and how alexithymia captures not only their psychological but social aspects. Moreover, it explains the female and male predominance in depression and alexithymia, respectively, and each gender's general inclination in resolving conflicts. Females tend to vent, an affective-oriented approach (i.e., difficulty identifying/expressing feelings for depressed individuals) while males tend to problem solve, an action-oriented approach (i.e., externally oriented thinking in alexithymic individuals). Hence, females unable to vent and not concerned with problem solving will be depressed; while overreliance on problem solving and ignoring emotions in males will result in alexithymia.

Recently, Campanella et al. (2012) showed that alexithymia and depression delayed the N2 and P3b components respectively in a facial emotion recognition task when sex was held constant. The sex differences were characterized as both genders being more responsive to strong negative-affect stimuli, with only females showing this sensitivity in positive-affect and weak negative-affect stimuli. These apparent sex-based differences disappeared when personality factors (depression, alexithymia) were controlled for, showing sex differences only exert effects in combination with personality factors. The N2-P3b was thought to reflect the preparation to process and respond stages (Campanella & Phillipot, 2006, c.f. Campanella et al. 2012). Although this study was visual and considered depression and alexithymia separately, it nicely illustrated the duality of both conditions and their effects in emotional processing and ERP components.

Hintikka, Honkalampi, Lehtonen & Viinamäki (2001) noted the importance of individual type when considering the relationship between alexithymia and depression as measured by the TAS-20 and BDI-II. For control individuals, there was slight overlap in physical concerns, signifying different psychological constructs. In depressed alexithymic individuals, measures overlapped extensively (e.g. deficient emotional awareness, externally oriented thinking, externally oriented interaction, appetite and weight loss), suggesting the generalizability of the alexithymia construct core, but also demonstrating its peripheral susceptibility to population and cultural contexts (Fukunishi et al., 1997; c.f. Hintikka, Honkalampi, Lehtonen & Viinamäki, 2001). It is thus possible for alexithymia levels to decrease when depression levels drop, while still being a stable personality trait in depressed individuals (Saarijärvi, Salminen & Toikka, 2006; Luminet, Bagby & Taylor, 2001; Saarijärvi, Salminen & Toikka, 2001), as reflected by their total and subscale scores.

Depressed alexithymic individuals are usually found to be more severely depressed with more psychopathological (Honkalampi et al., 1999), suicidal, somatic-affective symptoms and deficient interpersonal function (Vanheulue, Desmet, Verhaeghe & Bogaerts, 2007; Kim et al., 2008) than depressed individuals, but generally, this subgroup is rarely defined or studied. As mentioned, genetic polymorphisms of the BDNF and ANKK1 gene have been found to increase predisposition to depression (Aan het Rot et al., 2009) and have been observed in alexithymia (Walter, Montag, Markett & Reuter, 2011), possibly accounting for the overlapping characteristics between the two. Knowing how both conditions interact would help in pinpointing and tackling each condition more effectively (Leweke, Leichsenring, Kruse & Hermes, 2012).

Thus, including and contrasting the depressed alexithymic individuals with depressed, alexithymic and control individuals would be useful in determining the combined effects of alexithymia and depression and how they interact with one another. It would also reveal if one precedes or is more dominant than the other. Considering Campanella et al. (2012)'s visual study, alexithymia appears to exert its effects on emotional regulation before depression as the earliest impact of alexithymia was seen in the N2 latency while depression effects were isolated to the P3b. It remains to be seen if the same outcome is mirrored in our musical auditory task – a different modality – and whether effects are observed in amplitudes, latencies or both.

As with previous chapters, it is hypothesized that depressed alexithymic participants would display larger N300 and N400 responses (reflecting ease of emotional categorization and meaning, respectively) for emotionally incongruent trials and a larger P300 (emotional recognition) for emotionally congruent trials, but altered due to alexithymic (reduced conditional differences) and depressive (emotional negativity bias) effects when compared with controls. It is expected that alexithymic effects would manifest more in the N300 while depression influences would be more apparent in the P300. The extent of how and which component(s) are altered would elucidate the degree of the effects' predominance, interaction and relationship.

In addition, the expected paradigm differences are hypothesized to further reveal the combined effects of depression and alexithymia in contrast to their individual effects and that of the controls. The differing manifestations of alexithymia and depression in the paradigms would indicate each condition(s) precedence and predominance over the other. Given the primary materialization of alexithymic effects in the N2 and depressive effects in the P300 (Campanella et al., 2012), it is hypothesized that alexithymia effects precedes and predominates the influences of depression in emotional regulation, and would thus be more noticeable in the music-music paradigm.

5.2 METHODS

All stimuli, methods, materials, procedures, recruitment and eligibility details are identical to that of Chapter 2. None of the depressed alexithymic participants were medicated.

Participants: 13 individuals were tested, but data from 1 participant was discarded due to excessive drifts, leaving 12 participants (6 males, 6 females). Ten were dextral and 6 were native English speakers (age range 19-48 years, M = 25.17). None were musicians according to the OMSI scale (M = 174.25) and all were depressed as measured by the BDI-II (M = 21.83). All participants' PANAS scores showed more positive moods both at the beginning (M = 29/50) and end (M = 23.42/50) of the experiment, and all were responsive to musical emotion according to the AIMS scale (M = 113.67/170). All participants were alexithymic according to the BVAQ-B scale (M = 55.17), only 1 male (P10) was considered non-alexithymic according to the TAS-20 scale (M = 61.17). As his TAS-20 score was very much borderline (a point short of being alexithymic) compared to high scores in the BVAQ-B, he was considered depressed alexithymic. The BVAQ-B categorized all depressed alexithymic participants as Type II alexithymics (lack of emotional regulation). Table 5.1 lists the alexithymia and depression categorical scores for the depressed alexithymic group.

	Depressed alexithymic individuals (N = 12)
TAS-20 non-alexithymic	1 (8%)
TAS-20 intermediate	2 (17%)
TAS-20 alexithymic	9 (75%)
BVAQ-B non-alexithymic	-
BVAQ-B intermediate	3 (25%)
BVAQ-B alexithymic	9 (75%)
BDI-II minimal depression	-
BDI-II mild depression	12 (100%)

Table 5.1. Depressed alexithymic group categorical scores for alexithymia and depression.

EEG acquisition and analysis: Data acquisition and analyses were identical to Chapter 2. To compare control and depressed alexithymic groups, group (control, depressed alexithymic) was being added as a between subject factor in the initial omnibus ANOVA besides the initial condition (4 levels) and region (7 levels) factors to compare the depressed alexithymic and control groups. Each condition had at least a 56% trial acceptance rate. The lower rate was due to EEG drift in two participants tested over the summer (P18, P58), whose responses otherwise aligned with the hypotheses based on their sign test results. As we have specific hypotheses on conditional effects (i.e., target valence and its congruency with the prime), subsequent 2 x 2 ANOVAs for target valence (happy, sad) and congruency (congruent, incongruent) were run individually for the depressed alexithymic group in the region showing the largest amplitudes for each component after the initial omnibus ANOVA. As before, figures for these regions will not be displayed unless they differed from those by controls in Chapter 2.

5.3 RESULTS

5.3.1. *ERP sign test*

As the sign test compares two conditions by congruency to ascertain if component responses match the hypotheses, the term “condition comparisons” will be used to describe these evaluations (see page 56-57). The sign test determines the number of participants demonstrating the hypothesized response irrespective of its statistical significance. Thus, the condition and component consistency can be ascertained, which is essential for comparison to a TBI patient on an individual case basis. Data listed are for site Pz, which best illustrates experimental effects in all the examined ERP components.

Music-word paradigm: Table 5.2a summarizes and lists the number of participants responding as hypothesized for each condition comparison and component for this paradigm. In contrast to the atypically larger N300 to congruence in controls, the majority of the depressed alexithymic group displayed the hypothesized larger N300 to incongruence for both word targets primed by happy music (HH/HS).

Otherwise, both groups had similar results. For the majority of control and depressed alexithymic individuals, the N300 and N400 were larger to incongruence and the P300 to congruence in all condition comparisons as hypothesized except for both word targets primed by happy music (HH/HS), where both groups had atypically larger P300 responses to incongruence. SS/SH and HH/HS were the condition comparisons with the highest and lowest number of participants responding as hypothesized for both groups. Likewise, the N300 and P300 were the most and least, respectively, reliably observed components in terms of participant numbers - a result that supported the hypotheses for both control and depressed alexithymic groups.

Music-music paradigm: Table 5.2b summarizes and lists the number of participants responding as hypothesized for each condition comparison and

HH/SH			SS/HS			HH/HS			SS/SH		
N300 *	P300	N400	N300 *	P300	N400	N300	P300	N400	N300 **	P300 *	N400 ***
✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
9/12	7/12	8/12	9/12	8/12	7/12	6/12	4/12	7/12	10/12	9/12	11/12

(a)

HH/SH			SS/HS			HH/HS			SS/SH		
N300	P300	N400	N300	P300 *	N400 **	N300	P300	N400 *	N300	P300	N400 *
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
6/12	7/12	7/12	8/12	9/12	10/12	7/12	8/12	9/12	6/12	8/12	9/12

(b)

Table 5.2. ERP sign test for the depressed alexithymic group for the (a) music-word and (b) music-music paradigm. Results matching and contrary to the hypotheses are marked ✓ and grey respectively, participant response numbers are listed in the bottom row and significance is indicated *p=0.07, ** p=0.01, *** p=0.00. Data listed are based on site Pz, which best illustrates experimental effects in all the examined ERP components.

component for this paradigm. In contrast to the atypically larger N300 to congruence in controls, most depressed alexithymics showed the hypothesized larger N300 to incongruence for both music targets primed by sad music (SS/SH). SS/SH and HH/HS were the condition comparisons with the highest and lowest number of participants responding as hypothesized for the depressed alexithymics, compared to HH/HS and SS/SH in the controls.

Otherwise, both groups had similar results. For the majority of control and depressed alexithymic individuals, the N400 and N300 were larger to incongruence and the P300 larger to congruence for all condition comparisons as hypothesized. The N400 and N300 were the most and least reliably observed components in terms of participant numbers responding as hypothesized in both groups.

5.3.2. *ERP statistics*

ANOVA statistics for the control and depressed alexithymic groups are presented first, followed by those for just the depressed alexithymic group for each component. As we have specific hypotheses on conditional effects (i.e., the valence of the target and its congruency with the prime), additional 2 x 2 ANOVAs with the factors target condition valence (happy, sad) and congruency (congruent, incongruent) were run in the region where the component showed the highest mean amplitude (e.g. maximal distribution) after the initial omnibus ANOVA. As before, unless specified, all values reported assume sphericity criteria have been met by the data. The Greenhouse-Geisser correction is applied to account for violations of sphericity when appropriate.

Music-word paradigm

<u>N300</u>

Control and depressed alexithymic groups: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 106.39, p = 0.0001 and the interaction between condition and region χ^2 (170) = 449.8, p = 0.0001. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.37 for the main effect of region and 0.28 for the interaction between condition and region). A main effect of region found in the initial omnibus ANOVA (F(2.24,49.34)=13.983, p=0.0001) reflected a primarily left parietal distribution seen for the N300 response.

A significant condition x region interaction (F(5.12, 112.39)=3.753, p=0.003) was found in the initial omnibus ANOVA. Further analyses were run in the left parietal region using a separate 2 (valence, happy vs. sad) x 2 (congruence, congruent vs. incongruent) x 2 (group, control vs. depressed alexithymic) ANOVA. A main effect of congruence was found (F(1, 22)=12.424, p=0.002), revealing a larger N300 to incongruent over congruent target conditions (Figure 5.1a).

Depressed alexithymic group: When the depressed alexithymic group were analyzed separately, Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 58.84, p = 0.0001. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.35). A main effect of region found in the initial omnibus ANOVA (F(2.08, 22.86)=7.321, p=0.003) was primarily attributable to increased amplitudes in the left parietal region.

A significant condition x region interaction (F(18,198)=2.278, p=0.003) was found in the initial omnibus ANOVA. Further analyses were run in the left parietal region with a separate 2 (valence, happy vs. sad) x 2 (congruence, congruent vs. incongruent) ANOVA. A congruence trend was found (F(1, 11)=4.509, p=0.0572), reflecting a larger N300 to incongruent versus congruent target conditions (Figure 5.2a).

P300

Control and depressed alexithymic groups: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 113.48, p = 0.0001 and condition χ^2 (5) = 15.59, p = 0.0001. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.35 for the main effect of region and 0.28 for the main effect of condition). A significant main effect of region found in the initial omnibus ANOVA (F(2.07, 45.51)=9.018, p=0.0001) reflected a primarily right central distribution.

A main effect of condition (*F*(2.26, 49.7)=5.041, *p*=0.008) was found in the initial omnibus ANOVA. This was further analyzed in the right central region with a separate 2 (valence, happy vs. sad) x 2 (congruence, congruent vs. incongruent) x 2 (group, control vs. depressed alexithymic) ANOVA. A main effect of valence (*F*(1, 22)=15.415, *p*=0.0007) was found, signified by a larger P300 to sad over happy valence target conditions (Figure 5.1b).

Depressed alexithymic group: When depressed alexithymic participants were analyzed separately, Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 63.33, p = 0.0001 and condition χ^2 (5) = 13.01, p = 0.024. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.33 for the main effect of region and 0.67 for the main effect of condition). A significant main effect of region found in the initial omnibus ANOVA (*F*(1.96, 21.53)=4.981, *p*=0.017) was primarily attributed to a right central distribution.

A condition trend (*F*(2, 22.03)=3.105, *p*=0.065) was observed in the initial omnibus ANOVA. This was further analyzed in the right central region with a separate 2 (valence, happy vs. sad) x 2 (congruence, congruent vs. incongruent) ANOVA. A main effect of valence (*F*(1, 11)=9.239, *p*=0.0113) was found, reflecting a larger P300 to sad compared to happy valence target conditions (Figure 5.2b).

<u>N400</u>

Control and depressed alexithymic groups: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 109.32, p = 0.0001. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.36). A main effect of region found in the initial omnibus ANOVA (F(2.16, 47.53)=3.383, p=0.039) was primarily attributable to increased amplitudes in the left parietal region.

Further analysis were run in the left parietal region with a separate 2 (valence, happy vs. sad) x 2 (congruence, congruent vs. incongruent) x 2 (group, control vs. depressed alexithymic) ANOVA. A main effect of valence was found (F(1, 22)=6.311, p=0.0198), attributable to a larger N400 to happy over sad valence target conditions (Figure 5.1c).

Depressed alexithymic group: Results for the initial omnibus ANOVA did not reach statistical significance. Further analysis were run in the left parietal region using a separate 2 (valence, happy vs. sad) x 2 (congruence, congruent vs. incongruent) ANOVA. A strong valence trend was observed (F(1, 11)=4.658, p=0.0539), revealing a larger N400 to happy compared to sad valence target conditions (Figure 5.2c).

Music-music paradigm

N300

Control and depressed alexithymic groups: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 121.38, p = 0.0001. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.34). A main effect of region found in the initial omnibus ANOVA (F(2.03, 44.65)=28.518, p=0.0001) was primarily attributable to increased amplitudes in the left parietal region.

Depressed alexithymic group: When the depressed alexithymic group were analyzed separately, Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 51.96, p = 0.0001. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.37). A main effect of region found in the initial omnibus ANOVA (F(2.23, 24.48)=20.201, p=0.0001) reflected a left parietal distribution.

<u>P300</u>

Control and depressed alexithymic groups: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 123.64, p = 0.0001. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.33). A main effect of region found in the initial omnibus ANOVA (F(1.96, 43.13)=22.096, p=0.0001) revealed increased amplitudes in the right frontal region.

Depressed alexithymic group: When depressed alexithymic participants were analyzed separately, Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 48.81, p = 0.001. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.38). A main effect of region found in the initial omnibus ANOVA (F(2.3, 25.27)=15.017, p=0.0001) reflected a right frontal distribution.

<u>N400</u>

Control and depressed alexithymic groups: Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 104.73, p = 0.0001. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.35). A main effect of region found in the initial omnibus ANOVA (F(2.11, 46.46)=13.448, p=0.0001) was primarily attributable to increased amplitudes in the left parietal region.

Further analysis were in the left parietal region using a separate 2 (valence, happy vs. sad) x 2 (congruence, congruent vs. incongruent) x 2 (group, control vs. depressed alexithymic) ANOVA. A valence x group interaction was found (F(1, 22)=4.627, p=0.0427), reflecting a larger N400 to happy target conditions in the controls compared to sad target conditions in the depressed alexithymic group (Figure 5.1d).

Depressed alexithymic group: When the depressed alexithymic group were analyzed separately, Mauchley's test indicated that the assumption of sphericity was violated for the main effect of region χ^2 (20) = 52.08, *p* = 0.0001. Thus, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.36). A main effect of region found in the initial omnibus ANOVA ($F(2.16, 23.76)=7.161$, $p=0.003$) reflected a left parietal distribution.

5.3.3 *Results summary*

The ERP sign test is a non-parametric test highlighting any median differences in two examined variables, showcasing the generalizability and reliability of the effect. The parametric ANOVA and corresponding contrast statistics deals with mean variances and if these variances are significantly different. Considering both methods enables a more comprehensive understanding of the results as both the average and median values are taken into account with the former providing an assessment of group behaviour and the latter an indication of the reliability of the measures at the individual subject level. As before, results are generally compatible between the ERP sign test and ANOVA statistics in the depressed alexithymic group.

Music-word: The larger N300 responses to incongruent over congruent target conditions in control and depressed alexithymic groups indicates intact emotional categorization of word targets irrespective of valence. This effect is primarily due to the controls as depressed alexithymics participants only exhibited a congruence trend when analyzed separately. As before, valence exerted strong effects on emotional recognition (P300) as both groups showed larger responses to sad versus happy target conditions, with enhanced amplitudes from depressed alexithymics compared to controls. This valence predominance extends to emotional meaning (N400), reflected by a larger N400 to happy over sad target conditions in both groups, an effect driven by the depressed alexithymic group.

Music-music: A larger N400 to happy target conditions in the control group over sad target conditions in the depressed alexithymic group shows the differential effect of valence in both groups. Controls had larger N400 responses to sad compared to happy valence targets conditions, while depressed alexithymics elicited a larger N400 to happy versus sad valence target conditions.

Figure 5.3a and 5.3b portrays the ERP responses for the music-word and music-music paradigms in the depressed alexithymic group at site Pz. It is noteworthy that statistical ANOVA results are based on regions where each component was maximally distributed, while the sign test and ERP figures are based on site Pz as it best illustrates experimental effects in all the examined ERP components and provides a standardized comparison measure across participant groups.

5.3.4 *Paired samples t-test: component amplitude vs. zero comparisons*

Music-word

N300: A significant difference in N300 amplitude for incongruent (M= -1.74µV, SD=2.41) and baseline conditions was observed ($t(11) = -2.502$, $p = 0.029$).

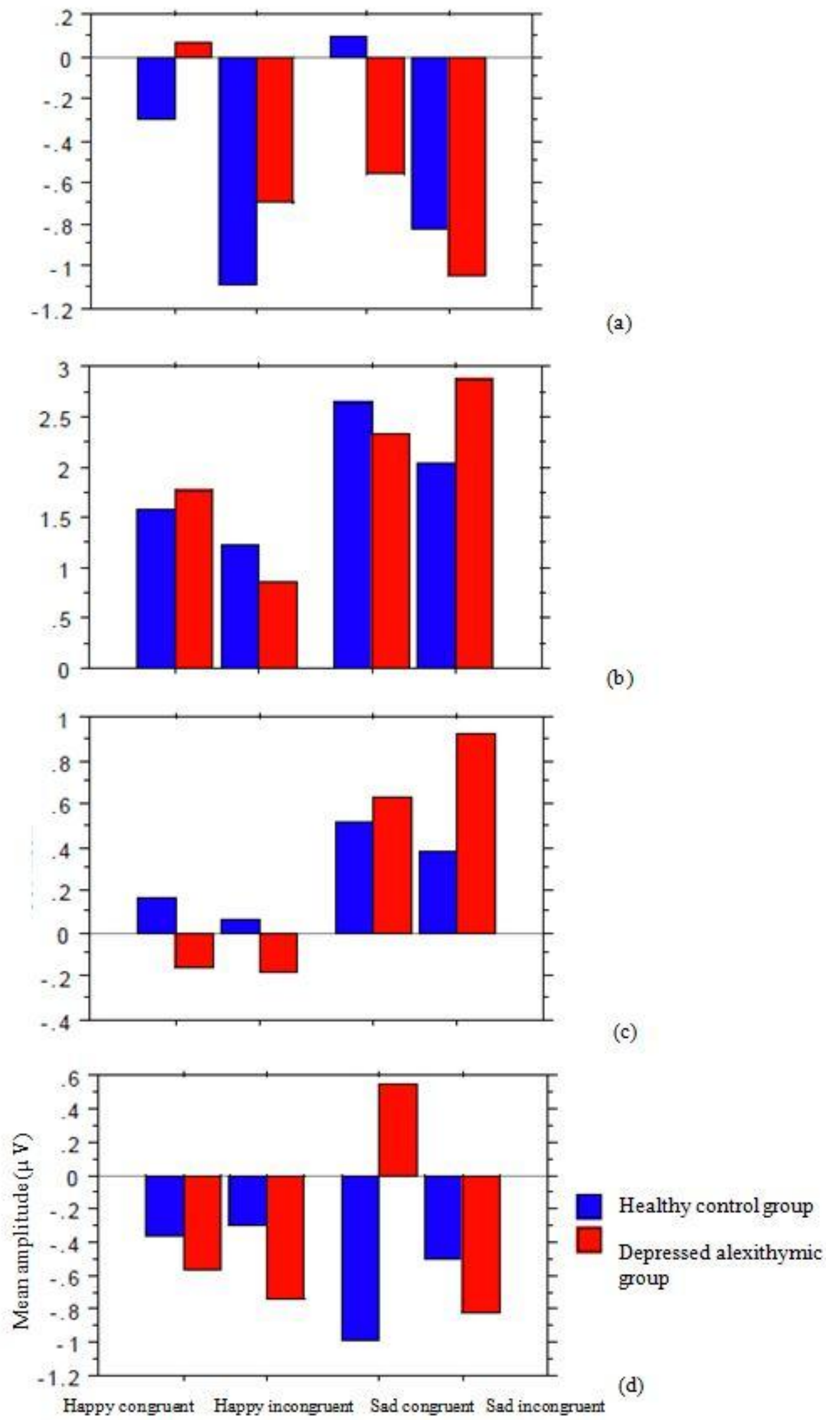

Figure 5.1. Control and depressed alexithymic group interaction graphs in the music-word paradigm for (a) N300 condition congruence effect in the left parietal region (b) P300 condition valence effect in the right central region (c) N400 condition valence effect in the left parietal region (d) Music-music paradigm N400 condition valence x group effect in the left parietal region.

