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MISMATCH NEGATIVITY IN MUSICAL CONTEXT

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Auditorinen poikkeavuusnegatiivisuus on elektroenkefalografilla (EEG) mitattavissa oleva negatiivinen aivovaste, jonka ajatellaan toimivan merkkinä aivojen suorittamalle automaattiselle äänenerottelulle. Tässä tutkielmassa esitellään lyhyesti poikkeavuusnegatiivisuus eri modaliteeteissa, sen neuraalisten generaattorien sijainti aivoissa, poikkeavuusnegatiivisuuden syntyyn liittyviä hypoteeseja sekä kuinka sitä voidaan mitata. Teoreettisen osuuden lisäksi tutkielmassa järjestettiin käytännön koe, josta muodostui myös käytännön pohja tieteelliselle tutkimukselle. Kokeeseen osallistui 11 minimaalisen tai amatööritason musikaalisen osaamisen omaavaa osallistujaa. Heidän aivotoimintaa mitattiin EEG-laitteella, tarkoituksena selvittää havaitseeko poikkeavuusnegatiivisuusmekanismi eri tasoisilla voimakkuuksilla moduloidut poikkeavat ärsykkeet ns. vakioärsykkeistä. Osallistujille esitetyt poikkeavat ärsykkeet poikkesivat vakioärsykkeistä kuudella eri tavalla, joista jokainen esitettiin kolmella eri voimakkuustasolla: sävelkorkeus, sijainti, voimakkuus, “slide”, äänivári ja rytmi. Kokeessa osoitettiin, että sävelkorkeuden, sijainnin, voimakkuuden ja “slide”:n osalta aivovasteet poikkesivat tilastollisesti merkittävästi vakioärsykkeistä.

Asiasanat: MMN, poikkeavuusnegatiivisuus, aivot, musikaalisuus

ABSTRACT

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Auditory mismatch negativity is a negative component measurable with electroencephalography (EEG) and is considered to be a marker for automatic sound discrimination. This thesis includes a brief introduction to mismatch negativity in different modalities, location of its neural generators within the brain, the different hypotheses behind MMN function and how MMN can be measured. In addition to the theoretical part, a practical study was conducted, which also became the experimental base for a scientific paper. The experiment consisted of 11 participants with minimal or amateur level musical skills. The participants' brain activity was measured with an EEG device to find out whether MMN correlates with levels of deviation presented to the participants. The deviants presented consisted of six types of deviance, each presented in three intensity levels: pitch, location, intensity, slide, timbre and rhythm. It was shown that pitch, location, intensity and slide differed significantly in all intensity levels from the standards.

Keywords: MMN, mismatch negativity, brains, musicality

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1 Introduction

There are numeral ways of measuring musicality or musical competence in people, most of them relying on subjective rating of teachers or other professionals. Usually these tests need to be taken when applying into music schools and such. This kind of tests are also susceptible to environmental and psychological noise, since not all variables within a test scenario can be controlled. For example, anxiety and the general state of mind might have negative impact on test results, even when the person has all the required qualifications. Thus, an objective way of measurement is needed.

The solution might be found via the mismatch negativity (MMN), a brain response measured by electroencephalography (EEG). It has been shown to indicate objectively the sound-discrimination accuracy of the brain (Näätänen et al. 2004). Mismatch negativity occurs when the underlying temporo-frontal neural network detects a difference in an incoming sound train. As an example, if a subject is presented three beeps, first two of them having the same frequency and the third beep having a different frequency. When the third beep is presented, the neural mechanism reacts to this difference automatically and elicits an MMN response.

Researching mismatch negativity in the context of music is not limited to only as a tool for indexing academic musical competence, as MMN has been shown to have clinical applications as well. Normal aging causes cognitive decline due to the cytological changes within the brain, affecting the efficacy of neural communication (Peters, 2002). Psychopathologies such as schizophrenia, major depressive disorder and Alzheimer’s disease are the result of abnormal changes in the neural circuitry. Research shows mismatch negativity to be modulated as a function of cognitive decline. This means that measuring MMN from patients could be used as a tool for diagnosing different brain related disorders, or even help preventing them before they manifest (e.g. Tsolaki et al. 2015; Fryer, 2020). In addition, psychopharmacological studies indicate that MMN is diminished or enhanced by certain drugs, so it has a potential use in the development of medical therapies as well (Javitt et al. 1996).

Whilst a variety of imaging techniques exist today, the use of EEG has the benefit of being relatively cost effective tool for measuring brain activity. As with most things in life, it has its downsides as well. Since EEG is measured from the scalp, it has the unfortunate effect of measuring large clusters of neurons with each signal interfering with each other. In addition, as the brain is not a smooth surface, but a complex topography of ridges (gyri) and depressions (sulci), the EEG measures voltage differences between electrodes, signals originating in the contours of the brain are difficult to measure, without the help of mathematical modeling or complementary imaging techniques. Furthermore, the skull and meninges (membranes between the skull and brain) attenuate and diffuse neural signals as the EEG measures voltages from the scalp.

In order to get clear signals from participants of a study, or patients, several measurements need to be made of the same stimuli per person. This leads to longer studies, which in turn affects the usefulness of the technique, especially with participants that are easily frustrated or have some form of neural dysfunction. For this reason, having the study length as short as possible or as pleasant as possible is a desirable goal. Musically rich stimuli could make sessions more enjoyable than using just pure tones.

The purpose of this thesis is to present a short introduction to the literature to accompany an empirical EEG study. The EEG study presented here is a continuation of study by Vuust et al. (2011) and is the experimental part of Vuust et al. (2016). In the experiment, we attempt to find out whether the MMN mechanism is able to differentiate between levels of deviation in the musical stimuli presented to the participants by comparing resulting brain responses.

This thesis consists of two main parts; the first one considers the theoretical aspects of mismatch negativity; the neural underpinnings of MMN are explored and methods on how it can be measured are presented, whilst addressing the complications described above. This is accompanied with a brief review of mismatch negativity in other modalities, and offer a glimpse to other music related MMN studies. The second part presents the experiment in accordance with the theoretical part, with results that are comparable with stimuli that are more traditional.

2 Mismatch Negativity

In the 1970's, Hillyard and Picton (1978) observed, that in some cases the N1 brain response, that occurs within the auditory cortex whenever an unexpected auditory input is perceived, is enhanced. This study led Näätänen et al. (1978) to conduct experiments with similar, albeit not identical parameters. These experiments indicated that the enhanced N1 Hillyard and Picton (1978) found were in reality a separate process from the N1 response; that response is known today as the mismatch negativity (MMN).

The mismatch negativity is an event-related potential (ERP) that occurs when the underlying temporo-prefrontal mechanism detects a deviation in an incoming sound train, peaking at 100-250ms from change onset. The degree of change is reflected on the MMN amplitude and latency; larger difference in the stimuli lead to lower latency and higher amplitude. It is largely automatic pre-attentive process, which also has been shown to be sensitive to training (Pakarinen et al. 2007). Due to these qualities, it is thought to be a measure of auditory discrimination accuracy and to be usable in practical applications.

In order for the MMN mechanism to work, two different types of stimuli are required, called standard and deviant. Standard is some form of auditory stimulus that the mechanism has "learned", whilst deviant is a stimulus that is in some manner different from the standard. The MMN mechanism is sensitive to changes in several different spectral characteristics. Modulation of either the time or the frequency components of sound stimuli elicit MMN, as does the complete omission of a stimulus. In addition to simpler forms of stimulus invariance, such as changing the pitch, more complex forms of invariance also elicit MMN. This means that the comparison is not done only on simple tones, but even musical melodies or rhythmic pattern elicit an MMN. (Näätänen et al. 2007).

Furthermore, MMN has been studied in other modalities as well, albeit in lesser extent. For example, in the visual modality, the difficulty has been establishing such experimental settings, in which confounding effects from attention or neural refractoriness can be controlled. Nevertheless, evidence is mounting (i.e. Stefanics et al. 2015).

2.1 Cerebral sources of MMN generators

Source localization of ERPs is the activity of mapping the location of brain activity within the brain tissue. It might seem like a trivial task to do, but it is nothing of the sort; for example techniques employing positron emission tomography (PET) or functional magnetic resonance imaging (fMRI) can achieve good spatial accuracy, but have limited temporal resolution and are rather expensive techniques. Temporal resolution is critical when measuring ERPs in the sub-second scale. The other limiting factor is that they do not measure the electrical activity of the neurons directly. These techniques rely on the fact that more brain activity consumes more oxygen, and from this fact one can then approximate brain activity in the brain by measuring the amount of oxygen in the blood vessels supplying blood to the neurons.

Magnetoencephalography (MEG) and electroencephalography (EEG) on the other hand provide superior temporal resolution and measure electrical activity directly. As the flipside of the coin, they lack in spatial resolution. They both also suffer from the inverse problem. As the data is measured from outside the head, location of the activity must be inferred from the data, which is problematic, as there exists infinite number of solutions that match the data. Recent mathematical techniques such as low-resolution electromagnetic tomography (LORETA) and its standardized variant sLORETA by Pascual-Marqui (2002) have been shown to enhance localization capability of EEG and MEG measurements.

Limitations of the imaging and measuring techniques are not the only hindrances in pinpointing the sources, as it has been shown that for example age, musical skills and cognitive impairments have effects on amplitudes and latencies of MMN ERPs. Age and certain psychopathologies, such as schizophrenia, also affect the localization of MMN (see: Tsolaki et al. 2015; Tsolaki et al. 2017, Näätänen et al. 2014, Rentzsch et al. 2015).

