Universidade do Minho
Escola de Psicologia

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The automatic processing of non-verbal emotional vocalizations: an electrophysiological investigation

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Trabalho realizado sob orientação da
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e da
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The automatic processing of non-verbal emotional vocalizations: an electrophysiological investigation

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AGRADECIMENTOS

27 páginas de texto, tabelas, gráficos e imagens parece muito pouco para descrever cerca de um ano de processo de investigação. Contudo, é precisamente o facto de todo o trabalho se ter condensado em poucas páginas que torna uma tese especial: por ensinar a ler, a criar e a transmitir conhecimento científico de forma coerente e sucinta.

Neste espaço, pretendo estender um enorme agradecimento a todos quantos partilharam deste trabalho comigo e ajudaram a fazer deste pedaço de percurso académico, mas também pessoal, um lugar feliz.

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If I have seen further it is by standing on the shoulders of giants. (Isaac Newton, 1976)

Integrated Master's in Psychology of University of Minho
Specialty in Clinical and Health Psychology

THE AUTOMATIC PROCESSING OF NON-VERBAL EMOTIONAL VOCALIZATIONS: AN ELECTROPHYSIOLOGICAL INVESTIGATION.

Margarida F. Gomes Vasconcelos

Ana P. Teixeira Pinheiro
Yvonne Delevoye-Turrell

ABSTRACT

The human voice is a critical channel for the exchange of information about the emotionality of a speaker. In this sense, it is important to investigate the neural correlates of non-verbal vocalizations processing, even when listeners are not attending to these events. We developed an oddball paradigm in which emotional (happy and angry) and neutral vocalizations were presented both as standard and deviant stimuli in four conditions: Happy, Angry, Neutral 1 (neutral vocalizations with angry context), and Neutral 2 (neutral vocalizations with happy context). To unfold the time course of the auditory change detection mechanisms indexed by the Mismatch Negativity (MMN) component, the Event–Related Potentials (ERP) methodology was used. ERPs were recorded in 17 healthy subjects. The results showed that Happy and Neutral 2 conditions elicited more negative MMN amplitude relative to the Angry condition, at midline (Fz, Cz) electrodes. Overall results suggest that automatic auditory change detection is enhanced for positive and neutral (in happy context) vocalizations than for negative stimuli.

Key-words: Auditory Processing; Non-verbal Vocalizations; Emotional Valence; Event-Related Potentials (ERP); Mismatch Negativity (MMN).

Mestrado Integrado em Psicologia da Universidade do Minho
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O PROCESSAMENTO AUTOMÁTICO DE VOCALIZAÇÕES NÃO-VERBAIS: UM ESTUDO ELECTROFISIOLÓGICO

Margarida F. Gomes Vasconcelos

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RESUMO

A voz humana é um canal vital na troca de informação sobre a emocionalidade do outro. Neste sentido, é importante investigar quais os correlatos neuronais associados ao processamento de vocalizações não-verbais, mesmo quando não é alocada atenção a estes estímulos. Foi criado um paradigma *oddball* com vocalizações emocionais (alegria e raiva) e neutras, que eram apresentadas como estímulos frequentes ou infrequentes em quatro condições distintas: Alegre, Raiva, Neutro 1 (vocalizações neutras em contexto de raiva) e Neutro 2 (vocalizações neutras em contexto de alegria). Para investigar o curso temporal dos mecanismos automáticos de detecção de mudança auditiva, foi usada a técnica de Potenciais Evocados e estudado o componente *Mismatch Negativity* (MMN). A amostra foi constituída por 17 indivíduos saudáveis. Os resultados mostraram que as condições Alegre e Neutro 2 elicitaram uma amplitude de MMN mais negativa comparativamente com a condição Raiva, para os eléctrodos situados na linha média do escalpe (Fz, Cz). Estes resultados indicam que existe um mecanismo neuronal de deteção de mudança auditiva mais pronunciado para vocalizações positivas e neutras (em contexto de alegria) comparativamente com vocalizações negativas.