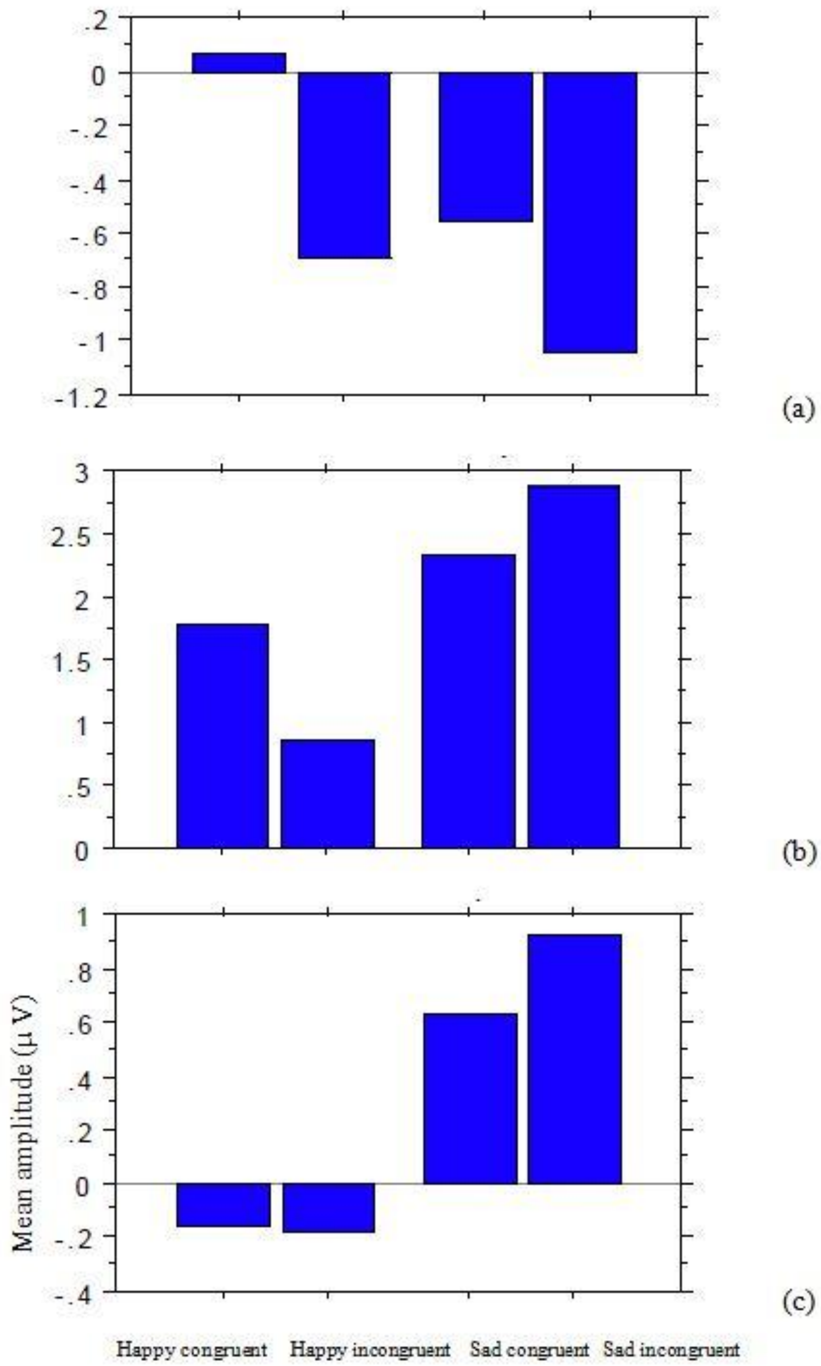

Figure 5.2. Depressed alexithymic group interaction graphs in the music-word paradigm for (a) N300 condition congruence effect in the left parietal region (b) P300 condition valence effect in the right central region (c) N400 condition valence effect in the left parietal region.

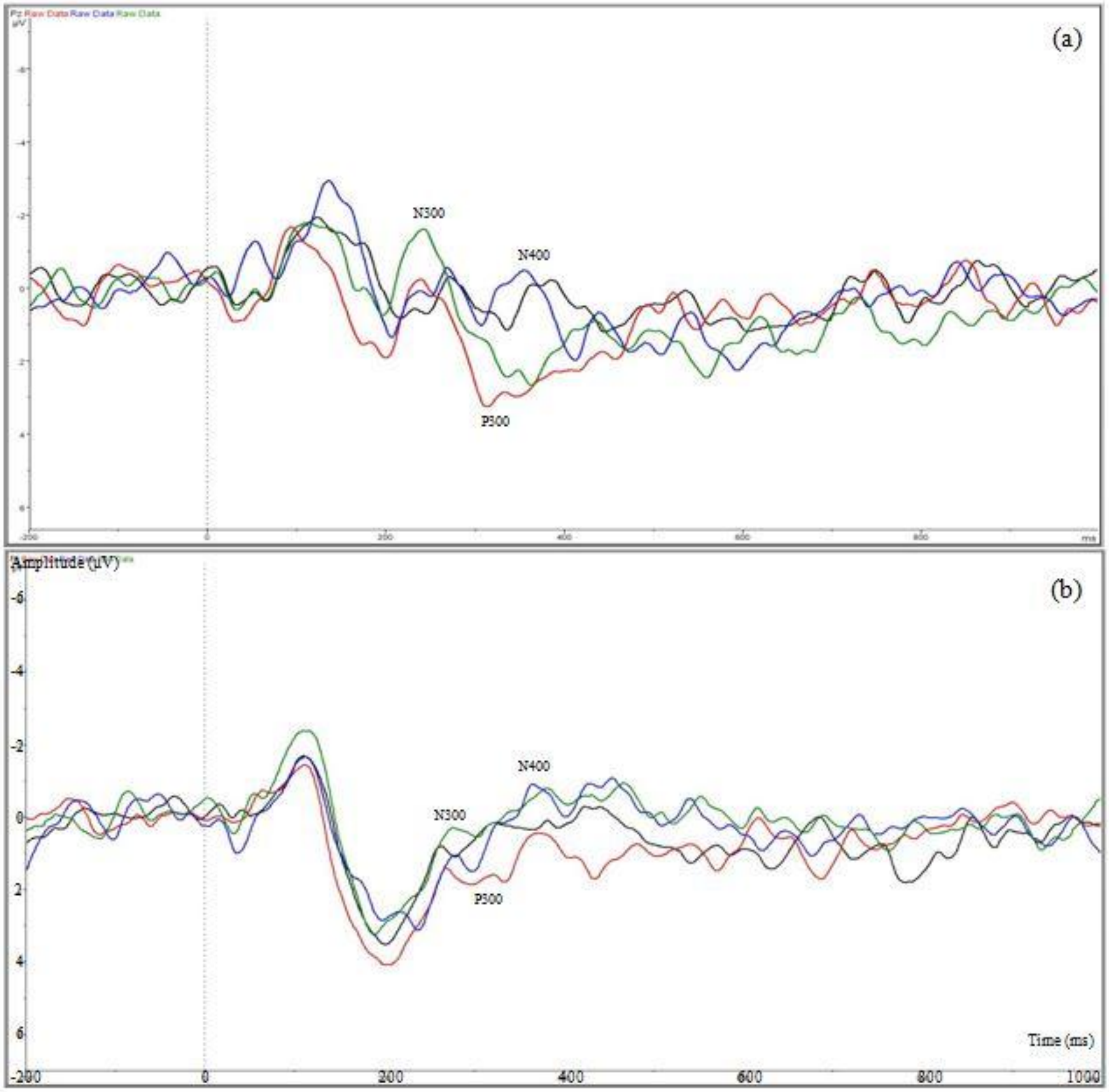

Figure 5.3. ERP responses in the depressed alexithymic group for the (a) Music-word and (b) Music-music paradigm. Negative is plotted up. Lines - Black: HH, Red: SS, Blue: SH, Green: HS. Site shown: Pz, which best illustrates experimental effects in all examined ERP components.

<u>P300:</u> The P300 was significantly different in amplitude for congruent (M= 4.11 μV, SD=4.87) and baseline conditions ($t(11) = 2.92$, $p = 0.014$).

<u>N400:</u> Results did not reach statistical significance.

Music-music:

<u>N300:</u> Results did not reach statistical significance.

<u>P300:</u> The P300 was significantly different in amplitude for congruent (M= 3.78 μV, SD=3.28) and baseline conditions ($t(11) = 3.99$, $p = 0.002$).

<u>N400:</u> The N400 was significantly different in amplitude for incongruent (M= -1.56μV, SD=2.44) and baseline conditions ($t(11) = -2.212$, $p = 0.049$).

5.4 DISCUSSION

Our results were generally compatible with the hypotheses. In the music-word paradigm, depressed alexithymic participants exhibited reduced responses compared to controls in the ERP gradient of emotional processing for the N300 (emotional categorization), but larger conditional response differences for the P300 (emotional recognition) and N400 (emotional meaning). The N300 responses were primarily influenced by congruence, while valence affected the P300 (sad) and N400 (happy) responses. Furthermore, the depressed alexithymic group specifically differed from the controls for the N400 in the music-music paradigm by showing a larger N400 to happy versus sad target conditions. This N400 pattern was reversed for the controls (larger N400 to sad over happy targets). Paradigm differences were characterized by the more differentiated ERP waveforms and amplitudes for the music-word (Figure 5.3a) over the more similar ERPs in the music-music paradigm (Figure 5.3b). While these paradigm differences replicated the general findings with the other groups in this research, the differences were more pronounced for the depressed alexithymic group. Both the control and the depressed alexithymic group demonstrated the same regional distributions for the N300, P300 and N400.

The similar emotional categorization in both groups reflected by a larger N300 to incongruent versus congruent word target conditions points to a *relatively* uncompromised processing stage in depressed alexithymic participants; although it was the controls who primarily accounted for the congruity effect. While both groups had larger P300 responses to sad over happy word targets in the emotional recognition stage, the depressed alexithymic group showed larger responses to sad incongruent compared to sad congruent target conditions, a reversal of the hypothesized response pattern shown by the controls (Figure 5.1b). This reversal suggests the manifestation of impaired recognition of sad word targets in depressed alexithymics. Even though both groups similarly showed larger N400 responses to happy compared to sad word targets in emotional meaning, the impaired processing of sad word targets continued to affect integration in emotional meaning for depressed alexithymics as larger responses are emitted to sad congruent than sad incongruent conditions (Figure 5.2c). Conversely, the controls had larger N400 responses to sad incongruent compared to sad congruent conditions (Figure 5.1c). Although the reversals observed in the P300 and N400 were not statistically significant, they will be discussed as these effects are strongly indicative of the influences of alexithymia and/or depression.

The larger P300 response to sad incongruent compared to sad congruent word targets in the depressed alexithymic group is observed only in the alexithymic group, who displayed larger and more statistically significant responses (Figure 3.2b). This specific impairment of emotional recognition in sad word targets following happy music targets is attributed to the compromised processing of negatively valenced word targets when primed by incongruently valenced music due to alexithymia (Vermeulen, Toussant & Luminet, 2010). Considering the simultaneous presence of depression in the depressed alexithymic group, this alexithymic influence is likely reduced because of the general response dampening manifested in depression, resulting in the effect failing to reach statistical significance. Conversely, the depressed group showed the opposite P300 response pattern for this specific condition, a stage first indicating the presence of the emotional negativity bias. In this sense, alexithymia effects appear to predominate those of depression although its effects were not apparent in the earlier N300, partially supporting results from Campanella et al. (2012).

The impaired P300 response to sad word targets following happy music primes extended to an atypically larger N400 in the same condition. This response pattern reflects another reversal of the hypothesized response. However, this time the reversal is observed in both the alexithymia and depressed group although effects are attributed to different causes. In the alexithymic group, integration of emotional meaning was the end product of successive impairment beginning at emotional categorization (N300). In the depressed group, the disrupted N400 response subsequent to the emotional negativity bias seen in the P300 suggests problems disengaging from sad word targets (i.e., a larger N400 to sad congruent than sad incongruent conditions) or cognitive rumination (Koval, Kuppens, Allen & Sheeber, 2012). Following the specific alexithymia influenced impairment of sad word targets preceded by happy music in the P300 of the depressed alexithymic group, it makes sense for the disrupted N400 response to follow and be attributed to alexithymia. However, it is also possible for the emotional negativity bias to manifest at this point in the form of difficulty disengaging, as an attentional bias would be rather delayed. In sum, the combinative effects of alexithymia and depression likely accounts for the atypical N400 response for sad word targets following happy music in depressed alexithymic participants.

In the music-music paradigm, the depressed alexithymic group had larger N400 responses to happy than sad targets, whereas the controls displayed larger responses to sad than happy target conditions. This finding points to group integration differences based on valence. For this reason, results for the N300 and P300 (both of which were not statistically significant) will be discussed as they affect processes leading up to integration (N400). The controls had larger responses to sad targets in the N300 (emotional categorization) and N400 (emotional meaning), but happy targets elicited larger P300 responses (emotional recognition). Conversely, depressed alexithymic participants were observed to show consistently larger amplitudes to happy target conditions for all three studied components.

Results from the controls complement literature on happy music being more easily recognized (larger P300) than sad music (Juslin & Laukka, 2003; Vieillard et al., 2008), as more effort would be needed to disambiguate the valence of sad music (larger N300, N400). Thus, the consistently larger responses of depressed alexithymic controls to happy targets suggests a specific processing deficit of positively valenced stimuli (Lemoult, Yoon & Joormann, 2012; Bodner et al., 2007; Punkanen, Eerola & Errkilä, 2011) with uncompromised processing for negatively valenced music targets. As results for the depressed and control groups were similar and results for the alexithymic and depressed alexithymic groups were comparable in terms of processing music target valence, it is our observation that the processing deficit in positively valenced stimuli (i.e., anhedonia) observed in depression is in fact attributable to alexithymia, and would account for why depressed alexithymic individuals were observed to be more severely depressed than depressed individuals (Honkalampi et al., 1999; Vanheulue, Desmet, Verhaeghe & Bogaerts, 2007).

Similar to results from the music-word paradigm, alexithymia influences appear to preside over depression but this time effects were clearly manifested in earlier components from the P300 (i.e., N300), a finding in line with Campanella et al. (2012). The earlier manifestation of alexithymic effects (N300) in the music-

music compared to the music-word (P300) paradigm in depressed alexithymic participants indicates alexithymia effects on emotional regulation precedes that of depression. This premise also aligns with the music-music paradigm being more automatic of the two paradigms.

5.5 CONCLUSION

The paradigm differences, regional dominance and response pattern in the ERP gradient of emotional processing were similar in the depressed alexithymic group, who showed decreased conditional response differences for emotional categorization (N300) but reversed response patterns for emotional recognition (P300) and emotional meaning (N400) for the music-word paradigm compared to controls. While this response pattern was comparable to that of the depressed group, the larger P300 to sad incongruent versus sad congruent conditions in the depressed alexithymic group differed from the depressed group and was attributed to alexithymia rather than the emotional negativity bias. Alexithymia continued to exert its influence in the more automatic music-music paradigm, where larger responses in the ERP gradient to happy music targets indicate specific deficits in the processing of positively valenced stimuli, a detail generally ascribed to depression. Our results thus evidence how alexithymia makes depressed alexithymia individuals appear more depressed than depressed individuals. The manifestation of alexithymia earlier (N300) in the more automatic music-music paradigm compared to the P300 in the music-word paradigm suggests alexithymia effects on emotional regulation may precede that of depression.

Chapter 6: Music as a measure of emotion: thesis database

"The truth is not always to be found among the disputants with the loudest voices."

(Allen, 2010).

The previous chapters on the control, alexithymic, depressed and depressed alexithymic groups form the participant database for this thesis (N=48). Clear ERP response differences for condition (Figure 6.1) and group (Figure 6.2) were evident in both paradigms, a clear testament to the feasibility and efficacy of the experimental task. While it would be interesting to statistically analyze and present all group and conditional differences, the sheer amount of data and detail would overwhelm and detract from this thesis' main clinical focus. It is more imperative to know how each group (alexithymic, depressed, depressed alexithymic) differ from normalcy (i.e., controls) than how alexithymic and depressed groups differ from each other; or how incongruent conditions (HS, SH) vary from congruent ones (HH, SS) than how happy and sad congruent/incongruent trials differ from each other (HH vs. SS, HS vs. SH). Relevant as they are, these questions and differences are more research based and are better addressed as future avenues of research designed to address these differences in detail.

Before delving into the database's ERP condition and group differences, the relations between depression, alexithymia and musicality will be examined by analyzing the various behavioural scales used in this thesis.

6.1 BEHAVIOURAL SCALE CORRELATIONS

The previous chapters have disclosed close relationships between depression, alexithymia and musical aptitude. Bivariate correlations were thus conducted using Pearson's correlation coefficient to examine correlations between the scores of the various assessment scales used (BDI-II, TAS-20, BVAQ-B, AIMS, OMSI, PANAS). As there were specific hypotheses and literature demonstrating strong correlations between the BDI-II with the TAS-20 (Hintikka, Honkalampi, Lehtonen & Viinamäki, 2001; Honkalampi et al. 2000) and PANAS (Watson, Clark & Tellegen, 1988), a one-tailed test was used.

Starting with the depression and alexithymia connection, results confirm past research as the BDI-II was positively correlated to the TAS-20 ($r = 0.564$, $p < 0.01$) and its subscales (Difficulty identifying feelings: $r = 0.588$, $p < 0.0001$; difficulty describing feelings: $r = 0.390$, $p < 0.003$; externally oriented thinking: $r = 0.300$, $p < 0.019$). While the BDI-II did not correlate with total BVAQ-B scores, it was negatively related to its poor fantasy ($r = -0.304$, $p < 0.018$), poor emotional excitability ($r = -0.260$, $p < 0.037$) subscales and positively related to poor insight ($r = 0.326$, $p < 0.012$). Thus, depression increases with alexithymia and their relationship appears to be more related to the cognitive regulation of emotions (measured by the TAS-20) rather than inherent emotional deficits (measured by the BVAQ-B on top of emotional regulation). This finding supports our results and that of past research on depressed alexithymic individuals being more depressed than depressed individuals (Honkalampi et al., 1999; Vanheule, Desmet, Verhaeghe & Bogaerts, 2007).

This cognitive integration deficit is further confirmed as all alexithymic participants in the present study were classified as Type 2 alexithymics (intact emotional experience, impaired emotion regulation) as opposed to Type 1 (absent emotional experience and emotion regulation) (Larsen, Brand, Bermond & Hijman, 2003) according to their BVAQ-B scores. Note that the TAS-20 and BVAQ-B are closely related ($r = 0.488$, $p < 0.0001$), replicating literature findings (Vorst & Bermond, 2001). The BDI-II correlations to BVAQ-B's poor fantasizing and poor emotional excitability subscales is suggestive of a state (i.e., peripheral effect influenced by culture and population) rather than a stable (i.e., core) trait in alexithymia (Fukunishi et al., 1997, c.f. Hintikka, Honkalampi, Lehtonen & Viinamäki, 2001). This fantasizing deficit could be related to the specific processing impairment for happy music targets in depressed alexithymics in our results. Taken together, these BVAQ-B subscales better reflect the combined effects of depression and alexithymia while the TAS-20 and BDI-II better showcases the separate influences of alexithymia and depression.

The negative correlation of the BDI-II with the PANAS, specifically the positive mood scale after completing the experiment ($r = -0.317$, $p < 0.014$) was also in line with previous findings, particularly the more accurate characterization of depression based on the positive rather than the negative PANAS scale (Tellegen 1985, c.f. Chung et al., 1996). Apart from an alexithymic female (P24) and a depressed alexithymic male (P10), all participants had positive moods. As mood effects would be more relevant to music induction studies, this result will not be further pursued. Moreover, it shows how depression and alexithymia are not affected by mood and experimental results are not transient.

An interesting and novel outcome was the correlation of the BDI-II with the AIMS (r = 0.274, p = 0.030). The AIMS has only been developed in the past few years to specifically measure and predict an individual's emotional response to music regardless of musical training (Sandstrom & Russo, 2011) and has not been utilized outside of the musical research domain. While there has been numerous associations of depression with music (mostly emotional regulation or therapy), this is the first study explicitly showing music emotional responsiveness increases with depression. Furthermore, this finding corroborates how the depressed and depressed alexithymic groups constitute the most musically responsive groups, followed by the alexithymic group, with the controls being the least responsive.

While the AIMS did not correlate with the TAS-20 or BVAQ-B total scores, it was positively related to the difficulty identifying feelings subscale for the TAS-20 (r = 0.274, p = 0.030) and negatively related to the poor fantasizing subscale in the BVAQ-B (r = -0.343, p = 0.009). This correlation is thus suggestive of the combined effects depression and alexithymia as the difficulty identifying feelings subscale has been specifically identified in previous studies (Conrad et al., 2009; Marchesi, Brusamonti & Maggini, 2000; Hendryx, Haviland

& Shaw, 1991), while the poor fantasizing skills identified here was another new finding of the present study. The absence of the poor fantasizing subscale in past research is because the BVAQ-B is not as widely used as the TAS-20 even in the alexithymia literature, and presently not used at all in the depressed alexithymia literature. In turn, the TAS-20 does not measure the daydreaming/fantasizing aspects of alexithymia. Thus, a possible reconciliation of the correlations of the AIMS and the subscales for difficulty identifying feelings (TAS-20) and poor fantasizing (BVAQ-B) with our findings in depressed alexithymia could be a problem in appropriately identifying and imagining feelings. This deficiency appears to be more particular to positive feelings, in contrast to negative ones (i.e., negativity bias) observed in depressed individuals. This result strongly advocates for a more comprehensive assessment of alexithymia and further separates the aspects contributing to the combined and individual effects of depression and alexithymia.