2.1.1 Temporal and frontal generators of MMN

A study by Rinne et al. (2000) made use of both EEG and MEG to measure MMN providing evidence for the notion that MMN is comprised of two different functional processes: temporal generators associated with sensory memory as the auditory cortex is located on the temporal lobe and an attention-switching process at frontal generators. Marco-Pallarés et al. (2005) utilized independent component analysis combined with LORETA providing support for six independent components relating to MMN. They reported sources at supratemporal and middle temporal cortex, right inferior frontal cortex, medial frontal cortex, cingulate cortex and right inferior parietal cortex. In addition, ERPs recorded from the frontal areas occur later than the temporal ERPs, which supports the notion that the comparison of sounds is done by the frontal areas. Support for at least two possible subcomponents of the MMN in the frontal areas has also been found via combined fMRI-EEG studies (Garrido et al. 2009). Lappe et al. (2013) used musical sequences for source localization of MMNn generators using a beamforming technique, which uses a mathematical model to combine results acquired with MEG and MRI scans. Their results also back the idea of frontal and temporal sources, with temporal sources having also a lower latency.

Involvement of prefrontal generators in MMN is supported by clinical studies, where patients with prefrontal lesions have had attenuated MMN responses (Alho et al. 1994). Tract-tracing study on primates made by Romanski et al. (1999) have found two-way neuronal connections between the prefrontal and auditory areas.

2.1.2 Effects of aging and cognitive dysfunction on MMN

As people age, multitude of changes happen in the body and the brain. In the middle ear auditory ossicles, which are the three bones responsible for the conversion of airborne sounds into electrical signals in the inner ear, stiffen with age because of calcification or arthritis. This causes auditory loss, mostly affecting the higher frequencies. Auditory nerve leading from the inner ear to the auditory cortex also degenerates with aging. (Stuart-Hamilton, 2006).

Aging related changes within the cortex are still somewhat unclear; it was long thought that the primary cause for this was the loss of neurons in the cortex, but studies have indicated that, whilst loss of cells does occur with aging, it cannot conclusively explain the cognitive decline (Morrison and Hof, 1997). Changes in the nerve fibers, the neuronal axons that deliver signals between neurons, have been found to be a contributing factor. Demyelination, the thinning of the protective myelin sheaths of these said axons affect signal conductivity by either slowing down or completely disrupting signals (Peters, 2002).

Although the effects of specific age-related cytological changes are still largely unknown, it has been observed that MMN is sensitive to aging; both latency and amplitude of MMN are affected as the person ages (see. Cheng et al. 2013; Tsolaki et al. 2015). In addition to normal aging related decline, e.g. patients diagnosed with mild cognitive impairment, Alzheimer’s disease or multiple sclerosis (MS) show a noticeable decline in MMN as a function of disease progression. Jung et al. (2006) compared auditory ERPs of MS patients and controls, with an additional comparison of patients with cognitive impairments and unimpaired patients. They found out that MS patients in general have reduced MMN components and patients who in addition exhibit cognitive impairments having a more pronounced reduction. Tsolaki et al. (2017) on the other hand did a three-way comparison between controls, patients with mild cognitive impairment (MCI) and patients diagnosed with Alzheimer’s disease. MCI is considered to be a transitive state between normal aging and dementia. Latencies and amplitudes of MMN were observed to be modulated by disease progression, albeit amplitude reduction did not reach statistical significance.

Another noticeable finding was that MMN source localization appears to change between healthy individuals and AD patients, although did not appear to correlate with disease progression as MCI patients had virtually identical localization as the controls.

Interest have been shown also towards utilizing ERPs such as the MMN for studying how psychotic disorders like schizophrenia develops. A study by Rentzsch et al. (2015) compared healthy controls with patients diagnosed with schizophrenia using predictive coding framework as an explanatory factor. According to the predictive coding framework, whenever the same stimulus is repeated often, the underlying neuronal apparatus' prediction gets increasingly accurate, or conversely its prediction error lessens; this is called repetition suppression. They used P50, N100 and P200 ERPs as indices for RS and correlated them with MMN. It was found that in healthy controls MMN and RS have a significant correlation, but no correlation on patients.

Similarly, Fryer (2020) used predictive framework as a basis to find out whether MMN, or more specifically its subcomponent, repetition positivity (RP), can function as an index for development of psychosis risk syndrome (PRS). Repetition positivity reflects the strengthening of a memory trace of a standard stimulus and prediction accuracy of the system. They compared healthy controls with participants meeting criteria with developing PRS. Results indicate that PRS individuals have in general reduced RP responses in comparison to the controls, with indication that psychosis onset is faster with more pronounced reduction of RP. They conclude that RP in itself, or in addition to traditional MMN, could act as a biomarker of psychosis risk.

2.1.3 MMN in other modalities

Research efforts of mismatch negativity has concentrated on the auditory modality for the past several decades. Naturally, one reason for this is its discovery in the auditory modality, moreover though, the auditory system, has the benefit of not having as strong attentional controls, when compared to the visual system. Attentional controls can have confounding effects especially when attempting to assess the automaticity of neural processes. The auditory cortices also are located beneficially for EEG recording purposes, so getting accurate readings has been more straightforward in auditory modality (Picton et al. 2000).

Today's technology when compared to the 70's or 80's, EEG and other imaging equipment is now more cost effective and more accurate, providing better insight what occurs within the brain. Development of powerful mathematical methods such as LORETA, beamforming, principal component analysis or dynamic causal modeling enable more venues for MMN research in general, as well as help pave the way in MMN research in other modalities.

Visual counterpart, vMMN, has been observed to elicit by changes in color, orientation, movement, spatial frequency, contrast, size and facial emotional expression (Kremláček et al. 2016). Stefanics et al. (2011) in their study controlled the participants attention to a cross located in the center of the visual field and asked to press a button whenever this cross changes its' shape. At the same time around the periphery, eight circles with changing color patterns according to pre-defined rules were shown. They demonstrated that the vMMN mechanism is capable, like the auditory MMN, of detecting rule-based deviances. In an editorial Stefanics et al. (2015) summarize several studies of vMMN, listing the variety of conditions in which vMMN is elicited at latencies between 100ms to 500ms.

Li et al. (2012) performed a study on a related form of vMMN, the expression-MMN (EMMN). EMMN is elicited whenever a change in facial expressions is observed in an unattended condition. They found support that memory based comparison is done when faces with differing facial expressions depicting different emotions and that the comparison is done on facial features specifically and not on primitive types, such as lines or contrasts.

Restuccia et al. (2009) studied somatosensory mismatch negativity in inattentive children. In their preliminary experiments, they found that attention switching related frontal positivity at 300ms latency, named P3a, was elicited, calling suspicion that maybe the deviants were too intense catching the participants' attention. They then decreased the deviant intensity and increased the cognitive load of the primary task, so that P3a contamination does not happen. With their new experimental design, they stimulated electrically the participants' right thumb (the standard) and fifth finger (deviant) at a ratio of 80/20, at an intensity barely above the sensory threshold. The study revealed contralateral negative peaks 160ms and 220ms after stimulus onset, at the parieto-central and frontal areas, respectively. In a study relating to somatosensory stimuli, Hu et al. (2013) experimented with nociception (feeling of pain). They found preliminary support for the idea that nociceptive MMN is distinct from the somatosensory MMN, although they do call for more research on the topic.

By utilizing EEG, study by Krauel et al. (1999) found support for automatic odor discrimination with a negative shift 500-600ms post-stimulus, occurring after olfactory N1 at 400-500ms post-stimulus. Sabri et al. (2005) used fMRI in an olfactory mismatch task to compare olfactory change detection in attentive an inattentive conditions. They found evidence, that posterior orbital and subgenual cingulate may indeed be crucial for inattentive detection of odors via a MMN-like mechanism.

2.2 Underlying mechanisms of MMN

Decades of MMN research have resulted two major hypotheses on how the MMN is generated: model adjustment hypothesis and adaptation hypothesis (Garrido et al. 2009). In addition to these two hypotheses, there is also a compelling alternative that could merge model adjustment and neuronal adaptation into one comprehensive theory: the predictive coding framework (see: Garrido et al. 2008); Garrido et al. 2009; Baldeweg, 2007).

2.2.1 The model adjustment hypothesis

Originally, MMN mechanism was thought to be a change detection system that compares incoming sound stimuli with previous stimuli stored ton an afferent memory trace. This view came under suspicion as it was observed that more complex, even abstract rules elicited MMN. The detection of these complex variances cannot purely rely just on the previous sound traces, but on relationships between the different stimuli; the mechanism was shown to elicit MMN when a regularity was violated, thus leading to the notion of it functioning as a marker for error or difference detection. Idea being that MMN mechanism not only compares incoming sounds, but also generates a model that is used to predict what the next sound input is going to be: whenever the prediction fails, MMN is elicited. In this view, MMN is considered a signal of an online modification of the perceptual model (Garrido et al. 2009).

2.2.2 Neuronal adaptation hypothesis

Jääskeläinen et al. (2004) suggest that MMN is an artifact borne by another, simpler mechanism, namely the N1 response. The N1 response is an early auditory response in the primary auditory cortex, peaking 100ms after stimulus onset. They postulate that in the event of an incoming sound train, the response to the standard stimulus is attenuated and delayed due to slow-lived neuronal adaptation. As the underlying neuronal system has been effectively "trained" to the standard stimulus, any deviant stimulus would cause the network to respond to reset the system to a new default, leading to a normal N1 response. The merits of this theory are in its simplicity, but studies (Garrido et al. 2009) have shown that it does have some issues explaining, e.g. why in some cases N1 is not elicited at all and MMN is. Studies such as Takasago et al. (2020) provide compelling evidence that mechanism generating the N1 differs from MMN. In addition, administration of NMDA antagonists block the formation of MMN, whilst leaving other cortical activity unaffected (Garrido et al. 2009).