Palavras-chave: Processamento auditivo; Vocalizações não-verbais; Valência emocional; Potenciais Evocados; *Mismatch Negativity* (MMN).

1. INTRODUCTION

During human evolution, emotions have developed and taught organisms how to adaptively respond to the environment at the individual, dyadic, group and cultural levels (Kring & Moran, 2008). Audition is one of the sensory modalities through which social communication is established. The main reason is that voice is a special channel to transmit meaning, intents and emotionality (Belin, Fecteau & Bédard, 2004).

Not only for humans, but also for primates, the emotion conveyed through the voice forms an auditory object that subjects learn how to decode from the early beginning of life (Sauter & Eimer, 2010; Leitman et al., 2010). The concept 'vocal expression' includes: speech – e.g., words, sentences, pseudo-sentences/words -, speech embedded-prosody, verbal interjections – e.g., 'No!'- and vocalizations. The expression of affect through words, sentences and suprasegmental characteristics of speech has been extensively studied (Banse & Scherer, 1996; Kotz, Meyer, Alter, Besson, von Cramon, & Friederici, 2003; Schirmer, Kotz, & Friederici, 2005), but only a small group of researchers has devoted attention to non-verbal vocalizations. Given the recognized relevance of human vocalizations as a distinct category of auditory stimuli (Aeschlimann, Knebel, Murray & Clarke, 2008), we will further focus our attention on this matter, mainly in how the emotional processing of non-verbal vocalizations occurs.

1.1 Non-Linguistic Affective Vocalizations

The study of nonlinguistic affective vocalizations has been a topic of interest for a long time (Scherer, 1994), despite the scarce number of scientific publications about it (Hawk, Van Kleef, Fischer & Van der Schalk, 2009). Scherer (1994) was the first author to introduce a term - 'affect bursts' – that was refined to define vocalizations and gave rise to the subsequent research related to the topic. Later, Schröder (2003, p. 103) refined the term and described vocalizations as "short, emotional non-speech expressions, comprising both clear non-speech sounds (e.g., laughter) and interjections with a phonemic structure (e.g., 'Wow!')". Vocalizations are also characterized by conveying meaning (Seyfarth, Cheney & Marler, 1980) and cues about the identity (e.g., gender, status), the affect and the emotional state of the speaker (Banse & Scherer, 1996; Ladd, Silverman, Tolkmitt, Bergmann & Scherer, 1985).

Evidence from Event-Related Potential (ERP) studies (Levy et al., 2001; Puce, Epling, Thompson & Carrick, 2007; Adolphs, 2012) suggests that not only deciphering human vocalizations in real time is of a remarkable importance for normal social interactions, as it is species-specific. In that sense, studies suggest that humans in comparison with monkeys show a preference for the human voice (Joly et al., 2012; Belin et al., 2004). Neuroimaging evidence indicates that human vocal processing engages the left prefrontal cortex (Fecteau, Armony, Joanette & Belin, 2005), namely the temporal pole, the orbitofrontal cortex and the frontal gyrus during emotional judgments (Royet et al., 2000). Right inferior-frontal and posterior regions, as subcortical structures and left frontal regions, are also critical during emotional prosody processing (Adolphs, 2012). Prosody is a set of suprasegmental acoustic parameters that vary during speech production and let the listener deduce the affective state of the speaker (Scherer, 1995). These findings suggest that vocal emotional processing involves a set of specific brain areas (Adolphs, 2012) that together ensure the primacy of vocal cues processing by means of voice-sensitive cortical regions, as specific areas of superior temporal sulcus (Belin, Zatorre, Lafaille, Ahad & Pike, 2000).