The OMSI was quite detached from the other scales although a strong trend with the AIMS was observed ($r = 0.222$, $p = 0.065$), complementing results from Bigand et al. (2005) of a marginal relationship between emotional response to music and musical skill. Like the AIMS, the OMSI is also another fairly recent development meant to index musical sophistication (e.g. musical knowledge, instrument playing, singing aptitudes, musical activity, understanding, responsiveness and creation abilities apart from musical training) (Ollen, 2006) and similarly, its utilization has been limited to the musical arena. Its sole correlation was with the TAS-20's difficulty identifying feelings subscale (r = 0.317, p = 0.014), indicating higher levels of musical sophistication increases with difficulty identifying feelings.

This somewhat counterintuitive finding actually complements research demonstrating musicians being more concerned with musical technicality and structure than emotion when listening to music (Peretz, Gaudreau & Bonnel, 1998; Bigand et al., 2005; Eschrich, Münte & Altenmüller, 2008). It also aligns with incidences of autistic musical savants, individuals whom are extremely gifted musically but characterized by pathologically blunted affect, with high incidences of alexithymia (Gaigg, 2012). In fact, alexithymia has been attributed to these individuals' deficient emotional responsiveness to music (Allen, Davis & Hill, 2012; Allen, 2010) and poor empathy skills (Bird et al., 2010) rather than autism itself, and they are also known to be more attracted to musical structure than musical emotion (Levitin, 2011). For the purposes of the current thesis however, the general independence of musical sophistication from depression, alexithymia and music emotional responsiveness bodes well for the applicability of the paradigm for clinical purposes, where responses are autonomous and generalizable to the population and not only to those who are musically skilled.

6.2 SIGN TEST AND ANOVA STATISTICS

Many of the analyses that follow combine data from across the four groups. Given the findings outlined in the preceding chapters, this practice would appear to be procedurally questionable. However, it should be noted that the psychological characteristics employed to categorize participants in this research are not typically employed in most ERP research studies examining emotion. Thus, combining datasets across the four groups was done in order to gain more power in the statistical analyses and to obtain a portrait of what patterns would emerge from a large, undifferentiated sample of "typical" people. As before, statistical ANOVA results are based on regions where each component was maximally distributed while the sign test and ERP figures are based on site Pz, as it best illustrates experimental effects and provides a standardized comparison measure across all groups.

The sign test determines the number of participants demonstrating the hypothesized response irrespective of its statistical significance. Thus, the condition and component consistency can be ascertained, which is essential for comparison to a TBI patient on an individual case basis. The sign tests (Table 6.1) for the thesis database most closely resembles the alexithymic group for the music-word paradigm (Table 3.2a, Chapter 3) and the depressed alexithymic group for the music-music paradigm (Table 5.2b, Chapter 5). Results from the sign test generally align with results from the statistical ANOVA for the thesis database. Based on the previous chapters, our specific hypotheses on condition effects (i.e., target valence and its congruency with the prime) and the consistent maximal distribution of the ERP components, a 2 x 2 x 4 ANOVA with the repeated factors of target condition valence (happy, sad) and congruency (congruent, incongruent) and between factor of group (control, alexithymic, depressed, depressed alexithymic) were run in the left parietal region for the N300 and N400, the right frontal region for the P300 in the music-music paradigm and right central region for the P300 in the music-word paradigm.

In the music-word paradigm, statistically significant results were only apparent for the P300 and N400 components. For the P300, the omnibus ANOVA found a main effect of group ($F(3, 44)=10.42$, $p=0.0001$), valence ($F(1, 44)=10.234$, $p=0.0026$) and a group x valence interaction ($F(3,44)=2.765$, $p=0.053$). These reflected valence differentially influencing P300 response in the depressed and alexithymic groups, being particularly large for sad word targets in the depressed group (i.e., emotional negativity bias) and weak for happy word targets in the alexithymic group (i.e., intact emotional recognition) (Figure 6.3a).

For the N400, the omnibus ANOVA found a main effect of valence ($F(1, 44)=6.79$, $p=0.0125$), reflecting larger responses to happy targets compared to sad target conditions for all groups (Figure 6.3b). A group trend was observed ($F(3, 44)=2.511$, $p=0.0709$), attributable to larger N400 responses in the alexithymic group (i.e., additional processing efforts) compared to the depressed alexithymic group for all conditions.

In the music-music paradigm, statistically significant results were apparent only for the P300. The omnibus ANOVA found a main of group ($F(3, 44)=13.212$, $p=0.0001$), reflecting larger responses in the depressed alexithymic

HH/SH			SS/HS			HH/HS			SS/SH		
N300 ***	P300 ***	N400 ***	N300 ***	P300	N400	N300	P300	N400 *	N300 ***	P300 ***	N400 ***
✓	✓	✓	✓	✓				✓	✓	✓	✓
38/48	34/48	36/48	32/48	25/48	23/48	22/48	17/48	30/48	42/48	38/48	38/48

(a)

HH/SH			SS/HS			HH/HS			SS/SH		
N300	P300	N400	N300	P300	N400 ***	N300 ***	P300 ***	N400 ***	N300	P300	N400 *
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
27/48	25/48	28/48	29/48	29/48	33/48	32/48	32/48	36/48	24/48	25/48	30/48

(b)

Table 6.1. ERP sign test for the thesis database for the (a) music-word and (b) music-music paradigm. Results matching and contrary to the hypotheses are marked ✓ and grey respectively, participant response numbers are listed in the bottom row and significance is indicated *p=0.06, ** p=0.03, *** p=0.02. Data listed are based on site Pz, which best illustrates experimental effects for all examined ERP components.

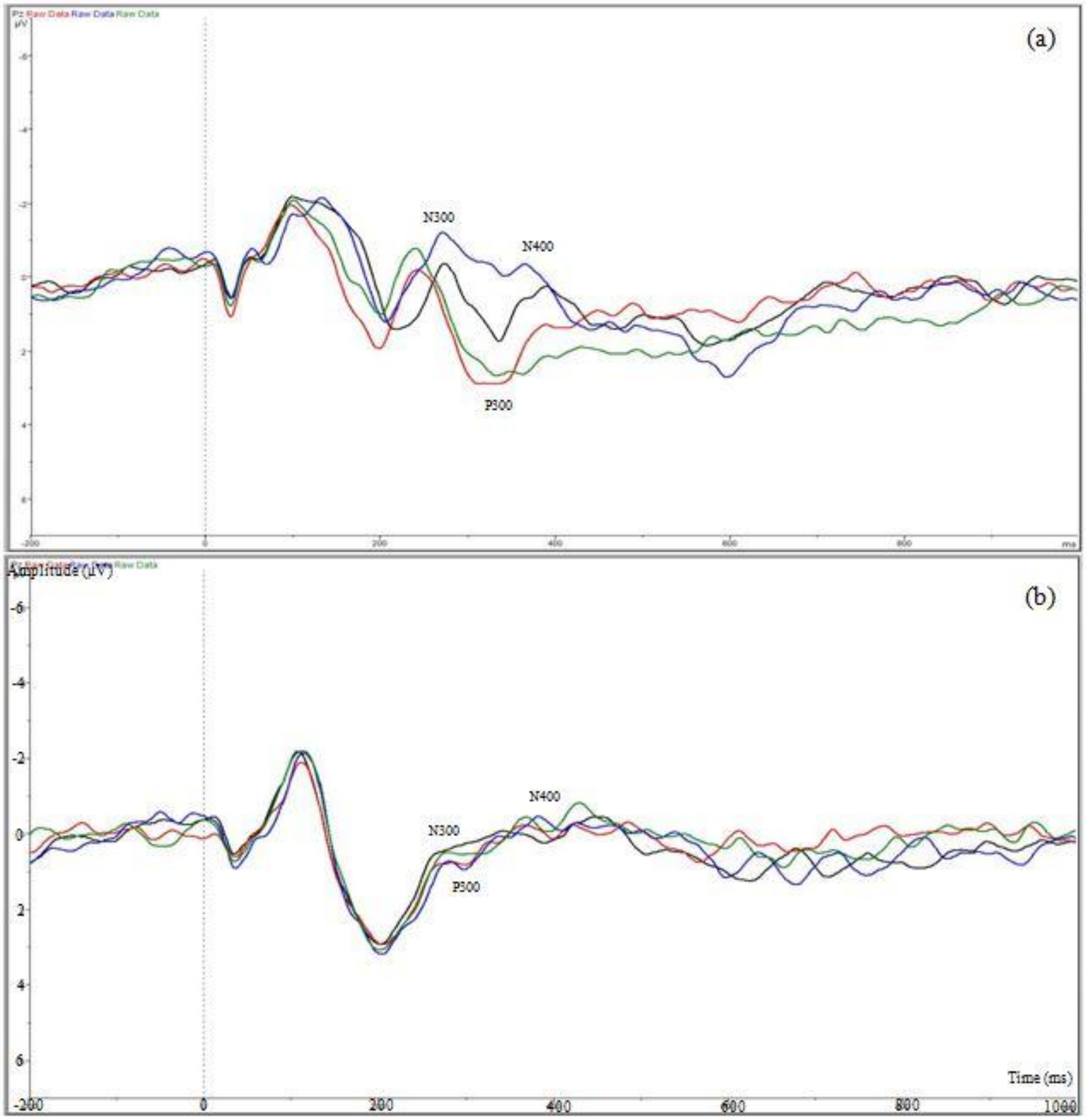

Figure 6.1. Thesis database ERP responses by condition for the (a) Music-word and (b) Music-music paradigm. Negative is plotted up. Lines - Black: HH, Red: SS, Blue: SH, Green: HS. Site shown: Pz, which best illustrates experimental effects in all examined ERP components.

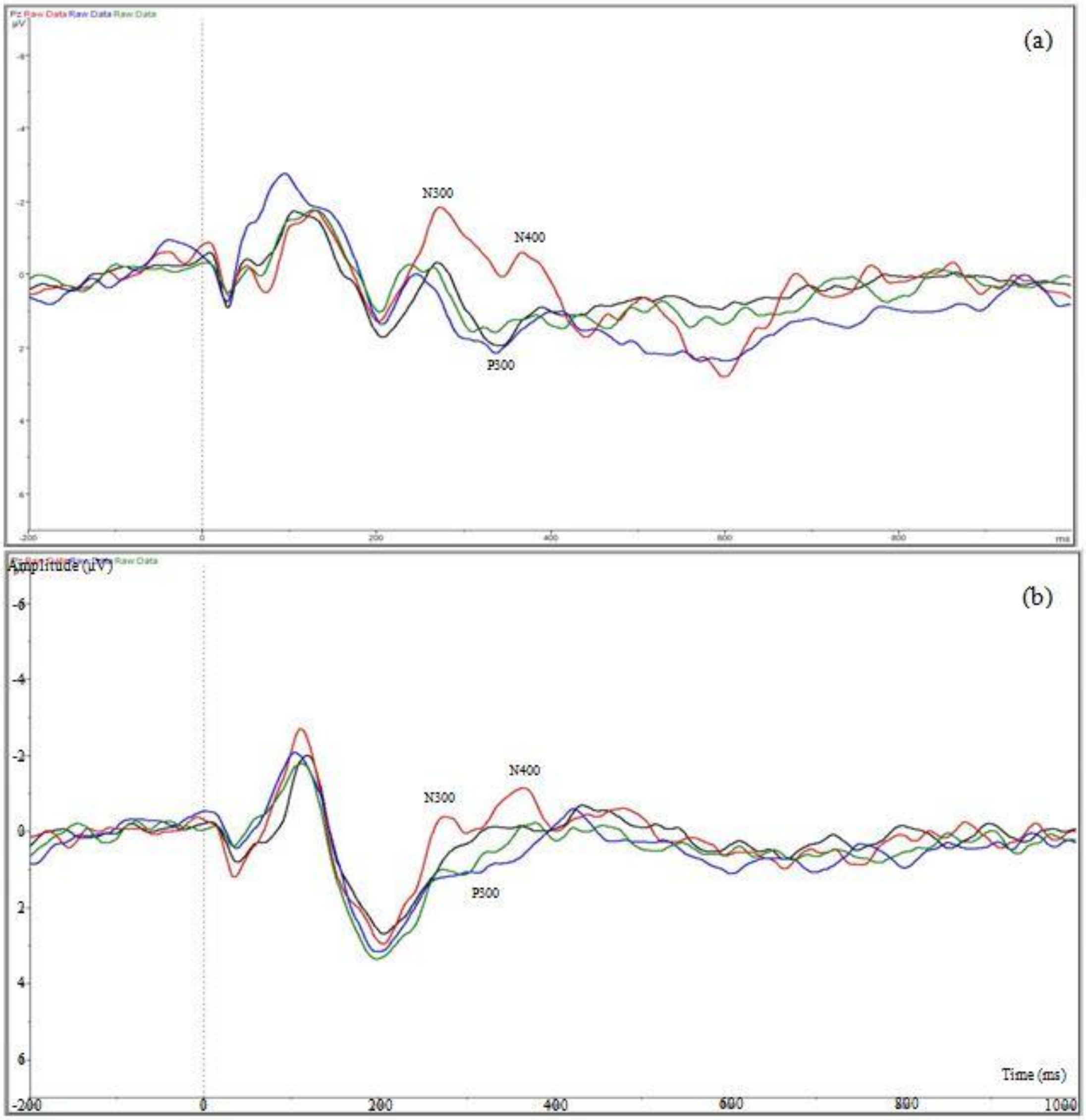

Figure 6.2. Thesis ERP responses by group for the (a) Music-word and (b) Music-music paradigm. Negative is plotted up. Lines - Black: Controls, Red: Alexithymic group, Blue: Depressed group, Green: Depressed alexithymic group. Site shown: Pz, which best illustrates experimental effects in all examined ERP components.

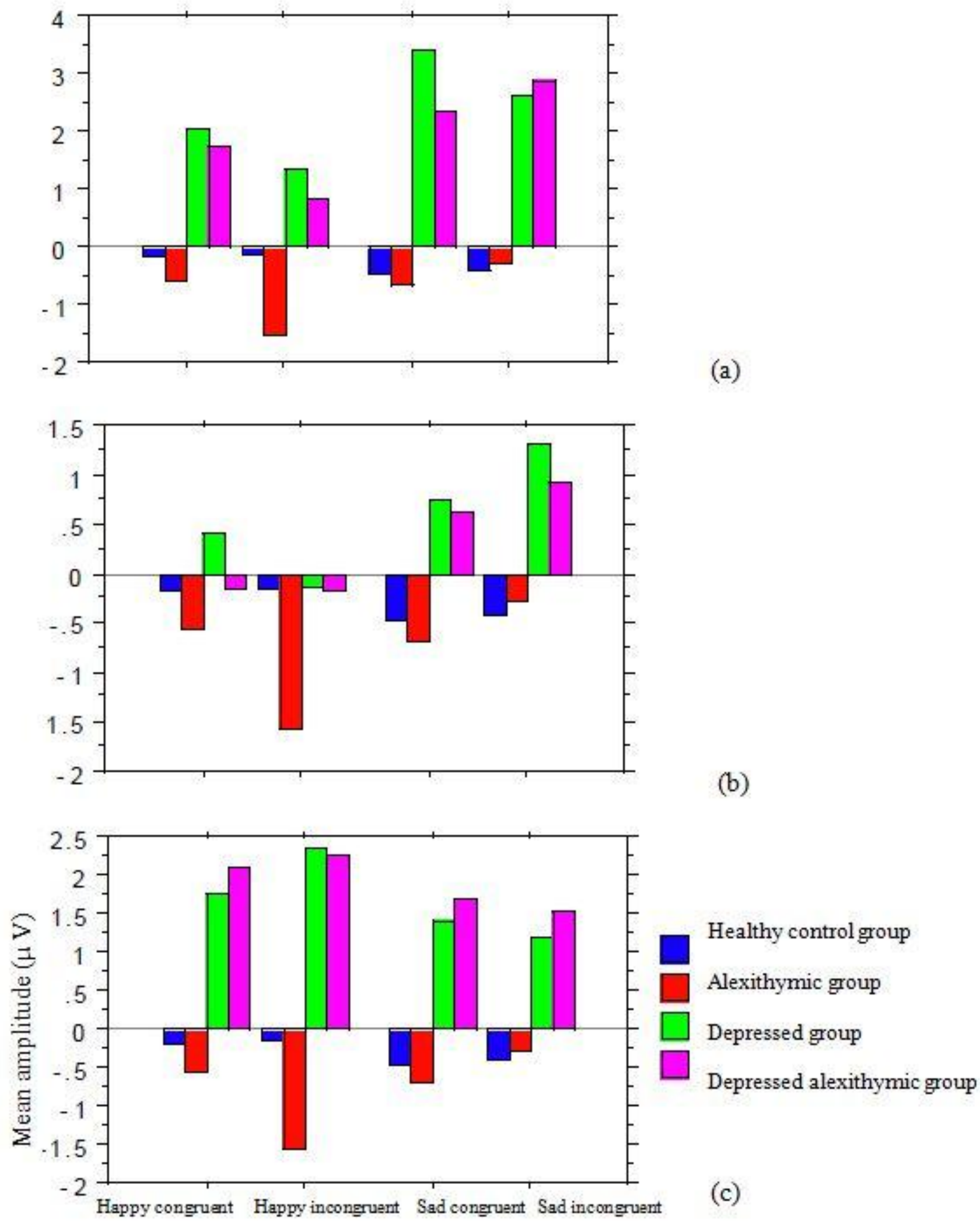

Figure 6.3. Thesis database interaction graphs in the music word paradigm for (a) P300 group x condition valence effect in the right central region (b) N400 condition valence effect in the left parietal region (c) Music-music paradigm P300 group effect in the right frontal region.

group (i.e., more intact emotional recognition) in comparison to the alexithymic group for all conditions (Figure 6.3c). These results will be elaborated in the following sections. Among all the ERP components, the P300 was the most reliably observed component reflecting group and conditional influences in both paradigms.

6.3 PARADIGM & CONDITION DIFFERENCES

Figure 6.1 portrays the thesis database ERP responses for both paradigms when all groups are averaged together to highlight condition differences. Variances in condition and ERP morphology are more differentiated in the music-word (Figure 6.1a) compared to the music-music paradigm (Figure 6.1b), a consistent finding replicated in all groups. Moreover, the resemblance of the P300 distribution in the music-word paradigm to the P3b (more parietal) and the music-music paradigm to the P3a (more frontal) aligns with the music-music paradigm being more automatic than the music-word paradigm. The sign tests (see page 170) and ERP morphology of the database's music-word paradigm is visually most similar to that of the alexithymic group (Figure 3.3a, Chapter 3, see also Figure 6.2a) while the database's music-music response was most comparable to the depressed alexithymic group (Figure 5.3b, Chapter 5). This observation suggests these groups primarily drove the effects in the respective paradigms, a finding that will be elaborated on in the section addressing group differences.

Given that all the database participants were non-musicians (as assessed by the OMSI scale) their generally larger response to music-word compared to music-music is compatible with current literature (Fitzroy & Sanders, 2013) and is reasonably attributed to the language predominance in humans. Based on debriefing accounts, most participants (67%) found the music-word paradigm to be easier ("less thinking, words already labelled"), 25% preferred the music-music paradigm ("same modality, easier association") while 8% perceived no difference. The fact that participant preferences varied between the two paradigms implies that task instruction rather than modality dominance determines their ease of performance or partiality. Interestingly, out of those who favoured the music-music paradigm; half were alexithymic while the remainder was evenly split between the other three groups. This detail supports Chapter 3 results of the alexithymic participants finding the music-word paradigm more challenging due to its inter-domain element.

The four groups performed fairly similarly and robustly for the music-word paradigm. This correspondence resulted in the conditions being ordered quite consistently with clear conditional differences, producing a distinctive ERP morphology for the thesis database for the music-word paradigm (Figure 6.1a). Conversely, there was considerably less similarity, response and demarcation for database data in the music-music paradigm, owing to the more implicit and subjective nature of music as well as conflicting trends observed between the groups. The large variability in the music-music paradigm likely compromised its statistical significance in all groups. Notably, the alexithymic (Figure 3.3b, Chapter 3) and depressed groups (Figure 4.3b, Chapter 4) displayed almost a complete reversal of condition order and responses, with the control and depressed alexithymic groups falling somewhere in between. Unsurprisingly, this resulted in a neutralized, more subtle and less contrasting response patterns for the music-music paradigm when all of the data was combined to form the larger thesis database (Figure 6.1b).

Upon considering these paradigm and condition differences across the groups, what becomes apparent is how there is not one best condition or paradigm, but rather how each paradigm and condition contributes to highlight nuances between the subgroups. This element becomes pertinent when dealing with TBI patients, who are often incapable of responding to traditional behavioural assessments. Furthermore, it cannot be emphasized enough how crucial adopting a battery testing approach is as opposed to a single test procedure when using these methods to assist in a clinical diagnosis (Connolly, 2012; Bardin et al., 2011; Coleman et al., 2009; Neumann & Kotchoubey, 2004). A more comprehensive and informative view can be gleaned when considering a series, rather than a single condition or paradigm. As seen in previous chapters, ERP responses differ for music priming effects despite the fact that music primes were unchanged across paradigms, demonstrating that *participant expectation*, rather than *experimental parameters*, is a key contributing factor in determining different responses in the present study (Mohanty & Sussman, 2013).

6.4 GROUP DIFFERENCES

Figure 6.2 depicts the thesis database ERP responses for both paradigms when all conditions are averaged together, emphasizing group differences. Four striking differences are immediately apparent: 1) The music-word paradigm demonstrates how dissimilar the alexithymic group is to the other groups, who appear tightly clustered together; 2) Differentiation amongst the group occurs earliest for the depressed group in the N1 component for the music-word paradigm, which shows a clearly distinct response unlike the other groups, who remain tightly clustered; 3) The music-music paradigm reveals how the alexithymic group is again the most dissimilar from the other groups starting from the N1 component, but these differences are *graded* as opposed to the *'all or none'* profile seen in the music-word paradigm; 4) Both paradigms exhibit an identical ordering of group responses, with the alexithymic group being most responsive (i.e., largest amplitudes), followed by the control, depressed alexithymic and finally the depressed group being the least responsive. These findings will be discussed in turn.

Alexithymics were found to exert considerably more processing effort (larger ERPs) in emotional regulation for the music-word paradigm than the controls in Chapter 3. This response amplification is characteristic of alexithymia (Morrison & Pihl, 1990) and suggests compromised emotional function (Franz et al., 2004). Therefore, it was not surprising to see their responses being the largest and most differentiated. The degree of separation from other groups is noteworthy suggesting the manner of which alexithymics processed musical emotion was altered and distinct from the other groups, and supporting results from Franz et al. (2004). While alexithymics were observed to exert more processing effort than controls in Chapter 3, it is evident here that this maladaptive overexertion extends to the other groups as well. It appears that the music-word paradigm may be particularly effective and reliable in identifying alexithymia, as the performance of the other groups was comparable to each other but clearly different from alexithymics (Figure 6.2a). Furthermore, it is clear how amplified responses from the alexithymics primarily shape and influence the conditional responses for the thesis database (Figure 6.1a).