2.2.3 Predictive coding framework

In the visual modality Rao and Ballard (1999) introduced a computational model in which there is a two-way connection between hierarchies in the brain. These hierarchies encompass everything from the lower level processes that process visual data to higher level reasoning processes. With their model, each level of hierarchy is reciprocally connected, each level making predictions of neural signals on the lower level and feeding these predictions back. The lower levels in turn compare the actual signal they receive and feedforward the error signal. If the lower level hierarchy detects a mismatch between predicted and the actual signal, the higher-level hierarchy can update its prediction model by incorporating information from the lower level. A review by Rauss et al. (2011) summarizes, that the classic notion of primary visual area V1 acting as only a simple encoder of sensory data, is debatable as it has been shown in multiple studies to act as a flexible top-down modulated processing mechanism.

Cytological studies show that the reciprocal connections between hierarchies differ from each other structurally and functionally; forward connections show less axonal bifurcation and higher level of topographical organization, with backwards connections having increased axonal bifurcation and are less topographically organized. In addition backwards connections are more abundant than forward connections. Connections also behave differently functionally, with forward connections constantly eliciting responses and backward connections appearing to modulate the lower hierarchy neurons that have forward connections. Furthermore, it has also been shown that the forward connections mediate the post-synaptic connections via GABA and AMPA receptors, whilst the backwards connections are mediated via NMDA receptors (Friston, 2003).

The predictive coding framework in the context of auditory MMN incorporates the core ideas of the model adjustment hypothesis and neuronal adaptation. From the predictive coding perspective, model adjustment hypothesis is a natural part of predictive coding; MMN acts a marker reflecting that the underlying neuronal system is updating the perceptual model and signaling for error. In other words, hierarchical top-down modulation from the frontal generators down to the temporal auditory cortex. Whenever prediction of sensory data is correctly predicted, the post-synaptic sensitivity is decreased by means of plastic adaptation of synaptic connections (Garrido et al. 2009).

Psychopharmacological studies, in which subjects are administered NMDA antagonists show diminished MMN responses (see: Javitt et al. 1996; Heekeren et al. 2008), but have no effect on other AEPs, results that both fit to the cytological studies and within the predictive coding framework.

2.3 Measurement paradigms

Measuring MMNs, or any kind of ERPs for that matter, from the scalp with EEG requires enough repetitions for each condition, as the signals on their own are too weak. By averaging several repetitions, the signal can be separated from noise, although at a cost of longer experiments. Pioneering work such as the ones from Hillyard and Picton (1978) and Näätänen et al. (1978) employed a simple oddball type paradigm in which only one type of deviance was used. Whilst the oddball paradigm is scientifically sound, only on type of deviance can be measured per session with this paradigm, thus lending itself to very long sessions.

Cowan et al. (1993) introduced the roving paradigm to establish that the MMN mechanism needs to have the concept of a standard tone to be saved in memory. In the roving paradigm there is no standards per se, but instead the deviant sound can become a standard by repetition. The first deviance will elicit an MMN, since the deviant differs from the previously played sound, but as the deviant is repeated, the underlying system "learns" to use it as a point of comparison, thus acting like a standard.

In a pursuit of leaner and faster experiments, Näätänen et al. (2004) presented Optimum-1 paradigm, in which every other tone is a standard, and every other is a deviant sound of different type (relative to previous deviant). With this method, several types of deviants can be measured within the same session. Compared to the oddball paradigm, the Optimum-1 paradigm resulted in comparable latencies and amplitudes, within a considerably smaller timeframe: the Optimum-1 paradigm took only 15 minutes whilst oddball took 75 minutes. Shortening the session time not only helps conducting research, but also enables the use of MMN measurement in clinical settings, where longer studies can be problematic.

The fast multi-feature MMN paradigm by Vuust et al. (2011), which the experimental part of this paper focuses on, uses a variation of the Optimum-1 by presenting the stimuli in a musical context, more specifically in an Alberti bass configuration.

2.3.1 MMN parameters

Mismatch negativity mechanism is sensitive to different types of changes in an incoming sound train, for example changes in physical properties of stimuli or the relationships between them. Picton et al. (2000) describes five different types of invariance: simple, complex, hypercomplex, pattern and abstract invariance. Simple invariance is the most trivial kind of invariance, with all the standards being identical and deviants can vary in any manner. Complex invariance, in a way, is the inverse of simple invariance, where none of the standards are identical, but all of them share some common feature and deviant is the stimulus that differs in that common feature (e.g. all of the standards have different pitch, but share the same intensity, deviants being stimuli that have differing intensity). Hypercomplex invariance expands the idea of complex invariance, so that standard stimuli have complex features like in complex invariance, but the deviants are stimuli that combine features from several standard stimuli. Pattern invariance related MMNs are elicited on the other hand when a relationship between stimuli change, whether it its rhythm or a change in a repeating sequence. Abstract invariance MMNs also elicit when a relationship between the stimuli change, but in more abstract manner - the invariance is defined by a rule. For example if an incoming sound train is such that each consecutive sound is higher in pitch than previous. Whenever this rule is broken (e.g. incoming sound is lower in pitch), the underlying mechanism elicits an MMN.

When considering the relationships between stimuli, within a sound train two concepts become invaluable as they have a key role in the interpretation of data measured with EEG. These concepts are the inter-stimulus interval (ISI) and stimulus-onset asynchrony (SOA).

ISI is the time interval between the end of a stimulus and onset of another. This can refer to any two stimuli, it can either measure the interval between two consecutive stimuli, between standard and deviant stimuli or even between any two stimuli. Defining the intervals is also critical for the measurement of MMNs as varying ISI can also elicit an MMN ERP, for example, when rhythm changes in musical stimuli. One does have to consider the evidence, which shows that varying ISI does not appear to have much of an effect on the amplitude of MMN, although some studies have shown the MMN to increase with decreasing ISI (Picton et al. 2000). Sshorter ISIs between two standards have been shown to elicit larger amplitude MMNs (Näätänen et al. 2007). The distinction between these two is that the latter considers only the ISI between standards, so varying the standard-standard ISI can have different effect than just varying the general stimulus-stimulus ISI or standard-deviant ISI.

The MMN mechanism appears to consider consecutive stimuli as a single auditory event, when the ISI between the stimuli is short enough, and stimuli with longer intervals as two separate events (Picton et al. 2000). Tervaniemi et al. (1994) found this threshold to be under 140ms, but later study by Kujala et al. (2001) showed it to be somewhere between 20-100ms. For non-pattern like invariance, three stimuli are required; two standards for baseline of comparison and one deviant. For pattern invariance, at least two sets of said three stimulus groups are required and they need to adhere to same rules regarding ISI, both within group and between groups (Picton et al. 2000).

Stimulus-onset asynchrony is the time interval between the beginning of one stimulus and the beginning of another. Varying either the length of the stimulus affects the SOA as does also varying the ISI. Cowan (1994) estimated for the capacity of auditory sensory memory, or echoic memory, to be somewhere between 10-20 seconds, so SOA should be designed to be less than that in a test setting. This comes apparent when designing a study with previously mentioned pattern invariances. Depending on the ISI and the length of stimuli, SOA can exceed the auditory sensory memory and lead to false negatives, as MMNs are not necessarily elicited.

Along with the temporal parameters, auditory MMN is sensitive to different kinds of spectral characteristics: a deviant can vary in pitch (frequency), intensity (amplitude) and perceived location, it can be a mixture of these, or be spectrally rich like in chords, phonemes or even words. So any type of deviation is detected by the mechanism, with the amplitude, latency and localization of the MMNs appearing to differ between types of invariance presented (Näätänen et al. 2007).

2.4 Auditory MMN in the context of music and musicality

As “western culture” is permeating and influencing ever more around the world, the umbrella term music, is rather easily defined to be a rhythmically and melodically laid out pattern of sounds generated by instruments or vocals. The reality is not quite as simple; some cultures do not have a separate term for dancing and playing instruments, but use the same term to describe both. Certain universals appear to be shared between cultures; for a large subset of cultures it has societal and group dynamical aspects, be it either ritualistic (religious chanting, reciting of scripture, etc.) or it can be just for the purpose of experience pleasure with peers. Caregivers across cultures also seem to have almost innate need to sing lullabies to their offspring (Trehub et al. 2015).

Language and music, at a glance, appear to have some sort of relationship between them. Both are rhythmically ordered with certain syntax and both carry a form of meaning with them. Brain studies on the other hand have shown that hemispheric lateralization of the brain puts language processing to the left hemisphere and musical processing on the right hemisphere (Bever and Chiarello, 1974). Recent research does indicate that at least some neuronal modules are common between these two circuitries. Deficiencies in pitch perception have been shown to affect the processing of tonal languages (e.g. Mandarin Chinese), in which raising or lowering the pitch at the beginning or end of a word change the meaning of words. They also present studies that show phonetic perception can be modulated by musical expertise (Jäncke, 2012).

2.4.1 Musical MMN studies

Great part of MMN and other auditory event-related response (AEP) research have concentrated on “purer” or “simpler” forms of deviance. Even though abstract and pattern-like deviants can have similar structures as musical stimuli, musical stimuli could be considered more natural in the sense that for many people it is a part of everyday life. As mentioned before, AEPs can be used in clinical settings as well, so intuitively speaking it would be beneficial for the patients wellbeing as well as for the quality of results from said measurements.