Behavioral evidence indicates that non-linguistic affect vocalizations can be decoded more accurately and have a communicational advantage over emotional prosody (Hawk et al., 2009). The study of Schirmer, Simpson and Escoffier (2007) indicates that intensity changes elicit more attentional resources when they are vocally expressed relative to when they are non-vocally expressed. The importance of studying non-verbal vocalizations is also supported by other arguments. Unlike spoken words or speech in general, they do not count with a referential context, a segmental structure and semantic information (Kotchoubey, Kaise, Bostanov, Lutzenberg & Birbaumer, 2009; Sauter & Eimer, 2010) and differ from emotional prosody in different ways (Laukka et al., 2013). Since non-verbal vocalizations are devoid of linguistic information, developing a branch of research devoted to its study avoids potential confounds relative, for example, to the overlapping processing of lexical-semantic and emotional information that is embedded in speech. Additionally, there is the need for increasing the amount of electrophysiological data on the contribution of specific auditory cues to the processing of emotion in non-linguistic vocalizations (Liu, Pinheiro, Deng et al., 2012).

1.2 Auditory Affective Processing

There is substantial evidence demonstrating the neural correlates of emotional processing in the visual modality, but the same cannot be said of auditory cues (Adolphs, 2012). Nevertheless, a recent study pointed out to the discriminability advantage that affective vocalizations can have in the absence of visual information, through the higher decodability of some vocalizations (e.g., e.g., anger, contempt, disgust, fear, sadness, and surprise) over faces (Hawk et al., 2009). The visual domain is often more attended than the auditory, but when this type of information is out of our focus vocal cues acquire vital relevance (Näätänen, Kujala, & Winkler, 2011). Vocal cues are central for the communication of emotional states, for the reorientation of attention (Scherer, 1994), and in the absence of other sources of information, for alerting to hypothetically meaningful events. Taking into account the competition of various stimuli from auditory and other sensory modalities to reach our attention (Schupp et al., 2003), it is of notable importance the role of auditory cues in prompting adaptive behavior and, ultimately, the survival process.

In the context of auditory processing research, the article from Schirmer and Kotz (2006) proposes a multi-stage model of vocal emotional processing. According to the authors, this processing consists of a cascade of individual sub-processes (Schirmer & Kotz, 2006). Each of the sub-processes has a distinct function, including: i) the analysis of acoustic cues; ii) the detection of the emotional salience of those acoustic cues; and iii) the cognitive evaluation of the emotional significance of a vocal stimulus. The first analysis consists of exploring acoustic properties such as amplitude, tempo, voice intensity, fundamental frequency (F0 or pitch) and voice quality (that indicates the emotional intent in speech) (Juslin & Laukka, 2001; Scherer, 2003; Schirmer & Kotz, 2006). Each emotion conveyed by sound is characterized by a specific constellation of these acoustic parameters that can be taken as a profile (Schirmer & Kotz, 2006). That subsequently works as an auditory object with a specific emotional salience (Paulmann & Kotz, 2008). For example, a fast speech rate, high intensity and mean pitch characterizes happiness; high intensity, high speech rate and mean F0 characterizes hot anger (Schirmer & Kotz, 2006).

The event-related potential (ERP) methodology has shed light on the time course of these sub-processes. The process of automatically detecting emotional salience from auditory cues was found to be indexed by a positive ERP component that peaks around 200 ms (P200). Some recent studies showed that the P200 reflects the prompt discrimination of emotional from neutral features of auditory stimuli (Liu, Pinheiro, Deng et al., 2012; Liu, Pinheiro, Zhao et al., 2012). There is increasing evidence highlighting ERPs as a unique methodology to unfold the mechanisms underlying vocal emotional processing. The last sub-process of the model proposed by Schirmer and Kotz (2006) is related to how the first stages are integrated to reach higher order cognitive operations, such as evaluative judgments or semantic processing.

The present work will be mainly focused on the electrophysiological correlates underlying the second stage of the model related to vocal emotional processing.