The earlier and larger N1 response in the depressed group compared to the attenuated response of the rest suggests the possibility of using this music-word paradigm and the N1 as a neural marker for depressive characteristics. However, this effect would need replication in a larger sample to be even remotely conclusive. Also, this effect was unexpected as it did not surface in individual group analyses (Figure 4.3a, Chapter 4) and depressed participants were the least responsive group, displaying symptoms of general response attenuation (Gillett, 2010). Although the auditory N1 was not assessed nor a point of focus in this thesis, it reflects attention and extraction of auditory cues (Luck, 2005), increases with somatic depressive symptoms (Linka et al., 2009) and indicates low serotonin levels (Linka, Müller, Bender & Satrory, 2004). The auditory N1 has also been shown to be more dominant in musically proficient individuals (Shahin, Bosnyak, Trainor & Roberts, 2003).

Moving on to the music-music paradigm, the alexithymic group was observed to differ most from the other groups (Figure 6.2b), but differences were more gradual compared to the 'all or none' fashion in the music-word paradigm (Figure 6.2a). Differences were again observed to begin at the N1 (which is not of focus for the present thesis), an aspect not evident in individual group analyses (Figure 3.3b, Chapter 3) or the music-word paradigm (Figure 3.3a, Chapter 3). Similar to observations in the music-word paradigm, the enhanced ERP responses (N300, P300, N400) are reflective of the alexithymics' additional effort in emotional processing. The alexithymic trademark of externalizing stimuli, precedence of physiological sensations over internal sentiments and difficulty distinguishing the sensations from sentiments only exacerbates the problem, particularly in a completely non-lexical setting like music-music as opposed to music-word. As discussed in Chapter 3, the alexithymic group appear to be able to intuitively and emotionally integrate music, just in a reduced fashion compared to the rest (unlike performances in the music-word paradigm). This decreased rather than compromised response explains the graded group response order, further bolstered by a wider margin of response subjectivity for interpreting a more subjective music target, as opposed to an explicit word.

In light of the numerous paradigm differences discussed, it is noteworthy that the group response order for the music-word and music-music paradigms were observed to be almost identical. The most responsive group were the alexithymic group, then controls, depressed alexithymics, with the depressed group being the least responsive. This consistency is suggestive of the experimental paradigms' efficacy in depicting a universal overlap of emotional conveyance in music and language, as well as each domain's distinctiveness. More importantly, the paradigms are able to reliably and informatively distinguish between the groups, which certainly bode well for clinical applications. The most noticeable aspect was how alexithymia and depression appear at opposite ends of the response spectrum, when both conditions have been demonstrated to be highly correlated.

Considering the increased processing effort and externalized focus in alexithymia, it was not entirely surprising to see these individuals showing the largest responses instead of the controls. Likewise, the general dulling of emotions and activity in depression fits well with this group constituting the least responsive group. It thus made sense that the simultaneous manifestation of alexithymia in depression would counter the latter's attenuating effects and make depressed individuals appear more "responsive" and closer to normalcy (i.e., controls) in terms of their ERP responses. So, although depressed alexithymic individuals are behaviourally more depressed and less responsive than depressed individuals (Vanheulue, Desmet, Verhaeghe & Bogaerts, 2007; Honkalampi et al., 1999), our results show their ERP responses to be conversely more responsive.

Therefore, ERPs provide a more sensitive and precise measure of alexithymia and depression compared to their behavioural counterparts, conditions our correlations and past research (Bankier, Aigner & Bach, 2001; Hintikka, Honkalampi, Lehtonen & Viinamäki, 2001; Saarijärvi, Salminen & Toikka, 2001) have shown to frequently overlap with each other. As our results are able to discriminate between the separate and combined effects of alexithymia and depression, ERP measures may reflect these conditions more appropriately. This resulting intermediacy of depressed alexithymics, along with their larger P300 attributed to the specific processing deficit of happy music targets likely accounts for why the overall thesis database ERP responses for the music-music paradigm (Figure 6.1b) resembles the waveforms from the depressed alexithymic group.

The chapter on depressed alexithymics (Chapter 5) revealed that depressed and depressed alexithymics had very similar ERP responses in that emotional categorization (N300) was preserved and more influenced by congruence, but emotional recognition (P300) and meaning (N400) were more affected by valence for the music-word paradigm. This response similarity can be observed in Figure 6.2, 6.3a and 6.3c, hinting at depression being a more pervasive condition. However, the disruption extent of the P300 and N400 in both groups differed. As alexithymia modified depression effects and was responsible for the specific processing deficit of happy music targets in the depressed alexithymic group, this finding suggests alexithymia effects precedes that of depression in emotional regulation as the music-music paradigm is more automatic than the music-word paradigm. This issue is scrutinized further in the following discussion of the P300, the most statistically significant and reliably observed component across both paradigms and all groups in the present study.

6.5 P300: NEURAL MARKER FOR DEPRESSION & ALEXITHYMIA?

The P300 was the only component to differentiate between automaticity levels for both paradigms in terms of its topography, with the music-word paradigm displaying a more parietal distribution (akin to a less automatic P3b) and a more frontal distribution for the music-music paradigm (similar to a more automatic P3a). This result complements research literature, as the P300 has been proposed to constitute the initial point of consciousness (Kouider et al., 2013) and is associated with feeling intensity (Polich & Kok, 1995; Hamm et al., 2003; Pollatos et al., 2007, c.f. Pollatos & Gramann, 2011). This point is supplemented by Ledoux's statement of "all conscious emotional experiences are feelings" (Ledoux, 1996, c.f. Taylor & Bagby, 2011). In line with results from Campanella et al. (2012) isolating depressive effects to the P300 (specifically the P3b), Figure 6.3a and 6.3c illustrate how the groups are dramatically segregated based on the presence of depression in both paradigms. The depressed groups (depressed and depressed alexithymics) had significantly larger responses compared to the non-depressed groups (control and alexithymic groups), supplemented by them scoring the highest on the AIMS scale (musical emotion responsivity) and the positive correlation of the AIMS with the BDI-II. Thus, the P300 is reliably seen in depression for our musical affective priming paradigms.

Despite their generally larger responses, the alexithymic group produced the smallest P300 in both paradigms (see also Figure 6.2) compared to the depressed alexithymic group in the music-music paradigm and the depressed group in the music-word paradigm. This P300 reduction aligns with past research (Pollatos & Gramann, 2011) indicating a fundamental break at the point where emotion and cognition interact to become feelings, as alexithymia is likened to a series of disconnects in processing emotion (Frawley & Smith, 2001).

In this manner, our results partially agree with Lane, Ahern, Schwartz & Kaszniak (1997) in that the alexithymic group process emotion without being fully aware of it, but not the likening of alexithymia to ‘blind*feel*’ as the term implies that the underlying emotional processing is intact, as with the case of blindsight. This processing impairment is seen with the alexithymic group (Chapter 3), where processing is compromised from the initial stages of emotional categorization (N300) of word targets and informally, from the N1 stages of in the emotional processing of music targets (Figure 6.2b). Therefore, while the reduction of the P300 amplitude is also seen in alexithymia, it may be more fruitful to explore earlier components (see Campanella et al., 2012; Pollatos & Gramann, 2011) or consider them alongside the P300.

The appearance of alexithymics and depressed alexithymics at both ends of the spectrum for the music-music paradigm (Figure 6.3c) indirectly showcases the earlier manifestation and influence of alexithymia over depression as this paradigm is more automatic. Conversely, the more controlled and volitional music-word paradigm sees the depressed group and the alexithymic group at extreme ends, with depressed participants showing larger responses for sad word targets indicating the emotional negativity bias. These differential responses also showcase the efficacy of both musical affective priming paradigms in highlighting the separate and combinative effects of alexithymia and depression.

In sum, our present results indicate that depression is a more pervasive condition than alexithymia (i.e., the separation of groups based on depression rather than alexithymia in Figure 6.3 and the resemblance of ERP waveforms for depressed and depressed alexithymics in Figure 6.2). However, alexithymia effects precedes that of depression in emotional regulation, thereby modifying its response; an effect most apparent in the more automatic music-music paradigm. While alexithymia and depression have opposing effects when manifested individually, their concurrent materialization may in a sense “improve” emotional categorization of sad word targets (compared to the alexithymic group), “worsen” emotional recognition of sad word targets (compared to the depressed group), with the specific processing impairment of happy music targets being particular to both conditions’ combinative presence. This processing deficit for positively valenced stimuli (LeMoult, Yoon & Joormann, 2012; Bodner et al., 2007;

Punkanen, Eerola & Errkilä, 2011) is thought to make the depressed alexithymics appear more severely depressed than depressed individuals, and is important as the cause is due to alexithymia, not depression as originally presumed in the literature (Gotlib & Joormann, 2010). The P300 is particularly reliably seen in depression and alexithymia to a lesser extent, but its reliability will be increased when earlier and later components are considered in parallel.

Chapter 7: Summary and conclusion

"The focus is on the patient's potentials, not his deficiencies; on his expressions and activities, not his functions."

(Gustorff, 2002).

7.1 SUMMARY

This thesis investigated ERP responses to music as a measure of emotion in different participant groups (control, alexithymic, depressed, depressed alexithymic) varying in levels of emotion and consciousness (i.e., awareness) with the goal of establishing a clinical measure of emotion and consciousness in TBI. In two musical affective priming paradigms, participants mentally decided if the emotion expressed (happy, sad) by the music primes matched that of the following music (music-music) or word (music-word) target (happy, sad) or not. The music-word paradigm was consistently observed to be more controlled and less automatic than the music-music paradigm, producing more differentiated and larger responses in the ERP gradient of emotional processing (N300, P300, N400), reflecting emotional categorization, recognition and meaning of target stimuli respectively. This paradigm difference was evident even after collapsing responses across groups and conditions. Paradigm automaticity was also reflected in the distribution of the P300 component: a right frontal distribution in the music-music paradigm (i.e., P3a, an earlier component of the P300 reflecting stimulus detection) and a right central distribution in the music-word paradigm (i.e., P3b, later component of the P300 portion reflecting stimulus recognition).

The responsivity of the four groups was also consistently ordered in a similar manner in both paradigms (i.e., most responsive being the alexithymic, followed in order by the control, depressed alexithymic and depressed groups). The consistent placement of the alexithymic and depressed groups at the top and bottom end of the ERP response spectrum (with the control and depressed alexithymic groups consistently ordered in the middle) for both paradigms showcases the dichotomy between both conditions, notably the strong externalization and response amplification tendencies in alexithymia and the emotional blunting in depression. Impaired music-word integration in the alexithymic group resulted in a clear response deviation in the music-word paradigm compared to the similar responses of the other three groups, resulting in an all-or-none like response pattern. Responses were more gradual and graded for the music-music paradigm, an observation that aligns well with the more subjective responses to music compared to word targets. In turn, this subjectivity in the music-music paradigm reduces its effect strength (i.e., its reliability and thus, statistical significance) compared to the music-word paradigm.

The lack of an N400 component in both paradigms for the controls suggests minimal processing for emotional meaning, implying its negligible role for individuals whose emotional operating system is functioning optimally. This detail was supported as the N400 response was noticeably compromised in the three other groups. Alexithymic participants demonstrated impaired processing beginning at the emotional categorization stage (N300) for sad word targets and enhanced response amplitudes. This finding was interpreted as reflecting additional allocation of resources and processing effort and thus, a more controlled and volitional operation than the norm. Depressed participants exhibited an emotional negativity bias in sad word targets that was observable first at the emotional recognition stage (P300), attributed to problems disengaging (cognitive rumination) that manifested itself at the later stages of emotional processing. While the depressed alexithymic group performed similarly to the depressed group, impaired emotional recognition (P300) of sad word targets and integration (N400) of happy word targets were attributed to alexithymia rather than the emotional negativity bias due to alexithymia effects manifesting before depressive effects in emotional regulation.

The P300 (emotional recognition) emerged as the most reliably observed component and was reliably seen in depression, where it manifested as a larger P300 response. This detail aligns with the depressed groups (depressed and depressed alexithymic groups) having the highest scores in musical emotion responsivity (AIMS) and the positive correlation of the AIMS with the BDI-II. As the P300 was found to be the smallest in alexithymic controls, it can also be reliably observed in alexithymia; but as alexithymia affects an earlier component (e.g. N300) it would be more effective to consider earlier components in conjunction with the P300.

While depression and alexithymia are closely related (e.g. positive correlation of the BDI-II & TAS-20), their respective effects on ERP priming-related patterns were found to be conflicting when each condition (i.e., depression or alexithymia) was considered alone. When the two conditions were observed in the same individual (the depressed alexithymic group), the ERP responses more closely resembles patterns seen in the controls; it was as if the two opposing patterns associated with each condition individually "cancelled" each other, leaving a more standard appearing pattern. It is worth noting that behaviourally, alexithymia appears to worsen depressive symptoms in depressed alexithymics (i.e., deficit in processing positively valenced targets). This aspect reveals how ERP measures are more precise and sensitive compared to behavioural measures. Depression appears to be a more pervasive condition, but as alexithymia effects precede depressive ones in emotional regulation, alexithymia is capable of influencing depressive effects, making alexithymia appear more predominant.

In sum, both musical affective priming paradigms evidence that ERP responses to music can effectively measure emotion, as well as highlight different levels of automaticity and influences of alexithymia and depression. The weaker N300 response (emotional categorization) in the music-music paradigm compared to the music-word paradigm in controls suggests categorization is less necessary for music targets due to the more automatic nature of the music-music paradigm. In addition, the minimal N400 response (emotional meaning) in controls compared to larger responses in the other groups reflects the efficacy of the paradigms in targeting affective processing, which is more basic and would influence earlier components compared to semantic processing. In terms of concept communication in music, the present results resembles concepts from emotions that can (i.e., music-word paradigm) and cannot (i.e., music-music paradigm) be verbalized (Patel, 2008, c.f. Daltrozzo, Tillmann, Platel & Schön, 2009). The current N400 results are compatible with Koelsch's definition of extra musical indexical meaning as responses manifest based on the presence of an emotion (Koelsch, 2011). Collectively, these effects demonstrate that participant expectancy and experimental parameters are important contributing factors in determining different responses in this thesis.

7.2 LIMITATIONS & FUTURE DIRECTIONS

While every effort was made to minimize experimental confounds, there were areas that could be improved upon. Despite careful selection of the music stimuli (Eerola & Vuoskoski, 2011) and subsequent good accuracy and rating judgements of stimulus emotion (Chapter 1), some participants mentioned a few musical excerpts sounded emotionally ambiguous (ranged from 5-15% of the stimuli, mostly the sad stimuli), which may have added to the subjectivity and smaller responses in the music-music paradigm. Emotion ambiguity in sad music is common as sad music does not always correlate with negative valence (Eerola & Vuoskoski, 2011; Bigand et al., 2005), is deemed aesthetically beautiful and equally appreciated as happy music (Schellenburg, Peretz & Vieillard, 2008). Preferences can, of course, vary with context or mood (Hunter, Schellenburg & Griffith, 2011). Moreover, sad music produces weaker brain activations (Brattico, Bogert & Jacobsen, 2013) and is more distinguishable when paired with lyrics

(Brattico et al., 2011) in contrast to happy music. Thus, more effort should be directed to ensuring sad musical excerpts sound particularly and unambiguously sad in future, an aspect elaborated upon below.

Ten percent of the current experimental (9% sad) consisted of selections from the dimensional category (i.e., low tension, high/low energy), with the rest from the discrete category (i.e., happy, sad), which may have resulted in a less "pure" sounding happy/sad emotion. Tempo and mode are most often used to signal happy (fast, major) and sad (slow, minor) emotions in music respectively (Hunter & Schellenburg, 2010; Vieillard et al. 2008), enhancing recognition when these cues match than when they do not. In the case when cues mismatch (i.e., fast, minor; slow, major), the perceiver's mood may determine which cue predominates in the mixed happy and sad sounding music excerpt (Hunter, Schellenburg & Griffith, 2011), a situation both relevant and likely in our experiment. Adopting "purer" sounding happy and sad music in future studies would thus reduce ambiguity and subjectivity in the music-music paradigm while simultaneously eliciting more homogeneous ERP responses. Another would be using a single happy and sad music target (similar to how word targets were standardized in the music-word paradigm) instead of multiple music targets[3].

The sample size in each group (N=12) would benefit from larger participant numbers, which would allow condition and group effects to manifest more prominently and allow the examination of gender effects. The lack of power

[3] I am grateful to Dr. Elisabet Service for highlighting this.

with the current sample sizes was particularly evident in the music-music paradigm, where effects were more subtle and numerous trends observed just failed to reach significance. A larger sample size might also reduce the influence of outlier effects and enable multiple regression analyses to be conducted to thoroughly examine if the behavioural scale constructs (alexithymia, depression, musical emotion responsiveness) can predict ERP component responses in the various conditions and paradigms. Running these analyses would be critical in the final implementation stages of this experimental paradigm in TBI patients incapable of being assessed behaviourally and could permit distinguishing the influences of emotion from those of cognitive dysfunction or neurological insult. It would be essential to replicate and verify the results with larger participant numbers considering the number of comparisons made and subtle effects observed, to eradicate the possibility that these effects could be spurious.

Besides larger sample sizes in each group, investigating alexithymia and depression effects can be improved with adopting more stringent cut-off points when assessing alexithymia. As two alexithymic measures were used (TAS-20 & BVAQ-B), there were a few occasions in the present study when individuals were considered alexithymic in one scale and not the other. Although both scales are highly correlated and scores were primarily borderline (e.g. in one scale individuals were comfortably alexithymic, in the other they were just meeting or were a point away from being classified as alexithymic), including these individuals may have contaminated group assignment in that these individuals may be neither control nor fully alexithymic individuals, but rather intermediates. While this detail was a less of an issue with depression, future assessments may also want to ensure individuals classified as non-depressed have an unambiguously low score rather than an intermediate score a few points away from being classified as depressed. Considering how closely related alexithymia and depression are, adopting these strict cut-off scores may be crucial in further examining their effects.

Future studies isolating alexithymia and depression effects should also consider controlling for anxiety, which has a common occurrence in both conditions (Hendryx, Haviland & Shaw, 1991; Marchesi, Brusamonti & Maggini, 2000), particularly depression (Gotlib & Joormann, 2010). However, anxiety effects on alexithymia and depression are not consistent. Berthoz et al. (1999) found no correlation between alexithymia and depression after anxiety was controlled for, but used the lesser known QD 2A Depression Questionnaire, only examined females and admitted participants were minimally depressed. These limitations could be vital as alexithymia rates are higher in males (Levant, Hall, Williams & Hasan, 2009; Kokkonen et al., 2001) and dysphoric (more transient negative mood state) individuals tend to be diagnosed using other measures that do not incorporate the DSM (Gotlib & Joormann, 2010). Recently, Leweke, Leichsenring, Kruse & Hermes (2012) found no association between anxiety and alexithymia after controlling for depression using ICD guidelines. Anxiety effects also manifest early (attention bias) only to threat/negative valence stimuli (Gotlib

& Joormann, 2010). In contrast, the emotional negativity bias in the present depressed groups materializes later (difficulty disengaging). While alexithymic effects appear earlier in the depressed alexithymic group, disruption involved processing of positive, not negative valenced music targets. Thus, the effects of anxiety on the present results appear minimal, although it cannot be ruled out completely.

As seen in Chapter 6, the effects of the experimental paradigm are not restricted to the ERP gradient of emotional processing (N300, P300, N400) but also observed in a neighbouring component (e.g. N1) as well (Figure 6.2a). Further scrutiny of this component would profit from conducting several focussed experiments rather than one general experiment to effectively isolate and study these effects in detail. Contrasting these components and expanding the ERP gradient of emotional processing would also better reveal the automaticity levels of the current effects. Such analyses would also provide a more informative and comprehensive picture as more functions can be ascertained, which would be critical in assessing the awareness of TBI patients.

Although this thesis attempted to isolate prime and target effects by pairing and comparing the conditions in two separate comparisons (Chapter 2), an interesting progression from this would be to directly compare and analyse ERP responses to the prime[4] in addition to responses to the target (the norm in ERP research as was done here). That way, a clear dichotomy can be obtained by

[4] I am grateful to Dr. Laurel Trainor for highlighting this.

observing the influences of early and late processes in the same ERP components, with early, more automatic processes (e.g. N300) being more marked in the prime compared to the target (e.g. N400). This method will further validate proposed the automaticity and function of ERP components and experimental effects. Moreover, any differences in the manifestations of these earlier components in alexithymia and depression would be very informative in further delineating the relationship and influences of these two conditions.

Similarly, the emotional negativity bias evidenced here would benefit from the additional condition comparison of HH/SS and HS/SH without congruency being a contributing factor[5]. These condition comparisons would unveil basic processing differences between happy and sad musical stimuli, encouraging efforts to localize ERP effects and verifying any modifications in neural activity due to depression or brain injury. Investigating these effects would be also be useful as musical affective priming ERP research is primarily visual or cross modal (Painter & Koelsch, 2011; Steinbeis & Koelsch, 2009; Daltrozzo & Schön, 2009; Koelsch et al., 2004; Sollberger, Reber & Eckstein, 2003) as with ERP affective priming in general (Oloffson, Nordin, Sequeria & Polich, 2008).

7.3 NOVELTY, SIGNIFICANCE & IMPLICATIONS

This thesis presents a number of original discoveries. It pioneered the implementation of a music-music paradigm, enabling examination of how music

[5] I am grateful to Dr. Geoffrey Hall for pointing this out.

conveys emotion within a pure musical context compared to the more conventional music-word paradigm adopted in area. Contrasting these two paradigms illustrated how music and language differ in communicating emotion, including the level of automaticity. Although the effects seen in the music-music paradigm were reduced due to increased subjectivity of music target interpretation, it provided a crucial contrast in illustrating different group responses to word (all-or-none) or music (graded) targets. The paradigm also revealed the impaired processing of positively valenced music targets, a condition particular to depressed alexithymics. These responses provide a good foundation for further developing a musically based set of paradigms that would reliably reflect control, alexithymia, depressed and depressed alexithymia based solely on ERP responses. Given the four groups in this thesis are commonly lumped together as a control group in most studies, this thesis highlights the variability of what is considered “baseline” may be more variable than previously thought.