Study by Pei et al. (2004) focused their attention on nonmusicians using musical stimuli, with interest in the P300 and MMN AEPs. They presented four chord sequences to the participants with two different deviant conditions; the first condition having the third chord transposed to a different key and in the second condition third and fourth chord were transposed. In the first deviant condition two MMNs were measured, one from the deviant tone and second from the MMN from the fourth chord, with second deviant condition having the fourth chord MMN measured. They found statistically significant MMNs in each of the conditions.

Lopez et al. (2003) conducted an experiment with both EEG and MEG, measuring P300 and MMN from musicians and nonmusicians. With the use of more musical stimuli, they compared the amplitudes and latencies between the two groups and found significant differences, with the musicians showing higher peaks and lower peak latencies for both P300 and MMN than nonmusicians.

Whilst the previous two studies had the participants direct their attention to the stimuli, Fujioka et al. (2004) experimented whether inattentive musicians and nonmusicians elicit different magnitude magnetic MMNs, when they are presented with deviants with two different forms of encoding of musical information. These two encodings being contour code and interval code. Contour code refers to the direction of pitch change between two notes, whilst interval code refers to the absolute difference between two notes. They reported that musicians had larger MMNs in both conditions, whilst in a control condition of nonmusical tones both musicians and nonmusicians had similar responses. In MMN-research, studying inattentive conditions are important, since MMN is considered to reflect pre-attentive processing of auditory stimuli.

Not every study finds differences between the two groups though; Tervaniemi et al. (2005) examined pitch discrimination accuracy between musicians and nonmusicians in both attentive and inattentive conditions. They found that both groups elicited MMNs in both of the conditions, with amplitudes and latencies correlating with the amount of deviance, but they did not find any differences between the two groups.

3 Fast multi-feature MMN paradigm 3 (MUFE3) study

This study is a continuation of a previous study by Vuust et al. (2011). The exact same standard stimuli were used in this study, with the exception that of the original 24 keys only 12 keys were used. The deviant sounds were derived from the standards by means of software manipulation. This study extends the previously conducted one to have three different levels of deviance for each deviant type. Aim of the study was to find whether a fast paradigm with musically enriched stimuli can be used to index the underlying mechanisms ability to detect variance in different levels of deviants. The experimental part of this thesis is a part of study done by Vuust et al. (2016).

3.1 Methods

3.1.1 Participants

The participants were recruited mainly via two student organization mailing lists. Two of the participants were recruited through personal connections. Measurements were done with 12 participants, but due to electrical interference from poor electrode connections, the data from one participant had to be discarded from the final analysis. With 11 participants total (mean age 23, range 19-29; 7 females), all reported having normal hearing, no continuous medication and no diagnosed neurological disorders. Almost all of the participants had university backgrounds with the exception of two who had upper secondary education. One participant reported having no musical skills whatsoever, three participants reported having minimal skills, six considered themselves to be at an amateur level and one identified as a semi-professional. All participants gave an informed written consent. After the test, participants were awarded with two movie tickets.

Before the EEG measurement all participants answered to a background questionnaire, a Musicality Synthesizing – Musicality Empathizing (ME-MS) test and did a Musical Ear Test (MET). MET and MS-ME tests are used to approximate the participants' musical abilities and compared with participants' musicality self-assessment.

3.1.2 Musical Ear Test (MET)

The ME test by Wallentin et al. (2010) was developed for the assessment of musical competence reliably in a short duration for the purpose of distinguishing nonmusicians, amateurs and professionals from each other. In the test, pairs of consecutive sound blocks are played to the participant and the participant has to decide whether the sound blocks are similar or different. The test is comprised of two 10-minute parts, first one having 52 melody pairs and the second one 52 rhythmic pair.

On average, participants scored 75% on the test (N = 11; SD = 0.11; range: 0.51–0.88). Participants who reported to be either amateurs or semi-professionals had a mean score of 78% (N = 7; SD = 0.09; range: 0.61–0.88) and nonmusicians 68.5% (N = 4; SD = 0.13; range: 0.51–0.80).

According to Wallentin et al. (2010) mean score of amateur musicians is 78% in the MET and mean score of nonmusicians approximately 68%. This makes the participants of this study a mix of amateurs and nonmusicians. Participants' self-reported skills support these results (four nonmusicians, six amateurs, one semi-professional).

3.1.3 Music Synthesizing – Music Empathizing (MS-ME test)

The MS-ME test by Kreutz et al. (2008) is a qualitative questionnaire that has also been shown to be able to differentiate professional musicians from nonmusicians and to some extent professionals from amateurs. The questionnaire contains 25 ME (Music Empathizing) and 19 MS (Music Synthesizing) questions in four-point Likert-scale (Appendix C). The questions were translated from the original English materials into Finnish, since participants were all native Finnish speakers.

The mean score in MS-ME test on empathizing questions was 3.54 (N = 11; SD = 15.05; range: -29 –25) and on synthesizing questions the mean score was 1.73 (N = 11; SD = 12.01; range: -25 – 17). Kreutz et al. (2008) found that there was a correlation between MS scores and musical training, so only MS scores is used.

Synthesizing (MS) scores obtained by professionals and amateurs in the surveys conducted by Kreutz et al. (2008) were statistically very similar. Professionals, amateurs and nonmusicians received mean scores of 3.46, 3.39 and -6.27, respectively, making a distinction between amateurs and professionals difficult.

Participants mean score of the MS test obtained here (=3.54) is in the same ballpark as Kreutz et al. (2008), this would put our participants in the musicians group. Average MS scores received on this study for nonmusicians was 6.5 (N = 4; SD = 13.40; range: -25 – 7) and musicians (both self-reported amateurs and musicians grouped together) 6.4 (N= 7; SD = 8.92; range: -25 – 7), which also implies that the self-reported skills to be rather accurate, with a mix of nonmusicians and musicians.

3.1.4 Stimuli

The stimuli consist of 4-tone patterns arranged in an Alberti bass configuration in which the chords are presented in the order lowest, highest middle, highest. After each standard block, a deviant block was presented (Figure 1)

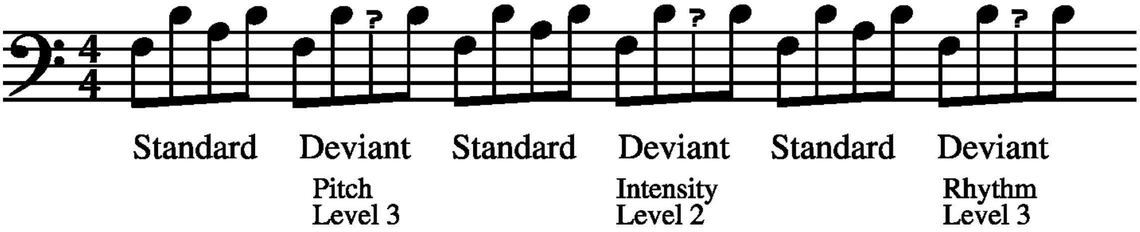

Figure 1: Standard and deviant sound blocks depicted in musical notation

In the deviant block, the third tone of the pattern was modified by altering a specific spectral characteristic of the tone in three different strength levels. Each tone was 200ms in length, with ISI of 5ms, with the exception of rhythm deviants (Figure 2). The rhythm deviant tones were shorter and also presented earlier than other deviants. All tones were in 44kHz stereo, uncompressed.

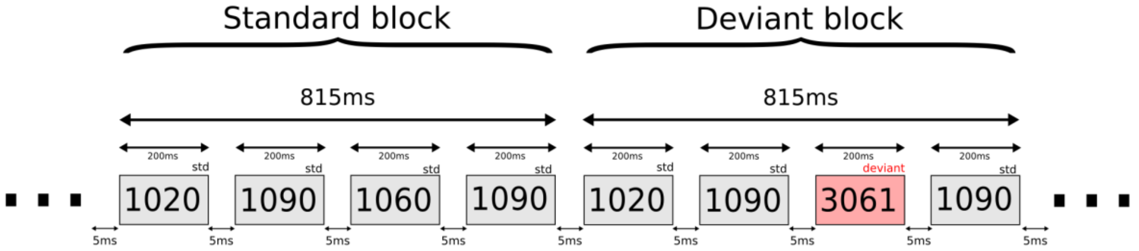

Figure 2: Standard and deviant blocks, with ISI and SOA

There were three different levels for each deviant stimulus, so in all there was 18 different deviants per each tone (12 keys). Physically the deviant sounds differed from the standards in pitch, intensity, location, slide, rhythm and timbre (Table 1). The stimuli were pseudo-randomized, with the standard pattern changing every sixth repeats. The keys were also transposed to different key periodically. This adds up to 216 different deviant sounds and 12 standards. Each deviant was presented 12 times. The length of the complete auditory block was 69.12 minutes.

Level	Pitch	Intensity	Slide	Location	Rhythm	Timbre
1	15 cents	-9 dB	15 cents	100 µs	-40 ms	200 Hz
2	25 cents	-12 dB	25 cents	200 µs	-50 ms	250 Hz
3	35 cents	-15 db	35 cents	300 µs	-60 ms	300 Hz

Table 1: Parameters of different stimuli

Pitch deviants were generated by increasing the pitch of the standard tone by 15, 25 and 35 cents, intensity deviants by decreasing the volume by 9, 12 and 15 dB, slide deviants by ’bending’ the pitch by 15, 25 and 35 cents, location deviants by delaying the right channel by 100, 200, 300 µs (thus altering the perceived location), rhythm deviants by shortening the duration of tone by 40, 50, 60 ms. In addition, the rhythm deviants were presented 40, 50, 60 ms earlier than standards. Since the shortening of rhythm deviants in essence were cut down by said times, it introduced and abrupt stop at the end of the deviants. This was mitigated by dampening the amplitude over the last 10 ms to bring about more natural sounding ending to the notes. Timbre deviants were recorded by passing the standards through a fifth order Butterworth high pass filter with cut-off frequencies set at 200, 250 and 300 Hz respectively.