1.3 Emotional Vs. Neutral Stimuli Processing

The recent literature corroborates the assumption of an early differentiation between neutral and emotional stimuli. Electrophysiological studies show that around 200 ms after stimulus onset it is possible to make a distinction between emotional and neutral acoustically matched control sounds (Sauter & Eimer, 2010) and natural sentences with emotional prosody (Paulmann & Kotz, 2008; Pinheiro et al., 2013). In the same sense, differences between emotional and neutral syllables (irrespective of speaker voice) were found through an oddball paradigm (Schirmer et al., 2005) similarly to what will be addressed by the present study. Despite being one of the few studies addressing the interesting issue of the automatic index of emotionality discrimination, the study used stimuli varying in emotional prosody, which does not allow the investigation of the pure emotionality effects giving that an overlapping linguistic processing could be occurring. Jessen and Kotz (2011) also found that emotional vs. neutral auditory stimuli discrimination is reflected by differences in the amplitude of N100, P200 and Late Positive Complex ERP components. These findings demonstrate the influence of emotional salience over early sensory (Spreckelmeyer, Kutas, Urbach, Altenmuller & Munte, 2009) and later information processing stages (Jessen & Kotz, 2011), indicating that the brain integrates basic acoustic cues and derives its emotional significance in a short time window (Liu, Pinheiro, Zhao et al., 2012).

Considering electrophysiological studies using non-verbal vocalizations only, Liu, Pinheiro, Deng and colleagues (2012) observed a distinct response to emotional compared to neutral vocalizations 50 ms after stimulus presentation. Such early mechanisms make sense in light of the significance that a quick and reliable detection of affective signals has in understanding the environment and the behavioral intentions of others. Other studies in this domain failed to use authentic vocalizations as neutral and emotional stimuli (Sauter & Eimer, 2010) or do not allow making comparisons between the two classes of auditory stimulation (Bostanov & Kotchubey, 2004).

Based on the abovementioned evidence suggesting an automatic processing of emotional compared to neutral stimuli, one could wonder how this type of processing occurs when the stimuli are non-verbal vocalizations varying in valence (neutral, positive and negative). According to Dolan (2002), valuable environmental events should have a privileged perceptual processing. In that sense, one can discuss if that enhanced perceptual experience has influence on the processing of stimuli varying in valence. Valence is a concept introduced by Lang, Greenwald, Bradley and Hamm (1993) within a dimensional approach to emotional processing. It is considered to be a continuum between positive and negative poles, which underlies appetitive or aversive ratings of stimuli, respectively, based on inner motivational systems (Stevenson & James, 2008). Considering the importance of studying non-verbal ecological sounds processing, it is worth it to investigate how the valence of those stimuli is processed under the electrophysiological scope.

1.4 The Event-Related Potentials Methodology And The Mismatch Negativity

Because of its excellent temporal resolution, the ERP methodology is ideal to investigate the time course of sensory and higher order cognitive operations (Light, Swerdlow & Braff, 2007; Duncan et al., 2009; Rissling et al., 2012). An ERP component is obtained through an electroencephalogram and consists of averaged electrophysiological data time-locked and associated with a physical or mental stimulus (Duncan et al., 2009). The latency, the polarity (positive or negative), the scalp distribution and the relationship with the eliciting events characterize the ERP component (Duncan et al., 2009). Unlike behavioral measures, this methodology can tap into different processing stages during overt responses or implicit tasks (without focused attention). The last case exemplifies the type of experiment through which the Mismatch negativity (MMN) component is elicited. MMN is an auditory ERP component that reflects an automatic form of sensory memory formation and a deviance detection mechanism (Näätänen, 2001, 2003; Schirmer, Striano & Friederici, 2005). To elicit the MMN it is necessary that a comparison between a novel stimulus and a well-formed 'echoic' memory trace occurs (Winkler, Cowan, Csépe, Czigler & Näätänen, 1996). The traditional oddball paradigm by which the auditory MMN is elicited consists of a sequence of standard stimuli – an invariant sequence of sounds – interrupted by infrequent stimuli that deviate from the first ones in any physical characteristic (e.g., frequency (pitch), duration (length), intensity or location) (Näätänen, 1995; Light et al., 2007). MMN is the difference waveform obtained by subtracting the averaged ERP of the standard stimulus to the averaged ERP of the deviant stimulus (Duncan et al., 2009). The MMN onset occurs as early as 50 ms and has expected peak latency that varies from 90 to 250 ms from stimulus onset (Light et al., 2007; Näätänen, 2001). The resulting waveform is a negative deflection in the scalp-recorded ERP that have about 5 mV maximum peak over fronto-central regions of the brain (Garrido, Kilner, Stephan & Friston, 2009). There are two main reasons for studying this ERP component. Firstly, MMN is an automatic brain response and so it can be elicited irrespective of the direction of attention or during the parallel performance of mental operations (Light et al., 2007). Secondly, it is stable over time and allows rapid evaluations (Light & Braff, 2005).