Besides extending the ERP gradient of emotional processing in Morgan, Choy & Connolly (2012) to music-music, this thesis is the first to characterize and examine musical emotion perception in alexithymia, depression and depressed alexithymia conditions, conditions are often lumped together. In particular, the P300 has not only emerged as the most consistently observed component, but is also reliably observed in depression (and alexithymia to a lesser extent), thus a promising neural marker for both conditions. In distinguishing the deficient emotional processing of sad word targets in alexithymia and emotional negativity bias in the form of difficulty disengaging (cognitive rumination) in depression, the individual effects of alexithymia and depression are differentiated from their combinative effects of impaired processing of happy music targets. These observations were supported by correlation analyses of the behavioural scales, with the BVAQ-B poor fantasizing and emotional excitability subscales better reflect depressed alexithymic conditions while the TAS-20 and BDI-II scores better reveal the individual effects of alexithymia and depression.

The significant positive correlation of depression and musical emotion responsiveness showcased by the BDI-II and AIMS scales was also new, as the depressed group was also shown to be the most responsive to musical emotion. Although the combined outcomes of alexithymia and depression have been narrowed down to difficulty in identifying feelings in the correlation of TAS-20 subscale with the BDI-II, poor fantasizing skills (BVAQ-B subscale) also contributed to this cumulative effect, another original finding. Taken together, the processing deficit in happy music targets is likely attributable to difficulty identifying and imagining positive feelings due to alexithymia rather than an emotional negativity bias due to depression. This is a significant discovery as the deficient processing of positively valenced stimuli is thought to be a depressive symptom (Lemoult, Yoon & Joormann, 2012; Bodner et al., 2007; Punkanen, Eerola & Errkilä, 2011). Instead, this thesis has demonstrated how alexithymia makes depressed alexithymic individuals appear more depressed behaviourally than they may be (Vanheulue, Desmet, Verhaeghe & Bogaerts, 2007; Honkalampi et al., 1999) and that their ERP responses are actually closer to normal compared to depressed individuals. This dissociation between ERP and behavioural findings merely highlights again the sensitivity of ERPs as an assessment tool.

In establishing a musical ERP paradigm designed to tap emotion processing, this thesis has clear clinical applications for the TBI population. The music-music paradigm was intended to include non-verbal, aphasic or other non-communicative clinical populations (e.g. autism) and language-compromised individuals who may not fare well with the current predominantly verbal assessment batteries. Indeed, the significance of developing language independent assessments is growing (Boly et al., 2011, c.f. Bruno et al., 2011). As music encompasses multiple brain areas, it provides access to functions that may not be accessible due to deficits in one area (e.g. language). Music also circumvents language, social and cultural barriers, creating a less demanding assessment environment (Särkämö et al., 2008; Magee, 2005).

Our experimental paradigms can also approximate a patient's level of consciousness (i.e. awareness), as both music paradigms have been demonstrated to have differing levels of automaticity. This detail is by no means trivial in facilitating patient diagnosis, recovery and rehabilitative efforts, and would assist in the development of other measures of consciousness. Approximately 6.8 million TBI cases are reported worldwide annually (Irimia et al., 2012) and is the leading cause of vegetative and minimally conscious state (MCS) cases (Wu & Yuan, 2012). The merits of investigating neural responses to emotion with

EEG/ERP rather than neuroimaging methods are numerous in terms of patient cost, comfort, feasibility and flexibility (Harrison & Connolly 2013). Moreover, O'Kelly & Magee (2012) have advocated for the use of music to facilitate diagnosis in disorders of consciousness. For instance, Bruno et al. (2011) found patients in the "plus" stage of the minimally conscious state (MCS+) demonstrated more preserved functional connectivity in language networks than those in the "minus" stage (MCS-). This language impairment may explain why MCS- patients fail to show command following or active paradigms, unlike MCS+ patients (Moreno et al., 2010; Majerus et al., 2009; Monti et al., 2010, c.f. Bruno et al., 2011). Hence, using music would be instrumental in bypassing language deficits and distinguishing between MCS+ and MCS- patients.

At this point, it may be worthwhile to highlight the significance of testing in the auditory domain in TBI and disorders of consciousness. Audition is the first developed sense and the last to atrophy in death, as acoustic tracts are less susceptible to oxygen loss and are well protected anatomically (Gustorff, 2002). As sound is more difficult to ignore or avoid than vision and perception does not require localizing or orienting towards its source (Armony, 2012), the continued presence of sound gives one a sense of time and connectedness. Hearing marks the start of consciousness (Behrend, 1986, c.f. Gustorff, 2002). For example, after fainting, people first reconnect with their environment through hearing. These points are relevant to TBI patients, who often have compromised vision, closed eyes, and suffer from confusion and disorientation resulting from their injuries and sedatives (Harrison & Connolly, 2013). Hence, the persistence and unavoidability of sound, in particular music, become instrumental in returning some perspective to the patient – a sense of being, time and space (Gembris, 1994; c.f. Gustorff, 2002). Moreover, audition effectively conveys emotion, being second to pain (and possibly olfaction) in terms of being the most emotional sensory experience due to close ties with the limbic system (Creutzfeldt 1983, c.f. Gustorff, 2002). Indeed, Koelsch et al. (2013) noted the auditory cortex to be a central hub of an affective-attention network that is more widespread than formerly thought.

More importantly, the present study contributes to filling the current gap in emotional measures and its functional neglect in TBI, as it is well documented that emotional deficits substantially interfere with a patient's recovery, cognition and social relationships (Cattran, Oddy & Wood, 2011; Ciurli et al., 2011; Hynes, Stone & Kelso, 2011; Särkämö et al., 2008). Moreover, in comparison to neuropsychological test performances, affective factors were found to better predict post-concussive symptoms after mild TBI (Clarke, Genat & Anderson, 2012). Considering the present experimental paradigms' ability to reliably differentiate between the separate and combined effects of alexithymic and depression, the utility of these paradigms would be invaluable as alexithymia and depression are particularly common outcomes of TBI (Rapoport, 2012; Henry et al., 2006; Koponen et al., 2005). Clinical and basic research in emotion, alexithymia and depression can also benefit from this musical ERP paradigm as it reveals the independence and interaction of these two conditions at the neurophysiological level. By providing an alternate, covert assessment for alexithymia and depression, the implementation of this paradigm would facilitate improvements in the diagnosis and treatment between both conditions.

Finally, the development of this musical paradigm promotes research on music and extends its utilities to the clinical domain. Music is used in clinical therapy (Magee, 2005; Tamplin, 2000) and its efficacy in evoking responses from non-communicative patients has been attributed to music's basic properties. Musical pitch, rhythm and tempo entrain physiological responses (Magee, 2005, Tamplin, 2000) while its inherent emotional elements evokes behaviour and communicates emotional states – cues we use to communicate even as infants (Trainor & Corrigall, 2010; Magee, 2005). Musical therapy successfully induced meaningful and emotional responses from two vegetative patients, contributing to a change in diagnosis and recovery (Gustorff, 2002; Magee, 2005). Although processing may differ given their impaired awareness (Magee, 2005) and transition between the vegetative and minimally conscious states, it does not preclude the fact that emotions can be present in the vegetative state, and music has the capacity to tap that function. The personal anecdotes of these patients (Gustroff, 2002) and others emerging from consciousness (Wilson, Gracey & Bainbridge, 2001) provide sound evidence for this premise. Thus, it is hoped that this musical paradigm will catalyze further developments of using music as an effective clinical diagnostic and therapeutic tool.

REFERENCES

Aan het Rot, M., Mathew, S.J. & Charney, D.S. (2009). Neurobiological mechanisms in major depressive disorder. *Canadian Medical Association Journal* 180 (3), 305-313.

Allen, R. (2010). A comparative study of the effects of music on emotional state in the normal and high-functioning autistic population. Doctoral dissertation, Goldsmiths, University of London. Retrieved from the World Wide Web on Jan 16 2012 http://eprints.gold.ac.uk/2886/

Allen, R., Davis, R. & Hill, E. (2012). The effects of autism and alexithymia on physiological and verbal responsiveness to music. *Journal of Autism and Developmental Disorders* 43 (2), 432-444.

Aru, J., Bachmann, T., Singer, W. & Melloni, L. (2012). Distilling the neural correlates of consciousness. *Neuroscience and Biobehavioral Reviews* 36, 737-746.

Augustenborg, C.C. (2010). The Endogenous Feedback Network: A new approach to the comprehensive study of consciousness. *Consciousness and Cognition* 19, 547-579.

Bagby, R.M., Parker, J.D.A. & Taylor, G.J. (1994). The twenty-item Toronto

Alexithymia Scale-I: item selection and cross validation of the factor structure. *Journal of Psychosomatic Research* 38, 23-32.

Bankier, B., Aigner, M. & Bach, M. (2001). Alexithymia in DSM-IV Disorder: Comparative evaluation of somatoform disorder, panic disorder, obsessive-compulsive disorder and depression. *Psychosomatics* 42 (3), 235-240.

Bardin, J.C., Fins, J.J., Katz, D.I., Hersh, J., Tabelow, K., Dyke, J.P., Ballon, D.J., Schiff, N.D. & Voss, H.U. (2011). Dissociations between behavioural and functional magnetic resonance imaging-based evaluations of cognitive function after brain injury. *Brain* 134 (3), 769-782.

Becerra, R., Amos, A. & Jongenelis, S. (2002). Organic alexithymia: a study of acquired emotional blindness. *Brain Injury* 16 (7), 633-645.

Bechara, A. & Damasio, A.R. (2005). The somatic marker hypothesis: A neural theory of economic decision. *Games and Economic Behaviour* 52, 336-372.

Beck, A. T., Brown, G. & Steer, R.A. (1996). Beck Depression Inventory II manual. San Antonio: TX: The Psychological Corporation.

Bermond, B., Vorst, H.C.M. & Moorman, P.P. (2006). Cognitive neuropsychology of alexithymia: implications for personality typology. *Cognitive Neuropsychiatry* 11 (3), 332-360.

Berridge, K.C. & Winkielman, P. (2003). What is an unconscious emotion? (The case for unconscious ‘liking’). *Cognition and Emotion* 17 (2), 181-211.

Berthoz, S., Consoli, S., Perez-Diaz, F. & Jouvent, R. (1999). Alexithymia and anxiety: compounded relationships? A psychometric study. *European Psychiatry* 14 (7), 372-378.

Berthoz, S. & Hill, E.L. (2005). The validity of using self-reports to assess emotion regulation abilities in adults with autism spectrum disorder. *European Psychiatry* 20, 291-298.

Bigand, R., Vieillard, S., Madurell, F., Marozeau, J. & Dacquet, A. (2005). Multidimensional scaling of emotional responses to music: the effect of musical expertise and of the duration of the excerpts. *Cognition & Emotion* 19 (8), 1113-1139.

Bird, G., Silani, G., Brindley, R., White, S., Frith, U. & Singer, T. (2010). Empathic brain responses in insula are modulated by levels of alexithymia but not autism. *Brain* 133, 1515-1525.

Bodner, E., Iancu, I., Gilboa, A., Sarel, A., Mazor, A. & Amir, D.A. (2007).

Finding words for emotions: the reactions of patients with major depressive disorders towards musical excerpts. *The Arts in Psychotherapy* 34, 142-150.

Boly, M., Coleman, M.R., Davis, M.H., Hampshire, A., Bor, D., Moonen, G., Maquet, P.A., Pickard, J.D., Laureys, S. & Owen, A.M. (2007). When thoughts become action: an fMRI paradigm to study volitional brain activity in non-communicative brain injured patients. *Neuroimage* 36 (3), 979-992.

Bostanov, V. & Kotchoubey, B. (2004). Recognition of affective prosody: continuous wavelet measures of event-related brain potentials to emotional exclamations. *Psychophysiology* 41, 259-268.

Brattico, E., Bogert, B. & Jacobsen, T. (2013). Toward a neural chronometry for the aesthetic experience of music. *Frontiers in Psychology* 4 (206). doi:10.3389/fpsyg.2013.00206

Brattico, E., Alluri, V., Bogert, B., Jacobsen, T., Vartiainen, N., Nieminen, S. & Tervaniemi, M. (2011). A functional MRI study of happy and sad emotions in music with and without lyrics. *Frontiers in Psychology* 2 (308). doi:10.3389/fpsyg.2011.00308

Bruno, M.A., Majerus, S., Boly, M., Vanhaudenhuyse, A., Schnakers, C., Gosseries, O., Boveroux, P., Kirsch, M., Demertzi, A., Bernard, C., Hustinx, R., Moonen, G. & Laureys, S. (2011). Functional neuroanatomy underlying the clinical subcategorization of minimally conscious state patients. *Journal of Neurology* 256 (6), 1087-1098.

Cabanac, M., Cabanec, A.J. & Patent, A. (2009). The emergence of consciousness in phylogeny. *Behavioural Brain Research* 198, 267-272.

Cacciopo, J.T., Gardner, W.L. & Bernston, G.G. (1999). The affect system has parallel and integrative processing components: form follows function. *Journal of Personality and Social Psychology* 76, 839-855.

Campanella, S., Falbo, L., Rossignol, M., Grynberg, D., Balconi, M., Verbanck, P. & Maurage, P. (2012). Sex differences on emotional processing are modulated by subclinical levels of alexithymia and depression: a preliminary assessment using event-related potentials. *Psychiatry Research* 197, 145-153.

Campanella, S., Vanhoolandt, M.E. & Phillipot, P. (2005). Emotional deficits in subjects with psychopathic tendencies as assessed by the Minnesota Multiphasic Personality Inventory-2: an event-related potentials study. *Neuroscience Letters* 373, 26-31.

Carretié, L., Iglesias, J., García, T. & Ballesteros, M. (1996). N300, P300 and the emotional processing of visual stimuli. *Electroencephalography and Clinical Neurophysiology* 103, 298-303.

Cattran, C., Oddy, M. & Wood, R. (2011). The development of a measure of emotional regulation following acquired brain injury. *Journal of Clinical and Experimental Neuropsychology* 33 (6), 672-679.

Chen, J., Yuan, J., Huang, H., Chen, C. & Li, H. (2008). Music-induced mood modulates the strength of the emotional negativity bias: an ERP study. *Neuroscience Letters* 445 (2), 135-139.

Chow, H.M., Horovitz, S.G., Carr, W.S., Picchioni, D., Coddington, N., Fukunaga, M., Xu, Y., Balkin, T.J., Duyn, J.H. & Braun, A.R. (2013). Rhythmic alternating patterns of brain activity distinguish rapid eye movement sleep from other states of consciousness. *Proceedings of the National Academy of Sciences* 110 (25), 10300-10305.

Chung, G., Tucker, D.M., West, P., Potts, G.F., Liotti, M., Luu, P. & Hartry, A. L. (1996). Emotional expectancy: brain electrical activity associated with an emotional bias in interpreting life events. *Psychophysiology* 33, 218-233.

Ciurli, P., Formisano, R., Bivona, U., Cantagallo, A., & Angelelli, P. (2011). Neuropsychiatric disorders in persons with severe traumatic brain injury: prevalence, phenomenology and relationship with demographic, clinical and functional features. *Journal of Head Trauma Rehabilitation* 26 (2), 116-126.

Clarke, L.A., Genat, R.C. & Anderson, J.F.I. (2012). Long-term cognitive complaint and post-concussive symptoms following mild traumatic brain injury: the role of cognitive and affective factors. *Brain Injury* 26 (3), 298-307.

Cleeremans, A. (2008). Consciousness: the radical plasticity thesis. In R. Banerjee & N.K. Chakrabati (Eds.), *Progress in Brain Research* 168, 19-33.

Coleman, M.R., Bekinschtein, T., Monti, M.M., Owen, A.M. & Pickard, J.D. (2009). A multimodal approach to the assessment of patients with disorders of consciousness. *Progress in Brain Research* 177, 231-248.

Connolly, J.F. (2012). Communicating with the non-communicative: assessing the mental life of non-verbal individuals using neurophysiological techniques. In S. Ojima, Y. Otsu, J.F. Connolly & G. Thierry (Eds.). *Future Trends in the Biology of Language*, Keio University Press, Tokyo, Japan.

Connolly, J.F. & D'Arcy, R.C.N. (2000). Innovations in neuropsychological assessment using event-related brain potentials. *International Journal of Psychophysiol*ogy 37, 31-47.

Connolly, J.F., D'Arcy, R.C.N., Newman, R.L. & Kemps, R. (2000). The application of cognitive event-related brain potentials (ERPs) in language-impaired individuals: review and case studies. *International Journal of Psychophysiology* 38, 55-70.

Connolly, J.F., Major, A., Allen, S. & D'Arcy, R.C.N. (1999). Performance on WISC-III and WAIS-R N1 vocabulary subtests assessed with event-related brain potentials: an innovative method of assessment. *Journal of Clinical and Experimental Neuropsychology* 21, 444-464.

Connolly, J.F., Mate-Kole, C.C. & Joyce, B. (1999). Global aphasia: an innovative assessment approach. *Archives of Physical Medicine and Rehabilitation* 80, 1309-1315.

Conrad, R., Wegener, I., Imbierowicz K., Liedtke, R. & Geiser, F. (2009). Alexithymia, temperament and character as predictors of psychopathology in patients with major depression. *Psychiatry Research* 165, 137-144.

Cross, I. (2008). Musicality and the human capacity for culture. *Musicae Scientiae*, 147-167.

Cruse, D. & Owen, A.M. (2010). Consciousness revealed: new insights into the vegetative and minimally conscious states. *Current Opinion in Neurology* 23 (6), 656-660.

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

Daltrozzo, J., Tillmann, B., Platel, H. & Schön, D. (2009). Temporal aspects of the feeling of familiarity for music and the emergence of conceptual processing. *Journal of Cognitive Neuroscience* 22(8), 1754-1769.

Damasio, A. (2000). *The feeling of what happens – Body, emotion and the making of consciousness.* Berkshire (Reading): Cox & Wyman Limited.

Deborde, A.S., Berthoz, S., Wallier, J.M., Fermanian, J., Falissard, B., Jeammet, P. & Corcos, M. (2008). The Bermond-Vorst Alexithymia Questionnaire cutoff scores: a study in eating-disordered and control subjects. *Psychopathology* 41 (1), 43-49.

Dellacherie, D., Ehrlé, N. & Samson, S. (2008). Is the neutral condition relevant to study musical emotion in patients? *Music and Emotion* 25 (4), 285-294.

Delplanque, S., Silvert, L., Hot, P., Rigoulot, S. & Sequeira, H. (2006). Arousal and valence effects on event-related P3a and P3b during emotional categorization. *International Journal of Psychophysiology* 60, 315-322.

Demertzi, A., Racine, E., Bruno, M.A., Ledoux, D., Gosseries, O., Vanhaudenhuyse, A., Thonnard, M., Soddu, A., Moonen, G. & Laureys, S. (2012). Pain perception in disorders of consciousness: Neuroscience, Clinical Care and Ethics in Dialogue. *Neuroethics* 1-14.

Dolan, R.J. (2002). Emotion, cognition and behavior. *Science* 298, 1191-1194.

Duncan, C.C., Barry, R.J., Connolly, J.F., Fischer, C., Michie, P.T., Näätänen, R., Polich, J., Reinvang, I., & Van Petten, C. (2009). Event-related potentials in clinical research: guidelines for eliciting, recoding and quantifying mismatch negativity, P300 and N400. *Clinical Neurophysiology* 120 (11), 1883-1908.

Eerola, T. & Vuoskoski, J.K. (2011). A comparison of the discrete and dimensional models of emotion in music. *Psychology of Music* 39, 18-49.

Eschrich, S., Münte, T.F. & Altenmüller, E.O. (2008). Unforgettable film music: the role of emotion in episodic long-term memory for music. *BMC Neuroscience* 9, 48.

Fazio, R.H., Sanbonmatsu, D.M., Powell, M.C. & Kardes, F.R. (1986). On the automatic activation of attitudes. *Journal of Personality and Social Psychology* 50 (2), 229-238.

Fernández-Espejo, D., Soddu, A., Cruse, D., Palacios, E.M., Junque, C., Vanhaudenhuyse, A., Rivas, E., Newcombe, V., Menon, D.K., Pickard, J.D., Laureys, S. & Owen, A.M. (2012). A role for the default mode network in the bases of disorders of consciousness. *Annals of Neurology* 72, 335-343.

Fins, J.J. (2008). Brain Injury: The Vegetative and Minimally Conscious States. *From Birth to Death and Bench to Clinic: The Hastings Center Briefing Book for Journalists, Policymakers and Campaigns.* Crowley M. (Ed.). Garrison (NY): The Hastings Center. 15-19.

Fitzroy, A.B. & Sanders, L.D. (2013). Musical expertise modulates early processing of syntactic violations in language. *Frontiers in Psychology* 3 (603). doi:10.3389/fpsyg.2012.00603

Flom, R., Gentile, D.A. & Pick, A.D. (2008). Infants' discrimination of happy and sad music. *Infant Behaviour and Development* 31, 716-728.

Franz, M., Schaefer, R., Schneider, C., Sitte, W. & Bachor, J. (2004). Visual event-related potentials in subjects with alexithymia: modified processing of emotional aversive information? *American Journal of Psychiatry* 161, 728-735.

Frawley, W. & Smith, R.N. (2001). A processing theory of alexithymia. *Journal of Cognitive Systems Research* 2, 189-206.

Gabrielsson, A. & Juslin, P.N. (2003). Emotional expression in Music. In H.H. Goldsmith, R.J. Davidson & K.R. Scherer (Eds). *Handbook of Affective Sciences* (503-534). Oxford University Press: New York.

Gaigg, S.B. (2012). The interplay of emotion and cognition in autism spectrum disorder: implications for developmental theory. *Frontiers in Integrative Neuroscience* 6 (113). doi:10.3389/fnint.2012.00113

Gawryluk, J.R., D'Arcy, R.C.N., Connolly, J.F., & Weaver, D.F. (2010). Improving the clinical assessment of consciousness with advances in electrophysiological and neuroimaging techniques. *BMC Neurology* 10, 11-17.

Giacino, J.T., Ashwal, S., Childs, N., Cranford, R., Jennett, B., Katz, D.I., Kelly, J.P., Rosenberg, J.H., Whyte, J., Zafonte, R.D., Zasler, N.D. (2002). The minimally conscious state: definition and diagnostic criteria. *Neurology* 58, 349-353.