3.1.5 Experimental design

The design used on this experiment follows the MUFE paradigm which was introduced in the paper by Vuust et al. (2011). MUFE paradigm was created for the purpose of developing a method for objectively measuring auditory and musical development in a relatively short time period.

Originally, the study was designed to be implemented using six levels of deviance. With six levels of deviance, the length of EEG measurement phase of the study increased to a total of roughly 140 minutes. Adding all the behavioral tests, background questionnaires, the preparation time of the EEG cap and instrumentation checks on top of the actual measurement, the length of session totaled up to 2 hours and 45 minutes per participant. In a pilot study with six deviants, the participant fell asleep at around the 90-minute mark of the EEG test and was followed by reports of discomfort, leading to the termination of the pilot study. For the actual study, the auditory block of the EEG measurement phase was reduced to 70 minutes long by lowering the amount of deviance levels down from six to three levels.

3.1.6 Procedure

The EEG laboratory is administered by the University of Jyväskylä’s faculty of music. The lab is located one floor down from ground level. The laboratory has been soundproofed and equipped with the required EEG equipment, playback devices and a comfortable sofa. Although the lab is soundproofed, some noises could be heard inside the laboratory, whenever there was activity in the adjacent auditorium.

When a participant arrived at the laboratory, the participant was asked to fill out the background questionnaire (Appendix C), the consent form, complete the MS-ME and ME test. For the ME test the volume was set to be at around 60dB so that it was comfortable for the participant. The test was begun whenever the participant was ready. Instructions were presented through the headphones again in English before the test stimuli.

After the ME test, preparations for the EEG measurement began. Firstly, earing threshold was measured. This was implemented so that the participant had the headphones on and volume was gradually increased until the participant reported hearing sound coming from the headphones. The final volume was set 50dB over the found threshold. Sounds used in the hearing threshold test were the same as what was used in the study.

Each participant was briefed to focus on a subtitled, silenced film while the auditory sequence was played through the headphones. Several movies were made available for the participant to choose from.

Every participant had a separately scheduled appointment so that only one participant was present in the laboratory at a time. There was approximately 30-45 minutes time between the participants. There was a maximum of three participants booked per day. The stimuli were presented using Neurobehavioral Systems Presentation and data was recorded via Biosemi ActiView.

The stimuli were processed using SoX, MathWorks MATLAB and Adobe Audition. Most of the processing was done using SoX, MATLAB was used for the timbre effect and Audition was used to achieve the slide effect.

3.2 EEG recording and analysis

The electroencephalograph used to record the EEG was a Biosemi ActiveTwo system. Recording was done using 64 Ag/AgCl active electrodes, with the addition of two electrodes on each earlobe and one per eye for artifact removal. Electrode paste was used with the head-cap to decrease the impedance. Additional electrodes were attached to the skin with double-sided adhesive electrode rings. Electrode positions corresponded to the international 10-20 system. The data was recorded with a sample rate of 2048 Hz, which was downsampled afterwards to 512 Hz using BDFDecimator software. Off-line band-pass (1-30Hz) filtering was performed in EEGLAB. Epochs were extracted between -100ms and 400ms from the stimulus onset, with the 100ms before the stimulus serving as baseline for amplitude measurement. Rejection level was set to be ±150 mV. The stimuli were presented with Sennheiser HD 210, which are consumer grade headphones.

For analysis, the Fz electrode was selected, as to conform with the settings in the previous MUFE study by Vuust et al. (2011). Fz was also visually confirmed to elicit the largest MMNs for most of the deviants. In addition, it is very commonly used electrode for measuring MMNs (e.g. Vuust et al. 2011; Näätänen et al. 2004; Pakarinen et al. 2007).

Peak MMN amplitudes were extracted between 100-250ms after stimulus onset. The MMN difference ERPs were obtained by calculating the average amplitude within 40ms window surrounding the peak amplitude of standards and deviants and then subtracting standard ERPs from deviant ERPs (Figure 3).
Results of the test were analyzed using IBM SPSS. Images were rendered in EEGLAB.

4 Results

In all of the six conditions, deviants elicited MMN responses peaking between 100-250ms from stimulus onset as can be seen in figure 3.3. Paired T-tests resulted in statistically significant differences between standard ERP's and deviant ERP's in the following conditions: Pitch L3: $t(10) = -3.35$, $p < 0.05$; Intensity L1: $t(10) = -2.36$, $p < 0.05$; Intensity L2: $t(10) = -3.39$, $p < 0.05$; Intensity L3: $t(10) = -5.50$, $p < 0.01$; Slide L2: $t(10) = -3.67$, $p < 0.01$; Slide L3: $t(10) = -4.18$, $p < 0.01$; Location L2: $t(10) = -3.45$, $p < 0.01$; Location L3: $t(10) = -7.22$, $p < 0.01$; Timbre L3: $t(10) = -2.63$, $p < 0.05$; Rhythm L1: $t(10) = -5.17$, $p < 0.01$; Rhythm L2: $t(10) = -5.00$, $p < 0.01$; Rhythm L3: $t(10) = -5.27$, $p < 0.01$; Pitch L1, Pitch L2, Slide L1, Location L1, Timbre L1 and Timbre L2 did not reach significance, $p >= 0.05$ (Table 2).

Repeated measures ANOVA on deviant-standard difference waves showed significant effects of the deviance level in four of six deviant types: Pitch: $F(2,20) = 5.46$, $p < 0.05$; Intensity: $F(2,20) = 8.34$, $p < 0.01$; Slide: $F(2,20) = 4.30$, $p < 0.05$; Location: $F(2,20) = 10.87$, $p < 0.01$; Timbre: $F(2,20) = 0.77$, $p > 0.05$; Rhythm: $F(2,20) = 1.82$, $p > 0.05$ (Table 3.3). Linear contrasts analysis shows that there is a statistically significant linear relationship between level of the deviance and the amplitude of MMN in four of six conditions. Pitch: $F(1,10) = 10.33$, $p < 0.01$; Intensity: $F(1,10) = 10.86$, $p < 0.01$; Slide: $F(1,10) = 7.27$; Location: $F(1,10) = 25.86$, $p < 0.01$; Timbre: $F(1,10) = 0.76$, $p > 0.05$; Rhythm: $F(1,10) = 2.30$, $p > 0.05$ (Table 3).

Pair	Mean	SD	t	df	p
Pitch L1	0.06	1.77	0.11	10	0.91
Pitch L2	-1.27	2.12	-1.99	10	0.07
Pitch L3	-2.19	2.18	-3.35	10	< 0.01
Intensity L1	-1.59	2.24	-2.36	10	< 0.05
Intensity L2	-2.73	2.67	-3.39	10	< 0.01
Intensity L3	-4.86	2.93	-5.50	10	< 0.01
Slide L1	-1.08	1.97	-1.83	10	0.11
Slide L2	-2.23	2.02	-3.66	10	< 0.01
Slide L3	-3.64	2.88	-4.18	10	< 0.01
Location L1	-0.11	1.44	-0.26	10	0.80
Location L2	-2.64	2.53	-3.45	10	< 0.01
Location L3	-3.34	1.53	-7.22	10	< 0.01
Timbre L1	-1.28	2.02	-2.11	10	0.06
Timbre L2	-1.38	2.27	-2.01	10	0.07
Timbre L3	-2.21	2.78	-2.63	10	< 0.05
Rhythm L1	-5.49	3.52	-5.17	10	< 0.01
Rhythm L2	-5.50	3.66	-5.00	10	< 0.01
Rhythm L3	-5.27	3.32	-5.27	10	< 0.01

Table 2: Paired T-test results on mean peak MMN amplitudes

Deviant	Within subjects effect		Linear contrasts	
	F(2,20)	p	F(1,10)	p
Pitch	5.46	<0.05	10.33	<0.01
Intensity	8.34	<0.01	10.86	<0.01
Slide	4.3	<0.05	7.27	<0.05
Location	10.87	<0.01	25.86	<0.01
Timbre	0.77	>0.05	0.77	>0.05
Rhythm	1.82	>0.05	2.30	>0.05