2. AIMS OF THE STUDY

The aims of this study were to investigate the time course of the processing of non-verbal vocalizations varying in valence (neutral vs. positive and negative), and to get a deeper understanding of how the automatic processing of emotional vs. neutral vocal stimuli occurs. The ERP methodology was used in order to better unfold these earliest stages of information processing with a millisecond precision. A modified oddball task was used based on evidence highlighting its value in the comprehension of auditory perception and sensory memory representations (Duncan et al., 2009). Given the assumption that eased stimuli discrimination produces more negative (increased) MMN amplitudes and considering the results reported by Schirmer and cols. (2005), we hypothesized that emotional compared to neutral vocalizations would elicit augmented MMN amplitude. We expected to observe a differential effect of positive and negative processing over MMN amplitude given that previous research showed that valence modulates the cognitive processes associated with different stages of information processing (Delplanque, Lavoie, Hot, Silvert & Sequeira, 2004). Given that literature suggests a negativity bias on information processing (Smith, Cacioppo, Larsen & Chartrand, 2003; Yuan et al., 2007) and that negative events require a quick and reliable detection for survival purposes, we hypothesized that increased MMN amplitude would be elicited for angry relatively to happy vocalizations. In addition, we explored the role of context in the modulation of the MMN amplitude of neutral stimuli by creating two types of conditions: one condition where neutral sounds will appear in the context of angry sounds and, another where neutral sounds will appear in the context of happy ones. We hypothesized that no statistical differences between the two neutral conditions would be observed, since only differences due to valence were expected.

3. METHODOLOGY

3.1 Participants

Participants were 17 healthy college students (8 females; 23.00 ± 3.40 years). Participants were recruited at the University of Minho, in Braga, Portugal. They received course credit for the participation in the experiment. All were right-handed, native Portuguese speakers, free of psychiatric or neuroleptic medication, substance use (e.g., caffeine, tobacco, drugs) and, psychological, neurological or hearing impairments. Ethics approval was obtained from the Ethics Committee on Research (School of Psychology, University of Minho). After a complete description of the study, all participants provided written informed consent. The cocio-demographical characteristics of the sample are displayed in Table 1.

Table 1.
Socio-demographical characteristics of the sample.

	N = 17	
	M (SD)	Range
Verbal IQ[1]	121.82 (10.41)	106-140
Verbal Comprehension Index (VC Index)[1]	122.76 (10.84)	106-139
Working Memory (WM Index)[1]	115.24 (15.27)	91-145
BSI (PSI)	1.23 (0.17)	1-1,50

	Age (years)	
	M (SD)	Range
Sex		
Female (*N* = 8)	21.75 (1.98)	19-24
Male (*N* = 9)	24.11 (3.82)	20-31

[1] The Verbal IQ [t (15) = 2.588, p = 0.021], the VC Index [t (15) = 2.271, p = 0.038], and the WM Index [t (15) = 2.645, p = 0.028] significantly differed between men and women: men showed superior IQ, VC and WM Indexes relatively to women.

Wechsler Adult Intelligence Scale – Third Edition (WAIS-III) (Wechsler, 2008) was administered in order to obtain a cognitive assessment of the participants. The three cognitive measures obtained were: Verbal Intelligence Quotient (IQ) (121.82 ± 10.41), Verbal Comprehension Index (122.76 ± 10.84), and Working Memory Index (115.24 ± 15.27). To rule out the presence of psychological or psychiatric symptoms, the Brief Symptom Inventory (Canavarro, 2007) was administered to participants and no evidence of symptoms was found (Positive Symptoms Index (PSI): 1.23 ± 0.17). The Edinburgh Handedness Inventory (Oldfield, 1971) was used to assess and select right-handed subjects, only.