Gianotti, L.R.R., Faber, P.L., Schuler, M., Pasqual-Marqui, R.D., Kochi, K. & Lehmann, D. (2008). First valence, then arousal: the temporal dynamics of brain electrical activity evoked by emotional stimuli. *Brain Topography* 20, 143-156.

Gillett, J. (2010). Minimally conscious, locked in and vegetative patients. Talk given at the 17th Annual Neurobehavioural Rehabilitation in Acquired Brain Injury Conference. May 6 2010, Hamilton.

Goerlich, K.S., Witteman, J., Schiller, N.O., Van Heuven, V.J., Aleman, A. & Martens, S. (2012). The nature of affective priming in music and speech. *Journal of Cognitive Neuroscience* 24 (8), 1725-1741.

Goerlich, K.S., Witteman, J., Aleman, A. & Martens, S. (2011). Hearing feelings: affective categorization of music and speech in alexithymia, an ERP study. *PLoS ONE.* 6 (5): e19501. doi:10.1371/journal.pone.0019501

Goldfine, A.M. & Schiff, N.D. (2011). Consciousness: Its Neurobiology and the Major Classes of Impairment. *Neurologic Clinics* 29, 723-737.

Goldfine, A.M., Victor, J.D., Conte, M.M., Bardin, J.C. & Schiff, N.D. (2011). Determination of awareness in patients with severe brain injury using EEG power spectral analysis. *Clinical Neurophysiology* 122 (11), 2157-2168.

Gotlib, I.H. & Joormann, J. (2010). Cognition and depression: current status and future directions. *Annual review of clinical psychology* 6, 285-312.

Gove, P.B. (Ed.) (1961). *Webster's Third New International Dictionary of the English Language, Unabridged.* Springfield: G. & C. Merriam Company.

Gratton, G., Coles, M.G.H. & Donchin, E. (1983). A new method for off-line removal of ocular artifact. *Electroencephalography and Clinical Neurophysiology* 55, 468-484.

Gustorff, D. (2002). Beyond words: Music therapy with comatose patients and those with impaired consciousness in intensive care. In D. Aldridge & J. Fachner (Eds.), *info cd rom iv, university witten herdecke: witten* (pp.353-377). Witten: Witten University.

Harrison, A.H. & Connolly, J.F. (2013). Finding a way in: A review and practical evaluation of fMRI and EEG for detection and assessment in disorders of consciousness. *Neuroscience and Biobehavioural Reviews* http://dx.doi.org/10/1016/jneurobiorev.2013.05.004

Hassanpour, K., Hotz-Boendermaker, S., Dokladal, P. & Curt, A. (2011). Low depressive symptoms in acute spinal cord injury compared to other neurological disorders. *Journal of Neurology* 259 (6), 1142-1150.

Hayes, J.P., VanElzakker, M.B. & Shin, L.M. (2012). Emotion and cognition interactions in PTSD: a review of cognitive and neuroimaging studies. *Frontiers in Integrative Neuroscience* 6 (89). doi:10.3389/fnint.2012.00089

Hendryx, M.S., Haviland, M.G. & Shaw, D.G. (1991). Dimensions of alexithymia and their relationships to anxiety and depression. *Journal of Personality Assessment* 56 (2), 227-237.

Henry, J.D., Phillips, L.H., Crawford, J.R., Theodorou, G. & Summers, F. (2006). Cognitive and psychosocial correlates of alexithymia following traumatic brain injury. *Neuropsychologia* 44, 62-72.

Herrmann, N., Rapoport, M.J., Rajaram, R.D., Chan, F., Kiss, A., Ma, A.K., Feinstein, A., McCullagh, S., Lanctôt, K.L. (2009). Factor analysis of the Rivermead Post-Concussion Symptoms Questionnaire in mild-to-moderate traumatic brain injury patients. *The Journal of Neuropsychiatry and Clinical Neurosciences* 21(2), 181-188.

Hintikka, J., Honkalampi, K., Lehtonen, J. & Viinamäki, H. (2001). Are alexithymia and depression distinct or overlapping constructs? A study in a general population. *Comprehensive Psychiatry* 42 (3), 234-239.

Homaifar, B.Y., Brenner, L.A., Gutierre, P.M. (2009). Sensitivity and specificity of the Beck Depression Inventory-II (BDI-II) in persons with traumatic brain injury. *Archives of Physical Medicine and Rehabilitation* 90, 652-656.

Honkalampi, K., Hintikka, J., Tanskanen, A., Lehtonen, J. & Viinamäki, H. (2000). Depression is strongly associated with alexithymia in the general population. *Journal of Psychosomatic Research* 48, 99-104.

Honkalampi, K., Saarinen, P., Hintikka, J., Virtanen, V. & Viinamäki, H. (1999). Factors associated with alexithymia in patients suffering from depression. *Psychotherapy and psychosomatics* 68 (5), 270-275.

Hopyan, T., Laughlin, S. & Dennis, M. (2010). Emotions and their cognitive control in children with cerebellar tumors. *Journal of the International Neuropsychological Society* 16, 1027-1038.

Hunter, P.G., Schellenberg, E.G. & Griffith, A.T. (2011). Misery loves company: mood-congruent emotional responding to music. *Emotion* 11 (5), 1068-1072.

Hunter, P.G. & Schellenberg, E.G. (2010). Music and emotion. In M.R. Jones, R.R. Fay & A.N. Popper (Eds.). *Music Perception* (p.129-164). New York: Springer.

Huron, D. (2001). Is music an evolutionary adaptation? *Biological Foundations of Music* 930, 43-61.

Hynes, C.A., Stone, V.E. & Kelso, L.A. (2011). Social and emotional competence in traumatic brain injury: new and established assessment tools. *Social Neuroscience* 6 (5-6), 599-614.

Izard, C. (2012). Forms and functions of emotions: matters of emotion-cognition interactions. *Emotion Review* 3 (4), 371-378.

Izard, C. (2009). Emotion Theory and Research: Highlights, Unanswered Questions and Emerging Issues. *Annual Reviews of Psychology* 60, 1-25.

Jackendoff, R. & Lerdahl, F. (2006). The capacity for music: What is it, and what's special about it? *Cognition* 100, 33-72.

Jäncke, L. (2008). Music, memory and emotion. *Journal of Biology* 7 (6), 21.

Javanbakht, A., Liberzon, I., Amirsadri, A., Gjini, K. & Boutros, N.N. (2011). Event-related potential studies of post-traumatic stress disorder: a critical review and synthesis. *Biology of Mood & Anxiety Disorders* 1 (5). doi.10.1185/2045-5380-1-5

Jørgensen, M.M., Zachariae, R., Skytthe, A. & Kyvik, K. (2007). Genetic and environmental factors in alexithymia: a population-based study of 8,785 Danish twin pairs. *Psychotherapy and Psychosomatics* 76, 369-375.

Juslin, P.N. & Laukka, P. (2003). Communication of emotions in vocal expression and music performance: different channels, same code? *Psychological Bulletin* 129 (5), 770-814.

Juslin, P.N & Västfjäll, D. (2008). Emotional responses to music: the need to consider underlying mechanisms. *Behavioral Brain Sciences* 31 (5), 559-621.

Kalinen, K. & Ravaja, N. (2006). Emotion perceived and emotion felt: same and different. *Musicae Scientiae* 10, 191-213.

Kim, J.H., Lee, S.J., Rim, H.D., Kim, H.W., Bae, G.Y. & Chang, S.M. (2008). The relationship between alexithymia and general symptoms of patients with depressive disorders. *Psychiatry Investigation* 5 (3), 179-185.

Knobe, J. & Prinz, J. (2008). Intuitions about consciousness: experimental studies. *Phenomenology and the Cognitive Sciences* 7, 67-83.

Koelsch, S., Skouras, S., Fritz, T., Herrera, P., Bonhage, C., Küssner, M.B. &

Jacobs, A.M. (2013). Neural correlates of music-evoked fear and joy: the roles of the auditory cortex and superficial amygdala. *NeuroImage* doi:10.1016/j.neuroimage.2013.05.008.

Koelsch, S. (2011). Towards a neural basis of music perception – a review and updated model. *Frontiers in Psychology* 2 (110). doi: 10.3389/fpsyg.2011.00110

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

Kokkonen, P., Karvonen, J.T., Veijola, J., Läksy, K., Jokelainen, J., Järvelin, M.R. & Joukamaa, M. (2001). Prevalence and sociodemographic correlates of alexithymia in a population sample of young adults. *Comprehensive Psychiatry* 42 (6), 471-476.

Koponen, S., Taiminen, T., Honkalampi, K., Joukamaa, M., Viinamaki, H., Kurki, T., Portin, R., Himanen, L., Isoniemi, H., Hinkka, S. & Tenovuo, O. (2005). Alexithymia after traumatic brain injury: its relation to magnetic resonance findings and psychiatric disorders. *Psychosomatic Medicine* 67, 807-812.

Kotchoubey, B., Kaiser, J., Bostanov, V., Lutzenberger, W. & Birbaumer, N.

(2009). Recognition of affective prosody in brain-damaged patients and healthy controls: a neurophysiological study using EEG and whole head MEG. *Cognitive, Affective & Behavioural Neuroscience* 9 (2), 153-167.

Kouider, S., Stahlhut, C., Gleskov, S.V., Barbosa, L.S., Dutat, M., de Gardelle, V., Christophe, A., Dehaene, S. & Dehaene-Lambertz, G. (2013). A neural marker of perceptual consciousness in infants. *Science* 340, 376-380.

Koval, P., Kuppens, P., Allen, N.B. & Sheeber, L. (2012). Getting stuck in depression: the roles of rumination and emotional inertia. *Cognition & Emotion* 26 (8), 1412-1417.

Kulkarni, B., Bentley, D.E., Elliott, R., Youell, P., Watson, A., Derbyshire, S.W.G., Francowiak, R.S.J., Friston, K.J. & Jones, A.K. P. (2005). Attention to pain localization and unpleasantness discriminates the functions of the medial and lateral pain systems. *European Journal of Neuroscience* 21, 3133-3142.

Kutas, M. & Federmeier, K.D. (2011). Thirty years and counting: finding meaning the N400 component of the event-related brain potential. *Annual Review of Psychology* 62, 621-647.

Krumhansl, C.I. (1997). An exploratory study of musical emotions and psychophysiology. *Canadian Journal of Experimental Psychology* 51(4), 336-353.

Krystal, H. (1988). *Integration and self-healing: affect-trauma-alexithymia.* Hillsdale (NJ): The Analytic Press.

Kupfer, D.J., Frank, E. & Phillips, M.L. (2012). Major depressive disorder: new clinical, neurobiological and treatment perspectives. *Lancet* 379, 1045-1055.

Lane, R.D., Ahern, G.L., Schwartz, G.E. & Kaszniak. A.W. (1997). Is alexithymia the emotional equivalent of blindsight? *Biological Psychiatry* 42, 834-844.

Larsen, J.K., Brand, N., Bermond, B. & Hijman, R. (2003). Cognitive and emotional characteristics of alexithymia: a review of neurobiological studies. *Journal of Psychosomatic Research* 54, 533-541.

Lau, H. & Rosenthal, D. (2011). Empirical support for higher-order theories of conscious awareness. *Trends in Cognitive Sciences* 15(8), 365-373.

Laureys, S. & Schiff, N. (2011). Coma and consciousness: paradigms (re)framed by neuroimaging. *NeuroImage*. doi:10.1016/j.neuroimage.2011.12.041

Laureys, S., Celesia, G.G., Cohadon, F., Lavrijsen, J., León-Carrión, J., Sannita, W.G., Sazbon, L., Schmutzhard, E., von Wild, K.R. Zeman, A., Dolce, G. & the European Task Force on Disorders of Consciousness. (2010). Unresponsive wakefulness syndrome: a new name for the vegetative state or apallic syndrome. *BMC Medicine* 8, 68.

Laureys, S., Giacino, J.T., Schiff, N.D., Schabus, M. & Owen, A.M. (2006). How should functional imaging of patients with disorders of consciousness contribute to their clinical rehabilitation needs? *Current Opinion in Neurology* 19 (6), 520-527.

LeDoux, J. (2012). Rethinking the emotional brain. *Neuron* 73,653-676.

LeMoult, J., Yoon, K.L. & Joormann, J. (2012). Affective priming in major depressive disorder. *Frontiers in Integrative Neuroscience* 6 (76). doi:10.3389/fnint.2012.00076

Levant, R.F., Hall, R.H., Williams, C.M. & Hasan, N.T. (2009). Gender differences in alexithymia. *Psychology of Men & Masculinity* 10 (3), 190-203.

Levitin, D.J. (2011). *This is your brain on music: Understanding a human obsession*. Atlantic books.

Levitin, D.J. (2008). The world in six songs: How the musical brain created human nature. Dutton books.

Levitin, D. J. & Tirovolas, A.K. (2009). Current advances in the cognitive neuroscience of music. *Annals of the New York Academy of Sciences* 1156, 211-231.

Leweke, F., Leichsenring, F., Kruse, J. & Hermes, S. (2012). Is alexithymia associated with specific mental disorders. *Psychopathology* 45 (1), 22-28.

Liemburg, E.J., Swart, M., Bruggeman, R., Kortekaas, R., Knegtering, H., Ćurčić-Blake, B., Aleman, A. (2012). Altered resting state connectivity of the default mode network in alexithymia. *Social Cognitive and Affective Neuroscience* 7 (6), 660-666.

Lima, C.F., Garrett, C. & Castro, S.L. (2013). Not all sounds the same: Parkinson's disease affects differently emotion processing in music and in speech prosody. *Journal of Clinical and Experimental Neuropsychology* doi:10.1080/13803395.2013.776518

Lindquist, K.A., Wager, T.D., Kober, H., Bliss-Moreau, E. & Barrett, L.F. (2012). The brain basis of emotion: a meta-analytic review. *Behavioural and Brain Sciences* 35, 121-202.

Lithari, C., Frantzidis, C.A., Papadelis, C., Vivas, A.B., Klados, M.A., Kourtidou-

Papadeli, C., Pappas, C., Ionnides, A.A. & Bamidis, P.D. (2010). Are females more responsive to emotional stimuli? A neuropsychological study across arousal and valence dimensions. *Brain Topography* 23, 27-40.

Lu, Y., Zhang, W., Hu, W. & Luo, Y. (2011). Understanding the subliminal affective priming effect of facial stimuli. *Neuroscience Letters* 502, 182-185.

Luck, S.J. (2005). *An introduction to the event-related potential technique.* Cambridge, MA: MIT Press.

Luminet, O., Bagby, M.R. & Taylor, G.J. (2001). An evaluation of the absolute and relative stability of alexithymia in patients with major depression. *Psychotherapy and Psychosomatics* 70, 254-260.

Lumley, M.A., Neely, L.C. & Burger, A.J. (2007). The assessment of alexithymia in medical settings: implications for understanding and treating health problems. *Journal of Personality Assessment* 89 (3), 230-246.

Lundh, L.G. & Simonsson-Sarneck, M. (2002). Alexithymia and cognitive bias for emotional information. *Personality and Individual Differences* 32 (6), 1063-1075.

Linka, T., Sartory, G., Gastpar, M., Sherbaum, N., Müller, B.W. (2009). Clinical symptoms of major depression are associated with the intensity dependence of auditory event-related potential components. *Psychiatry Research* 169, 139-143.

Linka, T., Müller, B.W., Bender, S. & Sartory, G. (2004). The intensity dependence of the auditory evoked N1 component as a predictor of response to Citalopram treatment in patients with major depression. *Neuroscience Letters* 367, 375-378.

Luo, W., Feng, W., He, W., Wang, N. & Luo, Y. (2010). Three stages of facial expression processing: ERP study with rapid serial visual presentation. *NeuroImage* 49, 1857-1867.

Maas, A.I.R., Stocchetti, N. & Bullock, R. (2008). Moderate to severe traumatic brain injury in adults. *Lancet Neurology*, 7 (8), 728-741.

Magee, W.L. (2005). Music therapy with patients in low awareness states: approaches to assessment and treatment in multidisciplinary care. *Neuropsychological Rehabilitation: An International Journal* 15 (3-4), 522-536.

Maidhof, C. & Koelsch, S. (2011). Effects of selective attention on syntax processing in music and language. *Journal of Cognitive Neuroscience* 23 (9), 2252-2267.

Marchesi, C., Brusamonti, E. & Maggini, C. (2000). Are alexithymia, depression and anxiety distinct constructs in affective disorders? *Journal of Psychosomatic Research* 49, 43-49.

Markl, A., Yu, T., Vogel, D., Müller, F., Kotchoubey, B. & Lang, S. (2012). Brain processing of pain in patients with unresponsive wakefulness syndrome. *Brain and Behaviour* doi:10.1002/brb3.110

Mashour, G.A. & Alkire, M.T. (2013). Evolution of consciousness: Phylogeny, ontogeny and emergence from general anesthesia. *Proceedings of the National Academy of Sciences*. doi/10.1073/pnas.1301188110

McDermott, J. & Hauser, M. (2005). The origins of music: innateness, uniqueness and evolution. *Music Perception* 23 (1), 29-59.

Mineka, S. & Öhman, A. (2002). Phobias and preparedness: the selective, automatic and encapsulated nature of fear. *Biological Psychiatry* 52 (10). 927-937.

Milovanov, R. & Tervaniemi, M. (2011). The interplay between musical and linguistic aptitudes: a review. *Frontiers in Psychology* 2 (321). doi: 10.3389/fpsyg.2011.00321

Mohanty, A. & Sussman, T. J. (2013). Top-down modulation of attention by emotion. *Frontiers in Human Neuroscience* 7 (102). doi:10.3389/fnhum.2013.00102.

Mohn, C., Argstatter, H., Wilker, F.W. (2011). Perception of six basic emotions in music. *Psychology of Music* 29 (4), 503-517.

Molnar-Szakacs, I. & Overy, K. (2006). Music and mirror neurons: from motion to 'e'motion. *Scan* 1, 235-241.

Monsell, S. (2003). Task switching. *Trends in Cognitive Sciences* 7(3), 134-140.

Moreau, P., Jolicœr, P. & Peretz, I. (2013). Pitch discrimination without awareness in congenital amusia: evidence from event-related potentials. *Brain & Cognition* 81 (2), 337-344.

Morgan, J., Choy, T.L. & Connolly, J.F. (2012). *The affective priming of words by music: an ERP study*. Manuscript in preparation.

Moriguchi, Y., Ohnishi, T., Decety, J., Hirakata, M., Maeda, M., Matsuda, H. & Komaki, G. (2009). The human mirror neuron system in a population with deficient self-awareness: an fMRI study in alexithymia. *Human Brain Mapping* 30, 2063-2076.

Morrison, S.L. & Pihl, R.O. (1990). Alexithymia and stimulus augmenting reducing. *Journal of Clinical Psychology* 46, 730-736.

Nemiah, J.C. & Sifneos, P.E. (1970). Psychosomatic illness: a problem in communication. *Psychotherapy and Psychosomatics* 18, 154-160.

Neuhaus, C., Knösche, T.R. & Friederici, A.D. (2009). Similarity and repetition: an ERP study on musical form perception. *Annals of the New York Academy of Sciences* 1169, 485-489.

Neumann, N. & Kotchoubey, B. (2004). Assessment of cognitive functions in severely paralyzed and severely brain-injured patients: neuropsychological and electrophysiological methods. *Brain Research. Brain Research Protocols* 14 (1), 25-36.

Ogrodniczuk, J.S., Piper, W.E. & Joyce, A.S. (2010). Effect of alexithymia on the process and outcome of psychotherapy: a programmatic review. *Psychiatric Research* 190 (1), 43-48.

Öhman, A. & Mineka, S. (2001). Fears, phobias and preparedness: Toward an evolved module of fear and fear learning. *Psychological Review New York* 108 (3), 483-522.

Oldfield, R.C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia* 9, 97-113.

Ollen, J. E. (2006). A criterion-related validity test of selected indicators of musical sophistication using expert ratings. Doctoral dissertation, Ohio State University. Retrieved from the World Wide Web on Jan 16 2012 http://etd.ohiolink.edu/view.cgi?osu1161705351

Oloffson, J.K. Nordin, S., Sequeira, H. & Polich, J. (2008). Affective picture processing: an integrative review of ERP findings. *Biological Psychology* 77, 247-265.

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

Panksepp, J. (2003). At the interface of affective, behavioral and cognitive neurosciences: Decoding the emotional feelings of the brain. *Brain and Cognition* 52, 4-14.

Parker, J.D.A., Keefer, K.V., Taylor, G.J. & Bagby, R.M. (2008). Latent structure of the alexithymia construct: a taxometric investigation. *Psychological Assessment* 20 (4), 385-396.

Parker, J.D.A., Bagby, R.M. & Taylor, G.J. (1991). Alexithymia and depression: distinct or overlapping constructs? *Comprehensive Psychiatry* 32 (5), 387-394.

Patel, A.D. (2011). Why would musical training benefit the neural encoding of speech? The OPERA hypothesis. *Frontiers in Psychology* 2 (142).

Peretz, I. (in press). The biological foundations of music: insights from congenital amusia. *The Psychology of Music.* D. Deutsch (Ed.). Elsevier.

Peretz, I. (2006). The nature of music from a biological perspective. *Cognition* 100, 1-32.

Peretz, I. (2002). Brain specialization for music. *The Neuroscientist* 8, 372-380.

Peretz, I. (1996). Can we lose memories for music? The case of music agnosia in a nonmusician. *Journal of Cognitive Neuroscience* 8, 481-496.

Peretz, I., Champod, A.S. & Hyde, K. (2003). Varieties of musical disorders – the Montreal Battery of Evaluation of Amusia. *Annals of the New York Academy of Sciences* 999, 58-75.

Peretz, I. & Gagnon, L. (1999). Dissociation between recognition and emotional judgement for melodies. *Neurocase: The Neural Basis of Cognition* 5 (1), 21-30.

Peretz, I., Gagnon, L. & Bouchard, B. (1998). Music and emotion: perceptual determinants, immediacy and isolation after brain damage. *Cognition* 68, 111-141.

Peretz, I., Gaudreau, D. & Bonnel, A. (1998). Exposure effects on music preference and recognition. *Memory & Cognition* 26 (5), 884-902.

Peretz, I., Kolinsky, R., Tramo, M., Labreque, R., Hublet, C., Demeurisse, G., Belleville, S. (1994). Functional dissociations following bilateral lesions of the auditory cortex. *Brain* 117, 1283-1302.