Table 3: Repeated measures on the three levels of deviant-standard waveforms

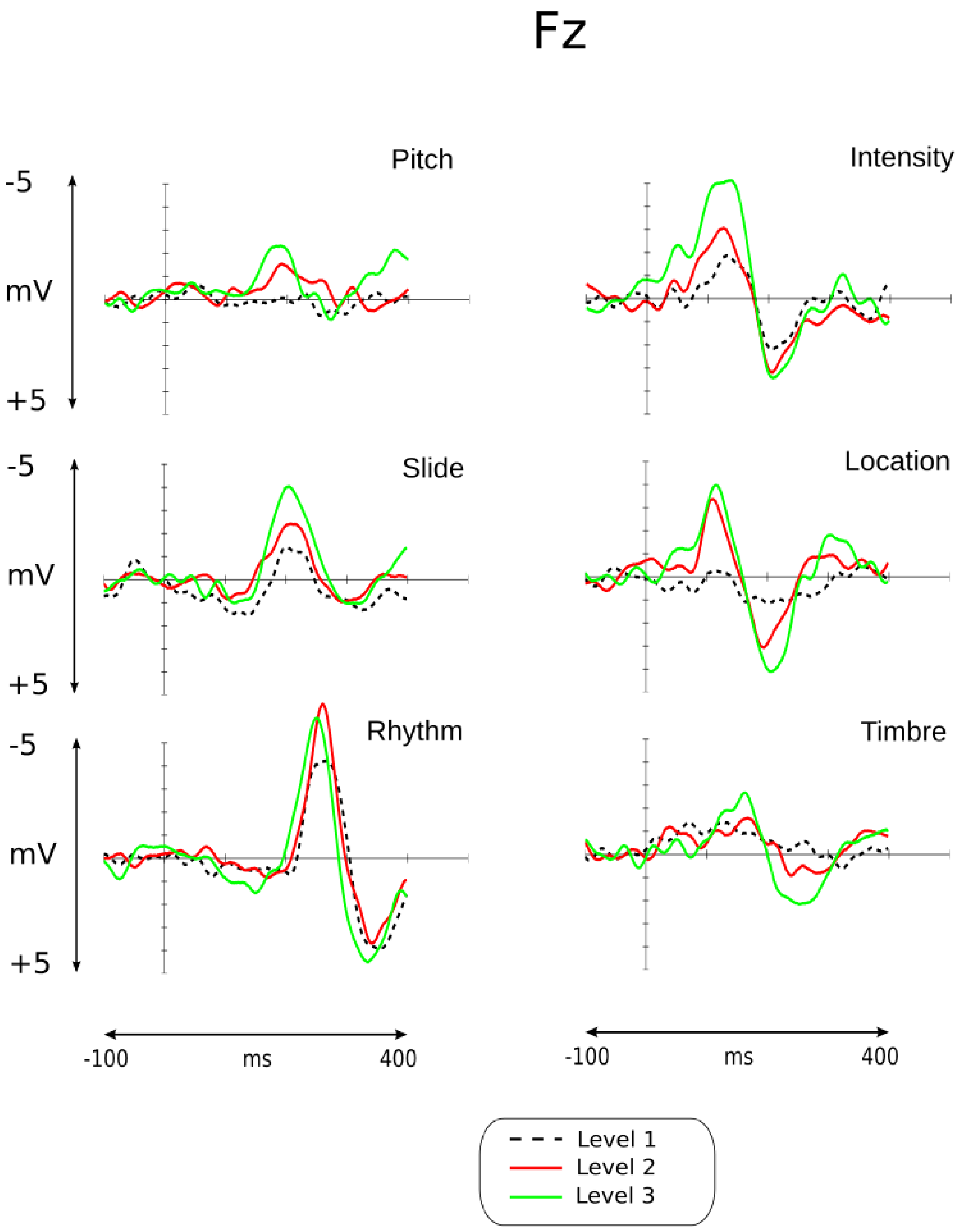

Figure 3: MMN difference waves recorded at Fz

5 Discussion and conclusions

We showed in this study, that using the MUFE paradigm introduced by Vuust et al. (2011), the MMN amplitude reflects the amount of deviance found in musical auditory stimuli (with the exception of timbre and rhythm deviants) in nonmusicians and amateur musicians.

Timbre deviant has been shown to elicit MMNs by e.g. Tervaniemi et al. (1997) and Vuust et al. (2011). In this study apparent MMNs were elicited, although only the most obvious deviant (Level 3, 300 Hz high-pass) did differ from the standard significantly ($p < 0.05$). There was no significant difference between the three levels of deviance as was indicated by the repeated measures ANOVA. It might be that the particular method of using a simple high-pass filter to generate the timbre deviant is not optimal solution, since it only cuts out the lowest frequencies.

On the part of the rhythm deviant, there was a noticeable MMN response in all three levels, but the amplitude of the response wave did not correlate with the level of deviance; this could have occurred due to the design of the rhythm deviant. The rhythm deviants were constructed by shortening the third note of the auditory block by 40ms, 50ms or 60ms with an additional anticipation of the third note correspondingly. This made the rhythm deviants play earlier than the respective standards. The shortening of the sound introduced more of an abrupt stop at the end of the note, albeit a dampening effect of the stimulus over a few milliseconds was added at the end of the rhythm deviant to alleviate the abruptness of the stop.

While this would explain why the amplitude of the MMN response is so noticeable, it does not offer any insight about why the difference between the levels of deviance does not appear to correlate with the measured amplitudes. It could be that the participants were not musically adept enough to discriminate the differences between the three different levels, or the more abrupt stop in the sound stimulus itself was so overwhelming that differentiation between the three different deviants is just much harder for the MMN mechanism to notice.

In the study by Vuust et al. (2011), the amplitude in the rhythm deviant was much smaller than seen here, but so was the latency as well. It is expected for the latency to be less in the rhythm deviant, since the note is played earlier with shorter duration. Based on this, the latency of the rhythm peak wave should be somewhere around 100-200ms after stimulus onset. Since the peak should be occurring much earlier and it's amplitude should be less prominent, as has been shown in the previous study, it could be that what we see here is an enhanced N1 response to the next stimulus. The last note of the deviant block starts playing at 200ms, within the window of the deviant stimulus. N1 response amplitude diminishes when the stimulus stays constant and increase when stimulus changes (Picton et al. 2000). In the rhythm deviants, we decreased the ISI between the standard and deviant blocks, but we also increased the ISI between the third note and the fourth note in the deviant block. Whilst shortening the ISI should not affect adversely in the MMN generation (Tervaniemi et al. 1994), modulation of the ISI can have an effect on the N1 response (Wang et al. 2008).

Although no analysis was done regarding MMN generator sources, visual inspection of the scalp distribution maps A.1 shows left temporal and right frontal deflections. Interestingly, but perhaps not surprisingly, location deviants appear to have more frontal deflection contralateral to the perceived location.

In conclusion, this study corroborates previous studies that the amplitude of the MMN response correlates with the amount of deviance present in the deviant stimulus. As only amplitude analysis was done in the scope of this study, its usefulness is rather limited. Latency analysis and source analysis of the ERPs would have added weight to the results extracted from amplitude analysis. Moreover, having a control group without musical background and an experimental group of musicians would have shed light whether the discrimination accuracy differs between groups, giving credence for using MMN as an index for musical competence.

In addition to finding out whether there are differences in MMN between nonmusicians, amateurs and professionals, it would also be interesting to see whether other musically related activities (i.e. extensive listening of music or playing musical games) can affect MMN amplitudes and latencies. Rudimentary information related to listening and gaming activities were asked in the background questionnaire of this study, but that information never got used in any manner (Appendix C).

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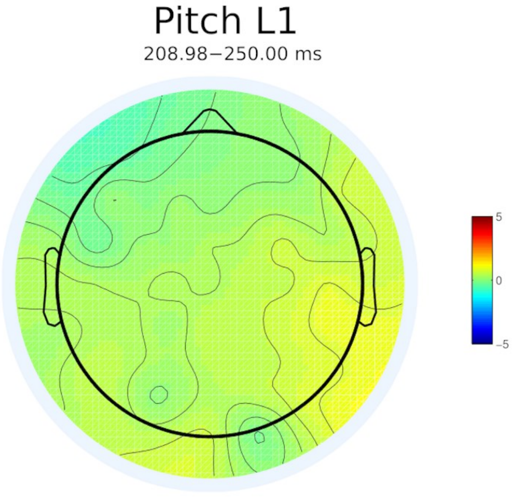
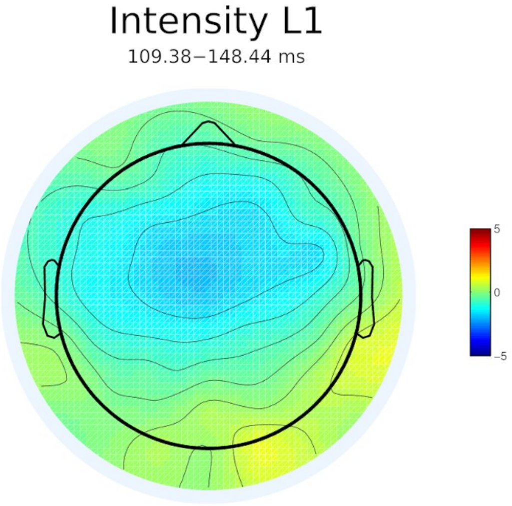
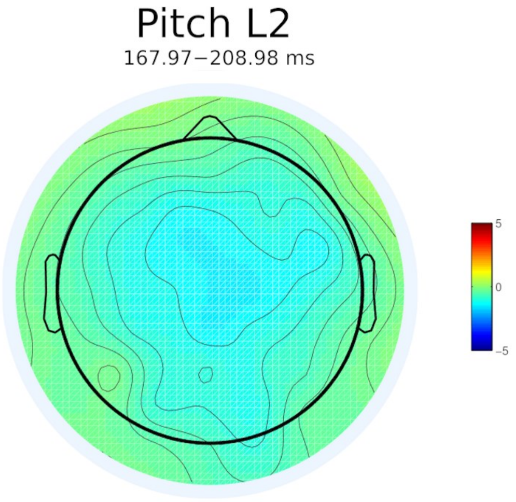
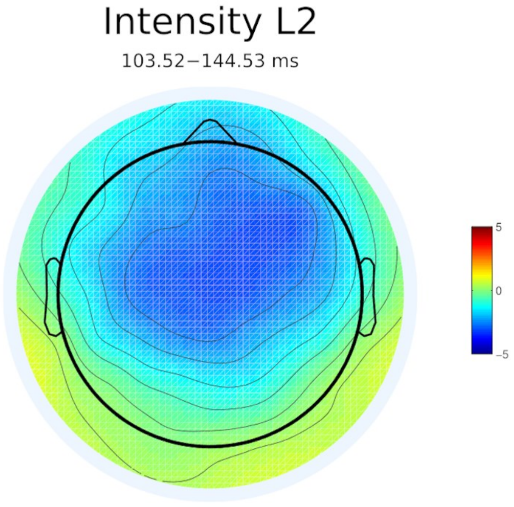
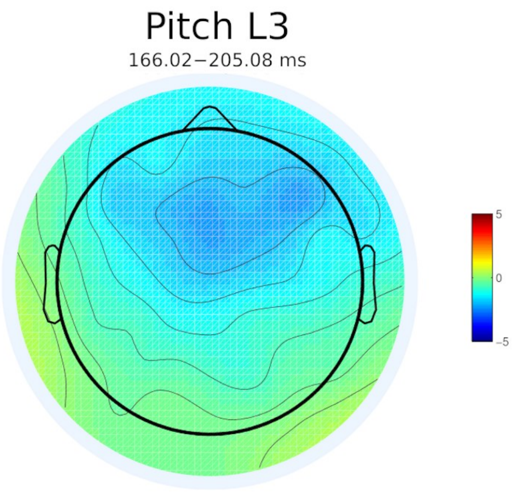
APPENDIX A EEG TOPOGRAPHIC SCALP MAPS