3.2 Materials and Stimuli

The auditory stimuli used in the oddball paradigm were examples of human vocalizations varying in emotional valence: happy, angry and neutral intonation. We picked anger and happiness vocalizations from negative and positive valence range emotions, respectively, because there is evidence that they are recognised cross-culturally and above chance (Laukka et al., 2013). The sounds were selected from the *Montreal Affective Voices* database (Belin, Fillion-Bilodeau & Gosselin, 2008) of non-verbal emotional bursts. In order to rule out any language-culture specific factors (Scherer, Banse, & Wallbott, 2001) related to the processing of affective vocalizations, the sounds were first validated to the European Portuguese population. The sample was composed of 60 participants (30 females; 21.97 ± 3.382 years) recruited at the University of Minho, in Braga, Portugal. They received course credit for the participation.

Based on valence, arousal and dominance ratings, three files, one of each supramentioned intonation, were chosen to be part of the experiment. The three vocalizations selected were reliable in terms of normative ratings of valence (5.32 ± 1.081, for happy; 4.67 ± 0.896, for neutral; and 3.40 ± 1.659, for angry vocalizations), arousal (5.33 ±2.237, for happy vocalizations; 3.32 ± 2.288, for neutral vocalizations; and 5.72 ±, 2.179 for angry vocalizations) and dominance (6.77 ± 1.779, for happy vocalizations; 6.02 ± 2.347, for neutral vocalizations; and 5.02 ± 2.266, for angry vocalizations).

Figure 1. shows the spectrograms for each of the selected vocalizations. They were normalized in terms of volume, and rise and decay parameters (10 ms) through Audacity software (version 2.0.3; http://audacity.sourceforge.net). Table 2. describes the acoustic properties of the three vocalizations.

During the presentation of the auditory MMN paradigm, subjects were instructed to watch a silent and low arousal characteristics video to divert attention from the auditory stimuli.