Perlovsky, L. (2010). Musical emotions: functions, origins, evolution. *Physics of Life Reviews* 7, 2-27.

Phelps, E.A. (2006). Emotion and cognition: insights from studies of the human amygdala. *Annual Reviews of Psychology* 57, 27-53.

Picardi, A., Fagnani, C., Gigantesco, A., Toccaceli, V., Lega, I., Stazi, M.A. (2011). Genetic influences on alexithymia and their relationship with depressive symptoms. *Journal of Psychometric Research* 71 (4), 256-263.

Pinheiro, A.P., Galdo-Álvarez, S., Rauber, A., Sampaio, A., Niznikiewicz, M. & Gonçalves, O.F. (2011). Abnormal processing of emotional prosody in Williams syndrome: an event-related potentials study. *Research in Developmental Disabilities* 32, 133-147.

Pollatos, O. & Gramann, K. (2011). Electrophysiological evidence of early processing deficits in alexithymia. *Biological Psychology* 87 (1), 113-121.

Polich, J. (2012). Neuropsychology of the P300. In S.J. Luck & E.S. Kappenman

(Eds.) *Handbook of event-related potential components* (159-188). Oxford University Press: In press.

Polich, J. (1989). Frequency, intensity and duration as determinants of P300 from auditory stimuli. *Journal of Clinical Neurophysiology* 6 (3), 277-286.

Polich, J., Ellerson, P.C. & Cohen, J. (1996). P300, stimulus intensity, modality and probability. *International Journal of Psychophysiology* 23, 55-62.

Posner, J.B., Saper, C.B., Schiff, N.D. & Plum, F. (Eds.) (2007). *Plum and Posner's Diagnosis of Stupor and Coma, 4th Edition.* New York: Oxford University Press.

Punkanen, M., Eerola, T. & Errkilä, J. (2011). Biased emotional recognition in depression: perception of emotion in music by depressed patients. *Journal of Affective Disorders* 130, 118-126.

Rapoport, M.J. (2012). Depression following traumatic brain injury: epidemiology, risk factors and management. *CNS Drugs* 26 (2), 111-121.

Rapoport, M.J., Kiss, A. & Feinstein, A. (2006). The impact of major depression on outcome following mild-to-moderate traumatic brain injury in older adults. *Journal of Affective Disorders* 92 (2-3), 273-276.

Russell, J.A. (2003). Core affect and the psychological construction of emotion.

Psychological Review 110, 145-172.

Saarijärvi, S., Salminen, J.K. & Toikka, T. (2006). Temporal stability of alexithymia over a five-year period in outpatients with major depression. *Psychotherapy and Psychosomatics* 75, 107-112.

Saarijärvi, S., Salminen, J.K. & Toikka, T. (2001). Alexithymia and depression: a 1-year follow-up study in outpatients with major depression. *Journal of Psychosomatic Research* 51, 729-733.

Saenz, A., Doé de Maindreville, A., Henry, A., de Labbey, S., Bakchine, S. & Ehrlé, N. (2012). Recognition of facial and musical emotions in Parkinson's disease. *European Journal of Neurology* 20 (3), 571-577.

Salminen, J., Saarijärvi, S., Äärelä, E., Toikka, T & Kauhanen, J. (1999). Prevalence of alexithymia and its association with sociodemographic variable in the general population of Finland. *Journal of Psychosomatic Research* 46 (1), 75-82.

Sammler, D., Koelsch, S., Ball, T., Brandt, A., Grigutsch, M., Huppertz, H.J., Knösche, T.R., Wellmer, J., Widman, G., Elger, C.E., Friederici, A.D., Schulze-Bondhage, A. (2012). Co-localizing linguistics and musical syntax with intracranial EEG. *NeuroImage* doi: 101.1016/j.neuroimgage.20120.09.035

Sandstrom, G.M. & Russo, F.A. (2011). Absorption in music: Development of a scale to identify individuals with strong emotional responses to music. *Psychology of Music* DOI: 10.1177/0305735611422508

Särkämö, T., Tervaniemi, M., Laitinen, S., Forsblom, A., Soinila, S., Mikkonen, M., Autti, T., Silvenoinen, H.M., Erkkilä, J., Laine, M., Peretz, I. & Hietanen, M. (2008). Music listening enhances cognitive recovery and mood after middle cerebral artery stroke. *Brain* 131, 866-876.

Schellenberg, E.G., Peretz, I. & Vieillard, S. (2008). Liking for happy and sad sounding music: effects of exposure. *Cognition & Emotion* 22 (2), 218-237.

Schiff, N.D. (2006). Measurements and models of cerebral function in the severely injured brain. *Journal of Neurotrauma* 23 (10), 1436-1449.

Schirmer, A. & Kotz, S.A. (2003). ERP evidence for a sex-specific Stroop effect in emotional speech. *Journal of Cognitive Neuroscience* 15(8), 1135-1148.

Schirmer, A., Kotz, S.A. & Friederici, A.D. (2005). On the role of attention for the processing of emotion in speech: sex differences revisited. *Cognitive Brain Research* 24 (3), 442-452.

Schnakers, C., Vanhaudenhuyse, A., Giacino, J., Ventura, M., Boly, M., Majerus, S., Moonen, G. & Laureys, S. (2009). Diagnostic accuracy of the vegetative and minimally conscious state: Clinical consensus versus standardized neurobehavioural assessment. *BMC Neurology* 9 (1), 35.

Searle, J.R. (1998). How to study consciousness scientifically. *Philosophical Transactions of the Royal Society of London. Series B, Biological sciences* 353 (1377), 1935-1942.

Shahin, A., Bosnyak, D.J., Trainor, L.J. & Roberts, L.E. (2003). Enhancement of the neuroplastic P2 and N1c auditory evoked potentials in musicians. *The Journal of Neuroscience* 23(12), 5545-5552.

Sifneos, P.E. (2000). Alexithymia, Clinical Issues, Politics and Crime. *Psychotherapy and Psychosomatics* 69, 113-116.

Sklar, J. (2013). People in a vegetative state may feel pain. *New Scientist* 217 (2905), 14.

Sollberger, B., Reber, R. & Eckstein, D. (2003). Musical chords as affective priming context in a word-evaluation task. *Music Perception* 3, 263-282.

Steinbeis, N. & Koelsch, S. (2009). Affective priming effects of musical sounds of the processing of word meaning. *Journal of Cognitive Neuroscience* 23 (3), 604-621.

Swart, M., Kortekaas, R. & Aleman, A. (2009). Dealing with feelings: characterization of trait alexithymia on emotion regulation strategies and cognitive-emotional processing. *PLoS ONE* 4 (6), e5751.

Tamietto, M. & de Gelder, B. (2010). Neural bases of the non-conscious perception of emotional signals. *Nature Reviews Neuroscience* 11, 697-709.

Tate, R.L. (2012). Traumatic brain injury. In *The Oxford Handbook of Rehabilitation Psychology*. (Kennedy, P., Ed.) New York: Oxford University Press. 248-273.

Taylor, G.J. & Bagby, R.M. (2011). Genetic contributions to alexithymia. *Psychosomatic Medicine* 73 (7), 633.

Taylor, G.J. & Bagby, M.R. (2004). New trends in alexithymia research. *Psychotherapy and Psychosomatics* 73, 68-77.

Taylor, G.J., Bagby, M.R. & Parker, J.D.A. (2003). The 20-item Toronto Alexithymia Scale. 4. Reliability and factorial validity in different languages and cultures. *Journal of Psychosomatic Research* 55, 277-283.

Taylor, G.J., Bagby, M.R. & Parker, J.D.A. (1997). *Disorders of affect regulation*

– *alexithymia in medical and psychiatry illness.* Cambridge (UK): Cambridge University Press.

Thalpar, A., Collishow, S., Pine, D.S. & Thalpar, A.K. (2012). Depression in adolescence. *Lancet* 379, 1056-1067.

Trainor, L.J. (2008). The neural roots of music. *Nature* 453, 598-599.

Trainor, L.J. & Corrigall, K.A. (2010). Music acquisition and effects of musical experience. In M. Riess-Jones & R. R. Fay (Eds.), *Springer Handbook of Auditory Research: Music Perception.* Heidelberg: Springer. 89-128.

Trainor, L.J., Desjardins, R.N. & Rockel, C. (1999). A comparison of contour and interval processing in musicians and nonmusicians using event-related potentials. *Australian Journal of Psychology* 51 (3), 147-153.

Trainor, L.J. & Schmidt, L.A. (2003). Processing emotions induced by music. In I. Peretz & R. Zatorre (Eds.), *The Cognitive Neuroscience of Music*. Oxford: Oxford University Press. 310-324.

Trainor, L.J., Austin, C.M. & Desjardins, R.N. (2000). Is infant-directed speech prosody a result of the vocal expression of emotion? *Psychological Science* 11 (3), 188-195.

Tsuchiya, N. & Adolphs, R. (2007). Emotion and consciousness. *TRENDS in*

Cognitive Sciences 11 (4), 158-167.

Vanheule, S., Desmet, M., Verhaeghe, P. & Bogaerts, S. (2007). Alexithymic depression: evidence for a depression subtype? *Psychotherapy and Psychosomatics* 76, 315-316.

Vermeulen, N., Toussaint, J. & Luminet, O. (2010). The influence of alexithymia and music on the incidental memory for emotion words. *European Journal of Personality* 24, 551-568.

Vermeulen, N., Luminet, O. & Corneille, O. (2006). Alexithymia and the automatic processing of affective information: evidence from the affective priming paradigm. *Cognition & Emotion* 20 (1), 64-91.

Vieillard, S., Peretz, I., Gosselin, N., Khalfa, S., Gagnon, L. & Bouchard, B. (2008). Happy, sad, scary and peaceful musical excerpts for research on emotions. *Cognition & Emotion* 22 (4), 720-752.

Villemure, C., Slotnick, B.M. & Bushnell, M.C. (2003). Effects on odors on pain perception: deciphering the roles of emotion and attention. *Pain* 106, 101-108.

Vorst, H.C.M. & Bermond, B. (2001). Validity and reliability of the Bermond-

Vorst Alexithymia Questionnaire. *Personality and Individual Differences* 30, 413-434.

Wallin, N., Merker, B. & Brown, S. (2000). *The origins of music.* Cambridge (MA): MIT Press.

Walter, N.T., Montag, C., Markett, S.A. & Reuter, M. (2011). Interaction effect of functional variants of the BDNF and DRD2/ANKK1 Gene is associated with alexithymia in healthy human subjects. *Psychosomatic Medicine* 73, 23-28.

Watson, D., Clark, L.A. & Tellegen, A. (1988). Development and validation of brief measures of Positive and Negative Affect: the PANAS Scales. *Journal of Personality & Social Psychology,* 54 (6), 1063-1070.

Weaver, S.M., Chau, A., Portelli, J.N. & Grafman, J. (2012). Genetic polymorphisms influence recovery from traumatic brain injury. *The Neuroscientist* doi:10.1177/1073858411435706

Whitnall, L., McMillan, T.M., Murray, G.D. & Teasdale, G.M. (2006). Disability in young people and adults after head injury: 5-7 year follow up of a prospective cohort study. *Journal of Neurology, Neurosurgery & Psychiatry* 77 (5), 640-645.

Willemsen, R., Roseeuw, D. & Vanderlinden, J. (2008). Alexithymia and dermatology: the state of the art. *International Journal of Dermatology* 47, 903-910.

Wood, R.L., Williams, C. & Lewis, R. (2010). Role of alexithymia in suicide ideation after traumatic brain injury. *Journal of the International Neuropsychological Society* 16, 1108-1114.

Wood, R.L. & Williams, C. (2007). Neuropsychological correlates of organic alexithymia. *Journal of the International Neuropsychological Society* 13, 471-479.

Wu, D. & Yuan, Y. (2012). Electroencephalography (EEG) and unconsciousness. doi:10.5772/48346.

APPENDIX A:

MUSICAL STIMULI LIST AND DETAILS

#	Name	Movie	Category	Sample	Rating*	Excerpt from sample	Rating**	Accuracy (%)
1	1a	Shallow Grave (Track/T6)	Happy	2:02-2:17s	7.3	0.0-1.0s	4.6	100
2	1b					1.5-2.5s	4.8	100
3	1c					3.0-4.0s	4.9	100
4	1d					8.0-9.0s	4.9	100
5	2a	The Rainmaker (T2)		1:54-2:07s	7.2	0.5-1.5s	4.5	100
6	2b					1.5-2.5s	4.4	100
7	2c					4.5-5.5s	4.4	100
8	2d					8.5-9.5s	4.3	88
9	3a	The Rainmaker (T3)		2:55-3:13s	7.2	3.5-4.5s	3.6	75
10	3b					5.0-6.0s	3.4	50
11	3c					8.0-9.0s	4.3	100
12	3d					9.5-10.5s	4.3	100
13	3e					12-13s	4.3	100
14	4a	Man of Galilee CD1 (T2)		3:02-3:18s	7.2	1.0-2.0s	4.5	100
15	4b					4.0-5.0s	3.6	63
16	4c					5.0-6.0s	4.1	88
17	4d					7.5-8.5s	4.1	88
18	4e					14.5-15.5s	3.8	75
19	5a	Shakespeare in Love (T1)		1:06-1:22s	7.2	0.0-1.0s	3.6	63
20	5b					1.5-2.5s	3.5	63
21	5c					3.0-4.0s	4.5	75
22	5d					6.5-7.5s	3.9	88
23	5e					13.5-14.5s	4.0	88
24	6a	The Rainmaker (T5)		3:07-3.23s	7.0	0.5-1.5s	4.4	100
25	6b					2.0-3.0s	4.0	100
26	6c					3.0-4.0s	4.3	100
27	6d					6.5-7.5s	4.3	88
28	7a	Man of Galilee CD1 (T11)		0:00-0:18s	7.0	2.5-3.5s	4.5	100
29	7b					3.5-4.5s	4.3	100
30	7c					6.0-7.0s	4.5	100
31	7d					13-14s	4.8	100
32	7e					14.5-15.5s	4.3	88
33	8a	Nostradamus (T1)		0:00-0:16s	7.0	3.5-4.5s	3.9	75
34	8b					4.5-5.5s	3.6	63
35	8c					7.0-8.0s	3.6	63
36	8d					8.5-9.5	4.1	88
37	8e					13-14s	4.6	88
38	8f					15-16s	4.0	75
39	9a	Band of Brothers (T3)		1:19-1:36	7.0	0.0-1.0s	4.0	88

40	9b					1.0-2.0s	4.1	88
41	9c					3.0-4.0s	3.4	50
42	9d					4.5-5.5s	4.0	75
43	9e					5.5-6.5s	4.0	75
44	9f					7.0-8.0s	3.7	71
45	9g					9.5-10.5s	4.4	100
46	9h					11.5-12.5s	3.9	63
47	9i					13-14s	4.0	88
48	9j					14-15s	3.8	63
49	9k					16-17s	3.9	88
50	10a	The Untouchables (T6)		1:50-2:05s	6.5	0.0-1.0s	3.4	63
51	10b					1.5-2.5s	3.5	63
52	10c					4.0-5.0s	3.9	75
53	10d					6.0-7.0s	4.1	75
54	10e					8.5-9.5s	3.4	63
55	10f					10-11s	4.4	100
56	10g					13-14s	4.5	88
57	11a	Shine (T5)		2:00-2:16	6.5	0.0-1.0s	3.8	75
58	11b					1.5-2.5s	3.4	63
59	11c					3.0-4.0s	3.3	38
60	11d					6.0-7.0s	3.4	38
61	12a	Shine (T13)		0:00-0:20s	6.3	5.0-6.0s	4.4	100
62	12b					7.0-8.0s	4.5	100
63	12c					10.5-11.5s	4.5	100
64	12d					13-14s	3.8	75
65	13a	Shallow Grave (T3)		1:45-2:00s	6.2	0.0-1.0s	4.0	88
66	13b					4.0-5.0s	3.8	63
67	13c					6.0-7.0s	3.6	63
68	13d					12-13s	3.9	75
69	15b	Shakespeare in Love (T17)		0:03-0:23s	5.5	7.0-8.0s	3.5	50
70	15c					12-13s	4.0	63
71	16c	Shine (T15)		1:00-1:19s	5.5	15-16s	4.1	100
72	16d					16.5-17.5s	3.9	50
73	17b	Big Fish (T13)		1:02-1:17s	5.5	1.0-2.0s	4.0	100
74	17c					2.0-3.0s	3.8	75
75	17d					4.0-5.0s	3.8	75
76	17e					6.0-7.0s	3.8	63
77	17f					8.0-9.0s	4.3	100
78	17g					9.5-10.5s	4.4	100
79	17h					13-14s	4.4	100

80	17i					16-17s	4.0	88
81	18c	Vertigo OST (T6)		4:42-4:57s	5.2	9.5-10.5	3.6	63
82	20a	Shakespeare in Love (T21)		0:03-0:21s	4.7	0.0-1.0s	3.9	75
83	20b					3.0-4.0s	4.0	88
84	20c					9.5-10.5s	4.0	88
85	20d					16-17s	3.9	75
86	21a	Big Fish T12		0:55-1:10s	4.2	11-12s	4.8	100
87	21b					12-13s	4.6	88
88	21c					14-15s	4.0	100
89	21d					15.5-16.5s	4.1	100
90	23a	Shallow Grave (T8)		0:00-0:15s	3.0	1.0-2.0s	3.4	50
91	23b					5.0-6.0s	4.0	75
92	23c					7.0-8.0s	4.5	88
93	24a	Batman (T9)	High valence	2:03-2:25s	4.8	13.5-14.5s	3.9	75
94	24c					18.5-19.5s	3.5	50
95	24d					19.5-20.5s	3.6	75
96	25a	Dances with Wolves (T10)		0:28-0:46s	4.3	0.0-1.0s	3.5	63
97	25b					2.0-3.0s	3.3	34
98	25c					6.5-7.5s	3.4	50
99	25d					9.0-10s	3.4	50
100	25e					10.5-11.5s	3.8	75
101	26b	Oliver Twist (T1)		0:17-0:34s	7.2	5.0-6.0s	3.4	50
102	26c					8.0-9.0s	3.4	50
103	26d					11-12s	3.8	88
104	26e					15-16s	3.8	88
105	26f					23-24s	4.0	88
106	27a	Juha (T1)		0:42-0:59s	7.0	0.0-1.0s	4.0	88
107	27b					3.0-4.0s	4.3	88
108	27c					5.0-6.0s	3.9	75
109	27d					6.0-7.0s	3.6	63
110	27e					9.0-10s	3.8	88
111	27f					15-16s	4.3	88
112	28b	Oliver Twist (T4)		1:10-1:30s	5.8	15.5-16.5s	3.6	75
113	29a	Batman (T20)		1:09-1:30s	7.0	2.0-3.0s	4.0	75
114	29b					4.0-5.0s	3.4	63
115	29c					5.0-6.0s	4.3	88
116	29d					7.5-8.5s	4.0	75
117	29e					9.5-10.5s	4.5	100
118	29f					13.5-14.5s	4.0	63
119	29g					16.5-17.5s	3.8	100

120	29h					17.5-18.5s	3.8	63
121	29i					19.5-20.5s	3.8	63
122	29j					20.5-21.5s	4.3	88
123	30a	Juha (T7)		0:17-0:36s	6.3	12-13s	4.1	88
124	30b					13-14s	3.8	75
125	31a	The Godfather (T11)	High energy	0:49-1:06s	7.0	0.0-1.0s	4.1	63
126	31b					1.0-2.0s	4.0	88
127	31c					2.0-3.0s	4.0	75
128	31d					3.5-4.5s	4.5	88
129	31f					8.5-9.5s	4.3	100
130	31g					9.5-10.5s	4.6	100
131	31h					10.5-11.5s	4.6	100
132	31i					15.5-16.5s	4.5	88
133	32a	Grizzly Man (T3)		1:01-1:18s	7.2	0.0-1.0s	3.9	75
134	32b					1.0-2.0s	4.3	88
135	32c					8.5-9.5s	4.0	88
136	32d					11-12s	4.1	88
137	32f					16.5-17.5s	3.6	63
138	33a	The Portrait of a Lady (T8)		0:37-0:56s	7.3	2.0-3.0s	3.9	75
139	33b					3.5-4.5s	4.4	100
140	33c					8.0-9.0s	4.4	100
141	33d					10.5-11.5s	4.5	100
142	34a	Oliver Twist (T8)		1:40-2:04s	3.5	4.0-5.0s	3.6	50
143	34b					10.5-11.5s	4.3	88
144	34c					16-17s	4.8	100
145	34d					18-19s	4.5	88
146	35a	Juha (T13)		1:05-1:20s	2.7	0.0-1.0s	4.1	75
147	35b					1.5-2.5s	3.8	63
148	35c					4.0-5.0s	4.1	88
149	35d					5.5-6.5s	4.4	100
150	35e					6.5-7.5s	4.0	88
151	35f					8.5-9.5s	4.4	88
152	35g					14-15s	4.3	50
153	36a	Outbreak (T2)		0:22-0:37s	1.5	1.0-2.0s	3.5	50
154	36b					3.5-4.5s	3.8	63
155	37a	Crouching Tiger. Hidden Dragon (T6)		0:38-0:51s	4.7	0.5-1.5s	4.1	75
156	37b					4.5-5.5s	3.9	63
157	37c					6.0-7.0s	4.3	88
158	38a	The Portrait of a Lady (T9)		1:50-2:10s	4.8	2.0-3.0s	4.5	100
159	38b					3.0-4.0s	3.8	63