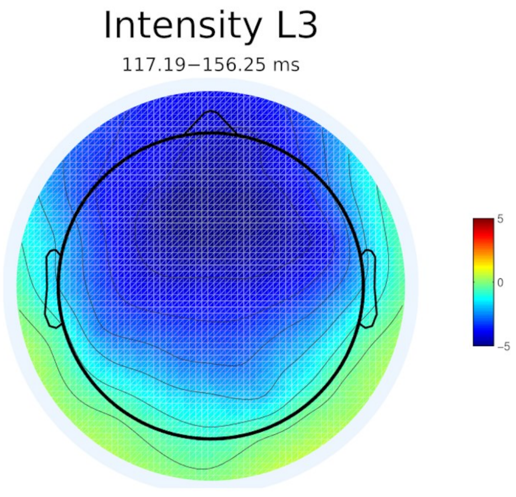


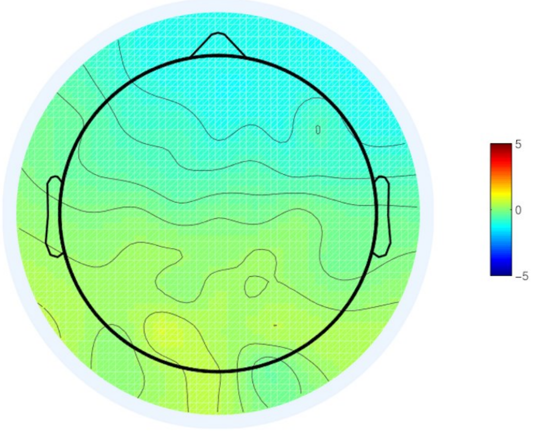






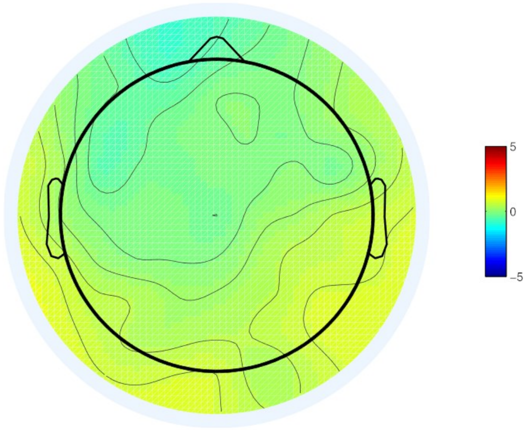






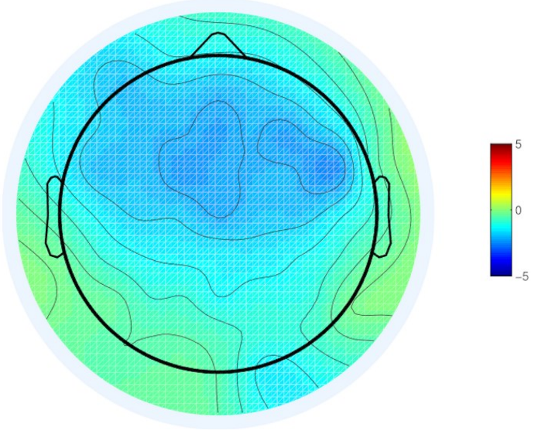
Slide L1

179.69−220.70 ms



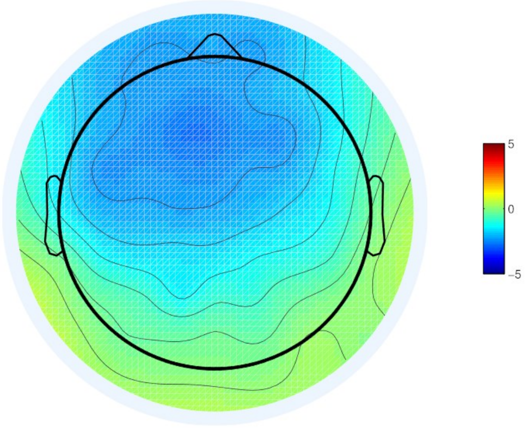
Location L1

91.80−132.81 ms



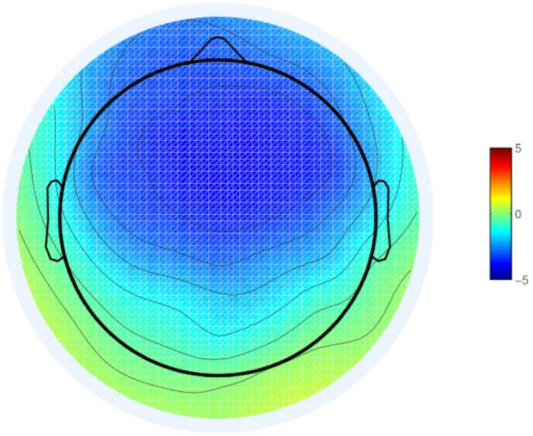
Slide L2

185.55−226.56 ms



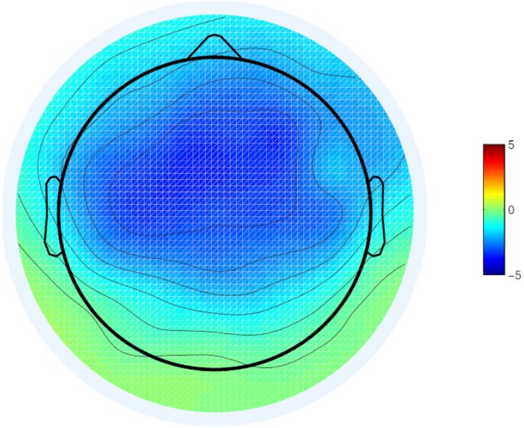
Location L2

87.89−128.91 ms



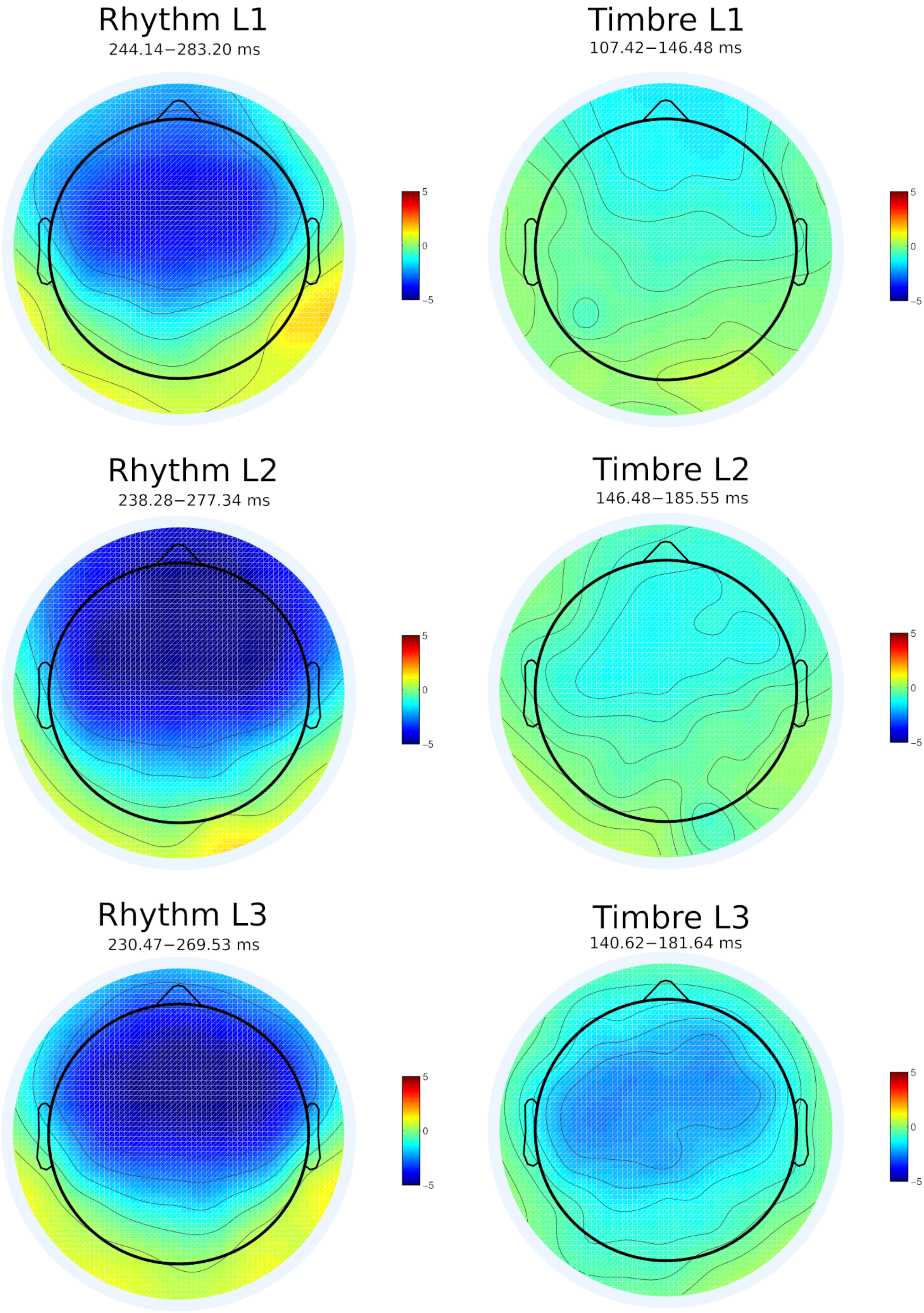
Slide L3

183.59−224.61 ms



Location L3

93.75−134.77 ms



Rhythm L1
244.14−283.20 ms

Timbre L1
107.42−146.48 ms

Rhythm L2
238.28−277.34 ms

Timbre L2
146.48−185.55 ms

Rhythm L3
230.47−269.53 ms

Timbre L3
140.62−181.64 ms

APPENDIX B ME-MS QUESTIONNAIRE ITEMS TRANSLATED INTO FINNISH

ME01 Hyvien muusikoiden persoonallisuus vetää minut musiikin pariin

ME02 Minun olisi vaikea päästä musiikkiin mukaan, jos esiintyvä muusikko on ahdistunut soittaessaan

ME03 Luulen, että voin helposti tuntea mitä esiintyjät tuntevat soittaessaan

ME04 Tykkään tanssia musiikille, joka on hyvää tanssimiseen

ME05 Tapaan pitää heikoista musiikkiesityksistä, jos voin samaistua esiintyjään

ME06 En koskaan kykene arvioimaan esiintyjien tunteita

ME07 Katselen mielummin live-esitystä, kuin kuuntelen nauhoituksia

ME08 Musiikki on tärkeätä minulle pääasiassa koska se ilmaisee jotain henkilökohtaista ja koskettavaa

ME09 Minusta esiintyjän musiikillisen identiteetin pitäisi olla vähemmän tärkeätä, kuin hänen soittamansa musiikin

ME10 Musiikinkuuntelu antaa minulle mielikuvia enemmän ihmisistä, kuin elottomista kappaleista

ME11 En pidä isojen rave-kekkereiden tai rokkikonserttien ilmapiiristä

ME12 Minulla on huono käsitys siitä mitä muusikon mielessä tapahtuu

ME13 Kuunnellessani hyvää instrumentaalimusiikkia, minusta tuntuu että minulle kerrottaisiin tarinaa

ME14 En koskaan koe lyriikoiden olevan merkityksellisiä

ME15 Musikkia kuunnellessani minulla on mielikuvia musiikin kirjoittajan/säveltäjän senhetkisestä tunnetilasta

ME16 En koe pystyväni samaistumaan mielimusiikkini laulajiin/kirjoittajiin

ME17 Musiikkia kuunnellessani koen ymmärtäväni mitä tunteita kirjoittaja/säveltäjä pyrkii ilmaisemaan

ME18 En välitä mitä mieliartistieni elämässä on tapahtunut albumien/kappaleiden tuotannon aikana

ME19 Tykkään lukea mieliartistieni biografioita

ME20 Minusta ei ole tärkeätä ymmärtää kappaleen takana olevia tunteita

ME21 Voin helposti valita esimerkkejä musiikkikokoelmastani, jotka aiheuttavat minussa tiettyjä tuntemuksia

ME22 Minun on vaikeata kuvitella mitä säveltäjien mielessä on liikkunut heidän tehdessä sävelmää

ME23 Koen useasti fysikaalisia tuntemuksia (kyyneliä, kylmiä väreitä jne.) kuunnellessani tiettyjä kappaleita

ME24 Musiikki voi aiheuttaa minulle tuntemuksia, kuten kylmiä väreitä

MS01 Musiikki on kieli, joka voi olla tehokkaampaa kuin normaali verbaali kieli
MS02 En ole kiinnostunut ymmärtämään musiikkikappaleen rakennetta
MS03 Luulen, että voin tuntea miltä esiintyjistä tuntuu musiikkia soittaessaan
MS04 En usko, että musiikki representoi universumia
MS05 Luulen, että ihmiset jotka ymmärtävät musiikin säveltämisen säännöt saavat enemmän musiikista irti