160	38c					4.0-5.0s	4.3	100
161	38e					15.5-16.5s	4.4	100
162	38f					16.5-17.5s	4.3	100
163	39a	The Ocellus Suite (T5)		3:47-4:00s	1.7	1.0-2.0s	3.5	63
164	39b					8.5-9.5s	3.5	50
165	40a	Batman (T4)		2:31-2:51s	6.8	0.0-1.0s	4.5	100
166	40b					1.0-2.0s	3.8	50
167	40c					2.0-3.0s	3.9	75
168	40d					3.0-4.0s	4.4	100
169	40e					4.0-5.0s	4.4	100
170	40f					8.0-9.0s	4.1	88
171	40g					9.0-10s	4.3	88
172	40h					11-12s	4.4	88
173	40i					15.5-16.5s	4.3	88
174	40j					17-18s	4.0	75
175	41b					8.0-9.0s	3.6	63
176	41c	Lethal Weapon 3 (T4)		1:40-2:00s	4.0	16.5-17.5s	3.6	50
177	41d					17.5-18.5s	4.3	88
178	42a	Pride & Prejudice (T4)		0:10-0:29s	7.5	0.0-1.0s	4.8	100
179	42b					1.0-2.0s	4.3	88
180	42c					2.0-3.0s	4.3	100
181	42d					3.0-4.0s	4.6	100
182	42e					4.0-5.0s	4.5	100
183	42f					9-10s	4.4	100
184	42g					10-11s	4.5	88
185	42h					11-12s	4.3	88
186	42i					15.5-16.5s	4.3	100
187	42j					17-18s	4.6	88
188	43a	Dances with Wolves (T10)		1:33-1:51s	6.2	8.0-9.0s	3.4	38
189	43b					13.5-14.5s	4.3	100
190	43c					14.5-15.5s	3.8	63
191	44a	Juha (T5)		0:29-0:43s	4.2	0.0-1.0s	3.8	63
192	44c					6.5-7.5s	4.3	88
193	44d					10.5-11.5s	3.4	38
194	46a	The Omen (T9)		0:00-0:24s	4.4	1.0-2.0s	3.9	88
195	46b					2.0-3.0s	3.6	75
196	46c					6.5-7.5s	3.8	75
197	46d					12.5-13.5s	3.4	38
198	47a	Juha (T2)	Low tension	2:11-2:26s	4.8	0.5-1.5s	4.0	75
199	47b					2.0-3.0s	4.0	75

200	48a	Grizzly Man (T2)		0:00-3.50s	3.5	0.5-1.5s	3.5	50
1	101a	The Four Feathers (T10)	Sad	1:15-1:34s	7.7	0.5-1.5s	2.0	88
2	101b					2.5-3.5s	1.5	100
3	101c					4.0-5.0s	2.0	88
4	101d					5.5-6.5s	2.0	75
5	101e					7.0-8.0s	2.4	50
6	101f					9.0-10s	2.1	75
7	101g					10.5-11.5s	2.1	75
8	101h					14.5-15.5s	1.9	88
9	101i					16-17s	1.9	100
10	102a	The English Patient (T18)		0:07-0:32s	7.5	0.5-1.5s	1.4	100
11	102b					2.5-3.5s	2.5	63
12	102c					8.5-9.5s	1.8	88
13	102d					9.5-10.5s	2.0	88
14	102e					10.5-11.5s	2.1	75
15	102f					11.5-12.5s	1.4	100
16	102g					13-14s	1.4	100
17	102h					17.5-18.5s	1.6	88
18	102i					20.5-21.5s	1.8	100
19	102j					23-24s	1.4	100
20	103a	The English Patient (T10)		0:24-0:52s	7.5	2.0-3.0s	2.1	75
21	103c					5.5-6.5s	1.9	100
22	103d					8.5-9.5s	2.0	100
23	103e					9.5-10.5s	2.1	88
24	103f					13-14s	2.0	100
25	103g					14.5-15.5s	2.1	75
26	103h					17-18s	2.0	100
27	103i					19-20s	2.1	88
28	103j					20-21s	2.0	88
29	103k					21-22s	2.3	75
30	103l					22.5-23.5s	1.9	88
31	103m					24-25s	1.6	100
32	103n					26.5-27.5s	2.0	88
33	104a	Band of Brothers (T12)		1:09-1:26s	7.3	0.5-1.5s	2.4	75
34	104b					3.0-4.0s	2.0	75
35	104c					6.0-7.0s	1.4	88
36	104d					11-12s	2.6	63
37	104e					14-15s	1.9	88
38	104f					15.5-16.5s	1.6	100
39	105b	Nostradamus (T20)		1:35-1:52s	7.2	2.0-3.0s	2.5	63

40	105f					10-11s	2.4	57
41	106a	Running Scared (T15)		2:06-2:27s	7.0	3.5-4.5s	1.6	88
42	106b					10.5-11.5s	1.4	100
43	106c					12.5-13.5s	1.6	100
44	106d					15-16s	2.0	75
45	106e					19-20s	1.8	100
46	107a	Psycho (T3)		0:58-1:24s	6.5	1.0-2.0s	1.9	100
47	107b					4.5-5.5s	2.4	50
48	107c					8.0-9.0s	1.8	88
49	107d					10.5-11.5s	2.1	75
50	107e					13-14s	2.1	75
51	107f					16-17s	2.1	75
52	107g					22-23s	1.8	75
53	108b	Big Fish (T15)		0:55-1:11s	6.5	2.5-3.5s	2.0	100
54	108c					4.0-5.0s	1.9	100
55	108d					5.5-6.5s	1.9	100
56	108e					7.0-8.0s	2.3	75
57	108f					9.0-10s	1.9	100
58	108g					11-12s	1.9	88
59	109a	Man of Galilee CD1 (T8)		1:20-1:37s	6.2	0.5-1.5s	2.5	63
60	109b					2.0-3.0s	2.3	75
61	109c					4.5-5.5s	2.6	50
62	109d					5.5-6.5	2.1	75
63	109f					8.5-9.5	2.5	50
64	109g					10-11s	2.0	88
65	109h					11.5-12.5s	2.5	63
66	109i					12.5-13.5s	1.9	88
67	109j					14-15s	2.0	63
68	110a	Big Fish (T22)		0.00-0:20s	6.2	1.0-2.0s	1.9	100
69	110b					2.5-3.5s	1.8	88
70	110c					9.0-10s	1.5	100
71	110d					13-14s	1.8	100
72	110e					17-18s	1.8	88
73	110f					19-20s	2.5	50
74	111a	The Untouchables (T4)		0:40-0:55s	6.0	0.5-1.5s	2.0	88
75	111b					2.0-3.0s	1.8	100
76	111c					3.5-4.5s	1.5	100
77	111d					7.5-8.5s	2.3	88
78	111e					11.5-12.5s	2.1	88
79	112a	Gladiator (T4)		0:48-1:06s	5.8	0.5-1.5s	1.6	88

80	112b					3.5-4.5s	2.6	50
81	113a	Gladiator (T14)		1:38-2:02s	5.8	0.0-1.0s	1.9	100
82	113b					2.5-3.5s	2.6	50
83	113e					13-14s	2.4	63
84	113g					22-23s	2.1	75
85	114a	Big Fish (T15)		0:02-0:17s	5.8	0.5-1.5s	1.9	88
86	114b					3.0-4.0s	2.1	88
87	114c					4.0-5.0s	2.1	88
88	114d					6.0-7.0s	2.4	63
89	114e					7.5-8.5s	1.6	100
90	114f					11-12s	1.8	100
91	114g					14-15s	2.4	63
92	114h					15.5-16.5s	2.3	50
93	114i					17-18s	1.9	100
94	114j					18-19s	1.9	100
95	115a	Road to Perdition (T22)		0:17-0:32s	5.3	0.0-1.0s	2.1	88
96	115b					1.0-2.0s	2.1	75
97	115c					8.0-9.0s	2.3	75
98	115d					9.0-10s	2.1	88
99	116a	The Rainmaker (T11)		0:37-0:57s	5.0	1.0-2.0s	2.3	63
100	116b					4.0-5.0s	2.1	63
101	116c					5.5-6.5s	1.9	100
102	116d					8.0-9.0s	1.5	100
103	116e					19-20s	2.1	75
104	117a	Band of Brothers (T3)		7:43-7:58s	5.0	0.5-1.5s	1.5	100
105	117b					1.5-2.5s	1.8	100
106	117c					5-6s	1.6	100
107	117d					6.5-7.5s	1.5	100
108	117e					10-11s	1.6	100
109	117f					11.5-12.5s	1.6	100
110	118a	The Missing (T2)		2:31-2:48s	4.6	4.5-5.5s	2.4	63
111	118b					5.5-6.5s	1.9	71
112	118d					10.5-11.5s	2.0	88
113	118f					16-17s	2.1	63
114	119a	Shakespeare in Love (T3)		0:59-1:17s	4.0	4.5-5.5s	1.6	88
115	119b					6.0-7.0s	2.4	75
116	119c					7.5-8.5s	1.8	88
117	119d					9.0-10s	2.0	88
118	119e					11-12s	4.1	100
119	119f					14-15s	2.4	50

120	120a	Shine (T18)		0:43-1:07s	3.8	2.0-3.0s	2.3	75
121	120b					4.5-5.5s	2.1	88
122	120c					8.5-9.5s	1.9	75
123	120d					13.5-14.5s	1.6	100
124	120e					18-19s	2.3	75
125	121b					4.5-5.5s	2.3	50
126	122a	Road to Perdition (T8)		0:38-0:53s	3.0	0.0-1.0s	1.6	100
127	122b					5.5-6.5s	2.3	63
128	125a	Shine (T28)		1:24-1:43s	1.0	0.5-1.5s	1.9	88
129	125c					4.0-5.0s	2.8	38
130	125d					9.5-10.5s	2.1	75
131	126a	The Fifth Element (T24)	High valence	1:39-2:03s	4.4	1.5-2.5s	2.3	63
132	126b					3.5-4.5s	1.6	100
133	126c					6.0-7.0s	1.9	88
134	126d					7.0-8.0s	2.3	63
135	126e					9.5-10.5s	2.3	75
136	126f					16-17s	2.4	75
137	126g					19.5-20.5s	2.0	88
138	127b					4.5-5.5s	2.3	75
139	128a	Mother of Mine (T1)		1:31-1:49s	2.8	3.0-4.0s	2.4	75
140	128b					4.0-5.0s	2.4	75
141	128c					8.0-9.0s	2.1	75
142	128d					10-11s	1.8	100
143	128e					12-13s	2.1	88
144	128f					16-17s	2.1	88
145	129a	Blanc (T12)		0:51-1:06s	2.5	4.0-5.0s	1.6	100
146	129b					6.0-7.0s	2.1	88
147	129c					9.5-10.5s	2.4	63
148	129d					11.5-12.5s	1.9	100
149	129f					14-15s	2.3	63
150	130a	Pride & Prejudice (T9)		0.01-0:21s	3.8	3.0-4.0s	2.5	50
151	130b					4.5-5.5s	2.3	75
152	130c					6.0-7.0s	2.1	75
153	130d					9.0-10s	2.3	75
154	130e					11-12s	2.0	88
155	130f					12.5-13.5s	2.3	75
156	130h					18-19s	2.3	75
157	134a	Mother of Mine (T4)		0:11-0:25s	5.7	0.0-1.0s	1.5	100
158	134b					2.5-3.5s	1.1	100
159	134c					3.5-4.5s	2.3	63

160	134d					5.0-6.0s	2.1	88
161	134e					9.0-10s	2.1	88
162	134f					10.5-11.5s	1.3	100
163	135a	The Omen (T2)		0:16-0:33s	1.0	3.5-4.5s	2.5	63
164	135c					8.5-9.5s	2.1	63
165	136a	Crouching Tiger, Hidden Dragon (T2)		1:40-1:57s	4.0	0.0-1.0s	1.9	88
166	136b					1.5-2.5s	2.6	50
167	136d					5.0-6.0s	2.6	50
168	136e					8.5-9.5s	2.6	50
169	136f					10.5-11.5s	2.4	63
170	136g					12-13s	1.9	100
171	136h					14.5-15.5s	1.9	100
172	137a	Blanc (T9)		0:17-0:35s	4.0	0.5-1.5s	1.9	63
173	137b					2.0-3.0s	1.4	88
174	137e					6.0-7.0s	2.5	75
175	137g					12.5-13.5s	2.9	50
176	137h					16-17s	2.6	50
177	138a	Crouching Tiger, Hidden Dragon (T13)		0:35-0:49s	4.6	1.0-2.0s	2.1	75
178	138b					3.5-4.5s	2.1	88
179	138c					6.0-7.0s	2.0	88
180	138d					10.5-11.5s	2.1	75
181	138e					12-13s	1.9	75
182	139a	Crouching Tiger, Hidden Dragon (T13)		1:52-2:10s	5.7	2.5-3.5s	2.6	50
183	139d					12-13s	1.8	88
184	140a	Blanc (T21)	High energy	0:04-0:17s	4.0	0.5-1.5s	2.6	50
185	141a	Pride & Prejudice (T15)	Low energy	1:18-1:33s	6.0	6.5-7.5s	1.3	100
186	141b					8.0-9.0s	1.5	88
187	141c					10-11s	1.6	100
188	141d					14-15s	2.1	75
189	142a	JFK (T11)		0:00-0:16s	5.8	1.0-2.0s	1.8	88
190	142b					4.5-5.5s	2.5	50
191	142c					15.5-16.5s	2.3	50
192	143a	The Last Samurai (T1)		0:05-0:29s	4.7	0.0-1.0s	1.8	100
193	143b					2.5-3.5s	2.3	88
194	143c					6.5-7.5s	1.8	100
195	143d					8.5-9.5s	1.8	100
196	143e					14.5-15.5s	2.1	88
197	144a	The Portrait of a Lady (T9)		0:00-0:22s	6.8	4.0-5.0s	1.6	100
198	144b					5.5-6.5s	1.6	100

199 200	144c 144d					14.5-15.5s 18-19s	2.1 1.8	75 100

* Original ratings: rated on a scale of 1 (low) to 7 (high) emotions expressed (Eerola &Vuoskoski, 2011).

**Thesis focus group ratings: rated on a scale of 1 (very sad) to 5 (very happy).

APPENDIX B:

EXPERIMENTAL FORMS

SCREENING FORM

Study # ____ Participant code: ______ Date of birth: ______ Test date: ______

Handedness: Right Left Ambidextrous Sex: Male Female

Highest level of education:

Languages in order of fluency:
1.________________2.________________3._______________4._______________

If English is not your first language: How old were you when you learned English?_______

If you were not born in Canada: How old were you when you moved to Canada?_________

History of substance abuse:
____

Is your hearing and vision normal? Yes No

If not, please describe: ____

Have you ever had any perceptual (colour blindness) learning/language problems? Yes No

If yes, please describe (age, length, recovery): _________________________________

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

If yes, please describe (age, length, recovery):__________________________________

Have you ever had a head injury, seizures, coordination problems/major surgeries? Yes No

If yes, please describe (age, length, recovery):__________________________________

Have you ever lost consciousness, had any fainting spells, paralysis or dizziness? Yes No

If yes, when and for how long? ____

Are you presently taking any medication? Yes No

If yes, which one(s)?____

Have you recently taken any medication? Yes No

If yes, which one(s), and when?____

Do you consume the following?

	Yes/No	How often?
Alcohol		
Cigarettes		
Drugs		

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

If yes, please specify:____

Have you consumed any 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?_____

EDINBURGH HANDEDNESS INVENTORY (Oldfield, 1971)

Please indicate your preference in the use of hands in the following activities by listing the "+" in the appropriate columns. When the preference is so strong that you would never try to use the other hand unless absolutely forced to, list "++". If, in any case you really are indifferent, put "+" in both columns. Some of the activities require both hands. In these cases, the part of the task or object, for which the preference is warranted is indicated in brackets. Please try to answer all the questions, and only leave the column blank if you have no experience at all of the object of the task.

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

Score = (Total left_____+ Total right_____)*100 = ____________________

PANAS (Watson, Clark & Tellegen, 1988)

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark one appropriate answer in the space next to that word. Indicate to what extent you feel this way right *now*, that is, *at the present moment*. Use the following options to record your answers.

1. Very slightly, or not at all

2. A little

3. Moderately

4. Quite a bit

5. Very much

Interested	Irritable
Distressed	Alert
Excited	Ashamed
Upset	Inspired
Strong	Nervous
Guilty	Determined
Scared	Attentive
Hostile	Jittery
Enthusiastic	Active
Proud	Afraid

AIMS (Sandstrom & Russo, 2011)

Indicate how much you agree or disagree with each statement by using one of the following options to record your answers. Choose option 3 (‘Neither agree nor disagree’) only if you are really unable to assess the sentence/experience.

1. Strongly disagree
2. Disagree
3. Neither agree nor disagree
4. Agree
5. Strongly agree

---

1. I will sometimes move my hand as if I were 'conducting' music
2. When listening to music, I sometimes temporarily forget where I am
3. I sometimes feel like I am 'one' with the music
4. When I listen to music I can get so caught up in it that I don't notice anything
5. When I feel that nobody understands me, I often turn on some music
6. I will stop everything that I'm doing in order to listen to a special song/piece of music that is playing
7. I can imagine a song/piece of music so vividly that it holds my attention as if I were hearing it live
8. When I hear good music I tend to lose my train of thought and forget what I was thinking about
9. Sometimes when listening to music I feel as if my mind can understand the whole world
10. I sometimes feel that I understand the songwriter/composer's intentions completely
11. I can change almost any sound into music by the way I listen to it
12. I have stopped walking to listen to music that I came across on my path
13. While listening to music, I may become so involved that I may forget about myself and my surroundings
14. If I want to feel creative, I will turn on some music

15. It is sometimes possible for me to be completely immersed in music and to feel as if my whole state of consciousness has been temporarily altered
16. I know what people mean when they talk about mind-altering musical experiences
17. At times when listening to music, I feel more connected with other people
18. I find that different sound have different colors (e.g., red, blue)
19. I spend as much time as I can every day listening to music
20. Sometimes music makes me feel and experience things as I did when I was a child
21. Sometimes I almost feel as if a song was written especially for/about me
22. I sometimes make my movements/actions (opening doors, pushing buttons, stepping of curbs) coincide with the music
23. I like to find patterns in everyday sounds
24. When listening to music I can lose all sense of time
25. Before I do an activity (e.g., exercise, study), I usually carefully consider what music to play along with it
26. The sound of a speaking voice can be so fascinating to me that I can just go on listening to it
27. Music sometimes helps me 'step outside' my usual self and experience an entirely different state of being
28. When listening to music, I often imagine the musicians playing the songs
29. When listening to great music I sometimes feel as if I am being lifted into the air
30. When I am listening to music, I can tune out everything else
31. I sometimes see vivid images in my head when I listen to music
32. I sometimes close my eyes so I can focus on the music I am listening to
33. There are times when I will do nothing except listen to music
34. I sometimes feel like I'm part of something bigger than myself when I listen to music.

OMSI (Ollen, 2006).

1. How old are you today? _____ age in years

2. At what age did you begin sustained musical activity? “Sustained musical activity” might include regular music lessons or daily musical practice that lasted for at least three consecutive years. *If you have never been musically active for a sustained time period, answer with zero.*
____ age at start of sustained musical activity

3. How many years of private music lessons have you received? *If you have received lessons on more than one instrument, including voice, give the number of years for the one instrument/voice you've studied longest. If you have never received private lessons, answer with zero.*
_____ years of private lessons

4. For how many years have you engaged in regular, daily practice of a musical instrument or singing? “Daily” can be defined as 5 to 7 days per week. A “year” can be defined as 10 to 12 months. *If you have never practiced regularly, or have practiced regularly for fewer than 10 months, answer with zero.*
_____ years of regular practice

5. Which category comes nearest to the amount of time you currently spend practicing an instrument (or voice)? Count individual practice time only; not group rehearsals.

□I rarely or never practice singing or playing an instrument
□About 1 hour per month
□About 1 hour per week
□About 15 minutes per day
□About 1 hour per day
□More than 2 hours per day

6. Have you ever enrolled in any music courses offered at college (or university)?

□No ˙ (Skip to #8)
□Yes

7. (If Yes) How much college-level coursework in music have you completed? *If more than one category applies, select your most recently completed level.*

□None
□1 or 2 non-major courses (e.g., music appreciation, playing or singing in an ensemble)

□3 or more courses for non-majors
□An introductory or preparatory music program for Bachelor's level work
□1 year of full-time coursework in a Bachelor of Music degree program (or equivalent)
□2 years of full-time coursework in a Bachelor of Music degree program (or equivalent)
□3 or more years of full-time coursework in a Bachelor of Music degree program (or equivalent)
□Completion of a Bachelor of Music degree program (or equivalent)
□One or more graduate-level music courses or degrees

8. Which option best describes your experience at composing music?

□Have never composed any music
□Have composed bits and pieces, but have never completed a piece of music
□Have composed one or more complete pieces, but none have been performed
□Have composed pieces as assignments or projects for one or more music classes; one or more of my pieces have been performed and/or recorded within the context of my educational environment
□Have composed pieces that have been performed for a local audience
□Have composed pieces that have been performed for a regional or national audience (e.g., nationally known performer or ensemble, major concert venue, broadly distributed recording)

9. To the best of your memory, how many live concerts (of any style, with free or paid admission) have you attended as an audience member in the past 12 months? Please do not include regular religious services in your count, but you may include special musical productions or events.

□None
□1 - 4
□5 - 8
□9 - 12
□13 or more

10. Which title best describes you?

□Non-musician
□Music-loving non-musician
□Amateur musician
□Serious amateur musician
□Semi-professional musician
□Professional musician

DEBRIEFING SHEET

Study #_________ Participant #________

TASK PERFORMANCE

- How did you find the task? Were you able to think clearly or were you rushed?
- Did you find one was easier than the other? If so, why? If the order was reversed, would it have made a difference?
- Were the stimuli clear? Did you encounter any difficulties or distractions that affected your task performance?
- Did you develop any strategies during the tasks? Were they effective?
- Were any of the musical excerpts familiar to you? Did you have a strong preference or dislike to it? If yes, do you think it affected your performance?
- Did you feel the emotion or just recognize it?
- Are you a more of a visual or auditory person?
- Is there anything that could have been changed to help you perform better?

MUSIC BACKGROUND & RESPONSE (Adapted from Allen, 2010).

- How often do you listen to music? How good are you at recognizing emotions expressed in music?
- What is it about music that makes you listen to it – what does it do for you?
- How often do you watch movies? Do you like watching movies and why?

- Do you see images when you listen to music (e.g. landscapes, shapes, people, colours)?
- How important are song lyrics to you, as opposed to the music?
- Does music make you feel emotional (e.g. happy, sad)?
- What is it about the music that makes you feel like that?
- Do you find different genres of music (e.g. jazz, rock, pop, etc) make you feel these things more than the other? Do you have a music genre preference? Would this preference have made a difference in your performance?
- If you watch a movie that was supposed to be sad, would it be less sad if you watched it without the music? Would it be the same if it was happy?
- Does music ever help you understand what was going on in films or TV?
- If you were feeling happy and heard sad music, would it change your mood? What if you were feeling sad and heard happy music?
- Do you have any music piece that you associate with something happy or sad that happened in the past? Or reminds you of someone? Why?
- Do you play any instruments, sing or dance? If yes, since when/how long/frequency/class type?
- Are you an emotional person? Introspective or empathetic?
- Do you have any further questions?