MS06 Minua ei kiehdo musikaalisten instrumenttien fysikaalinen tai akustinen perusta
MS07 Pohdin monesti musiikillisten instrumenttien mekaniikkaa ja toimintaperiaatteita
MS08 Koen musiikin ymmärtämisen monesti helpommaksi, kuin toisten ihmisten puheen ymmärtämisen
MS09 Minulle ei ole tärkeätä onko muilla ihmisillä sama musiikkimaku kuin minulla
MS10 Pyrin välttämään suuria konserttiyleisöjä
MS11 Pidän eri instrumenttien ja lauluäänien muodostamien kerrosten kuulemisesta
MS12 En ole koskaan jäänyt ihmettelemään mitä seuraavaksi tapahtuu mielimusiikkia kuunnellessani
MS13 Mielestäni kirjoitetut partituurit ovat mielenkiintoisia ja pidän erityisesti organisoidusta tavasta jolla musiikki on esitetty paperilla
MS14 En koe rytmin olevan kovinkaan kiinnostava tai tärkeä osa-alue musiikissa
MS15 Pidän siitä kuinka kappale muodostuu sen osien summana
MS16 Minusta ei ole tärkeätä, että musiikilla on matemaattiset perustat
MS17 Konsterteissa haluan nähdä bändin/orkesterin eri jäsenien roolit, sekä nähdä kuinka roolit toimivat yhdessä
MS18 Pidän musiikkikokoelmani selkeässä järjestyksessä (aakkosjärjestys, genreittäin jne.)
MS19 En ole kiinnostunut musiikin tuotantopuolesta tai käytetyistä teknologioista
MS20 Pidän siitä, että musiikki sopii selkeästi johonkin rajattuun genreen (klassinen, rock, folk jne.)
MS21 Tylsistyn helposti kappaleisiin, joissa on selkeästi määritelty rakenne

EQ14 Pystyn havaitsemaan toisten tunnetilat nopeasti ja intuitiivisesti
EQ22 Olen hyvä ennustamaan toisten tunteita ja tuntemuksia
EQ28 Toiset ihmiset sanovat, että olen hyvä ymmärtämään heidän tuntemuksiaan ja heidän ajatuksiaan
EQ34 Ystävät usein puhuvat minulle ongelmistaan, koska olen heidän mielestään hyvin ymmärtäväinen

SQ08	Olen kiinnostunut koneiden toimintaperiaatteista
SQ10	Koen vaikeaksi rakennusohjeiden ymmärtämisen
SQ12	Jos ostaisin stereot, haluaisin tietää sen täsmälliset tekniset ominaisuudet
SQ22	Jos ostaisin tietokoneen, haluaisin tietää sen täsmälliset tekniset tiedot

APPENDIX C BACKGROUND QUESTIONNAIRE

MuFe3

1. Ikä ☐

2. Sukupuoli
- ☐ Nainen
- ☐ Mies

3. Oletko opiskellut musiikin teoriaa?
(peruskouluopetus poislukien)
- ☐ Kyllä (oppilaitoksessa, yksityisopetuksessa tms)
- ☐ Kyllä, olen opiskellut itsenäisesti
- ☐ Ei

4. Oletko opiskellut laulamista
tai jonkin instrumentin soittoa?
(peruskouluopetus poislukien)
- ☐ Kyllä (oppilaitoksessa, yksityisopetuksessa tms)
- ☐ Kyllä, olen opiskellut itsenäisesti
- ☐ Ei

5. Kuinka paljon kuuntelet musiikkia
- ☐ alle tunnin päivässä
- ☐ 1-3 tuntia päivässä
- ☐ 4-6 tuntia päivässä
- ☐ jatkuvasti

6. Keskitytkö musiikin kuunteluun, vai soiko musiikki vain taustalla?

1									10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Keskityn aina									Taustalla aina

7. Pääosin kuuntelen seuraavíen genrejen artisteja

☐ Ambient
☐ Blues
☐ Country
☐ Dance
☐ Elektroninen
☐ Folk
☐ Hip hop
☐ House
☐ Indie
☐ Jatsi
☐ Klassinen
☐ Metalli
☐ New age
☐ Pop
☐ Punk
☐ R&B
☐ Rap
☐ Reggae
☐ Rock
☐ Muita, mitä?

8.Pelaatko ns. musiikkipelejä, kuten
Guitar Heroa tai Sing Staria?

☐ En
☐ En säännöllisesti
☐ Kyllä, n. ☐ tuntia viikossa

9. Mihin osa-alueeseen pääosin keskityt pel(e)issä?

☐ Kitara
☐ Basso
☐ Rummut
☐ Laulu