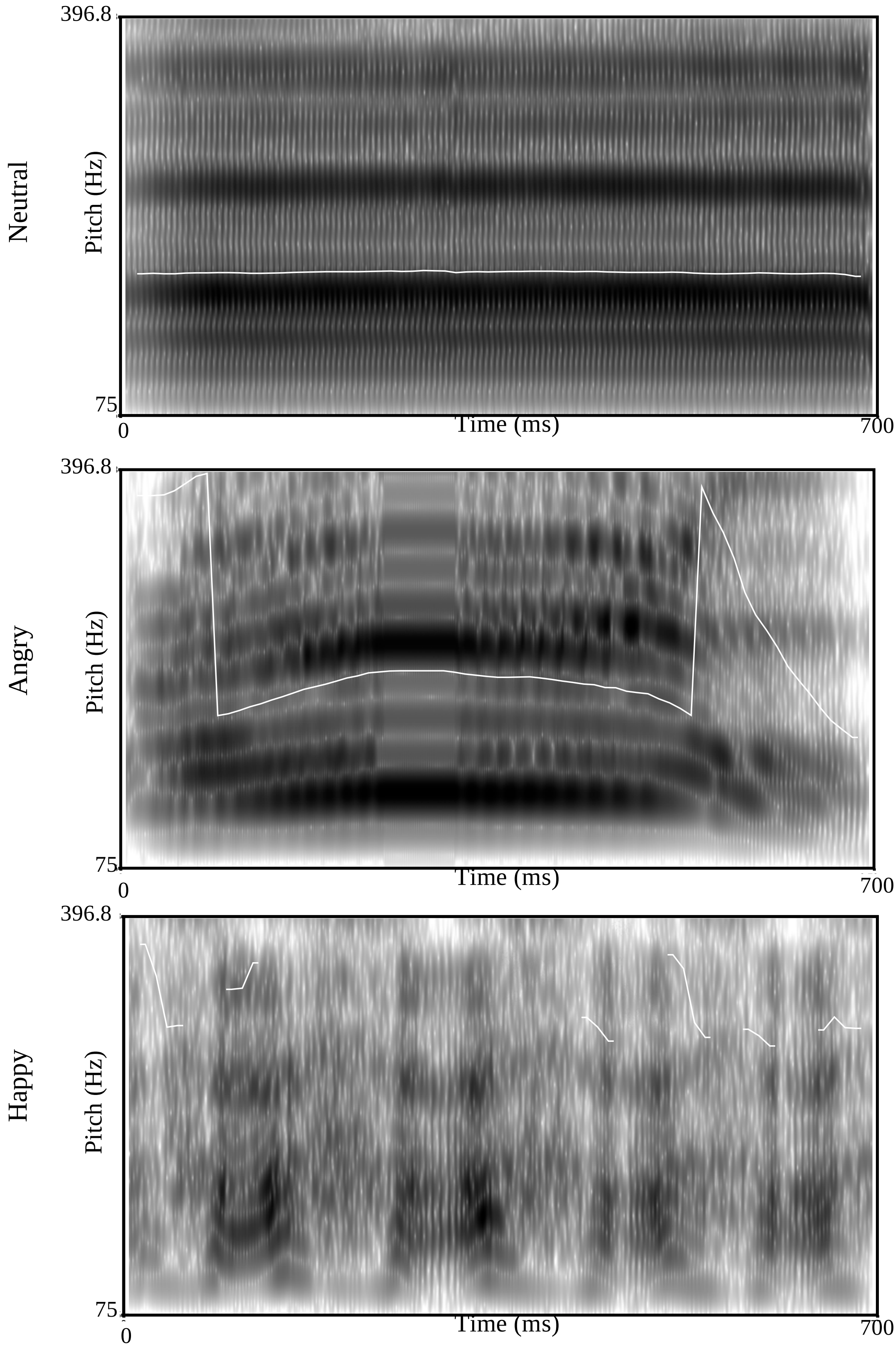

Figure 1. Spectograms for neutral, angry and happy vocalizations.

Table 2.
Acoustical properties of the sounds presented in the experiment.

	Neutral	Happy	Angry
Mean F0 (Hz)	190.57	322.02	248.32
Mean Intensity (dB)	74.89	70.56	78.04
Duration (ms)	700	700	700

The experiment was administered on a LG ACPI x86-based computer, using Presentation software (version 16.3; Neurobehavioral Systems, Inc., Albany, NY, USA) to manage the presentation and timing of auditory stimuli.

Participants filled a 9-point Self-Assessment Manikin scale (SAM, Bradley & Lang, 1994) at the end of the experimental sessions to rate the three vocalizations in terms of valence (1-Very Negative; 9- Very Positive), arousal (1-Low arousal; 9- High arousal) and dominance (1-Low dominance; 9-High dominance), and the expressed emotion in a forced-choice-task.

3.3 Procedure

The experiment took place in two sessions. The MMN paradigm was composed by two conditions – one condition per experimental session -, each one divided in two blocks. Each block had 1200 stimuli: 1050 Standard (STD) sounds and 150 Deviant (DEV) sounds (probabilities: STD=87,5%; DEV=12,5%). The three selected sounds (with neutral, angry and happy valence) were 700 ms long. Neutral, angry and happy vocalizations were used as both standards and deviants in different blocks in order to reduce the effect of the acoustic differences between the neutral and the emotional (angry and happy) conditions and to allow each sound to operate as its own acoustic control (Jacobsen & Schröger, 2003). A fixed inter-stimulus interval (ISI) of 500 ms was established. The block's design is exemplified in Figure 2.

The stimuli were presented in a pseudo-randomized order with a minimum of 6 standards occurring between each deviant. The order of the sounds' sequence per block was maintained equal across participants. In one of the conditions, the processing of angry vocalizations was tested and, neutral and angry vocalizations served as standards and deviants in two separate blocks. Neutral vocalizations were presented as standards and angry vocalizations as deviants in one block and, in a second block, the opposite occurred. The blocks' structure was the same for the other condition where the processing of happy vocalizations was tested. The presentation of the blocks was counterbalanced across participants as shown in Figure 3.

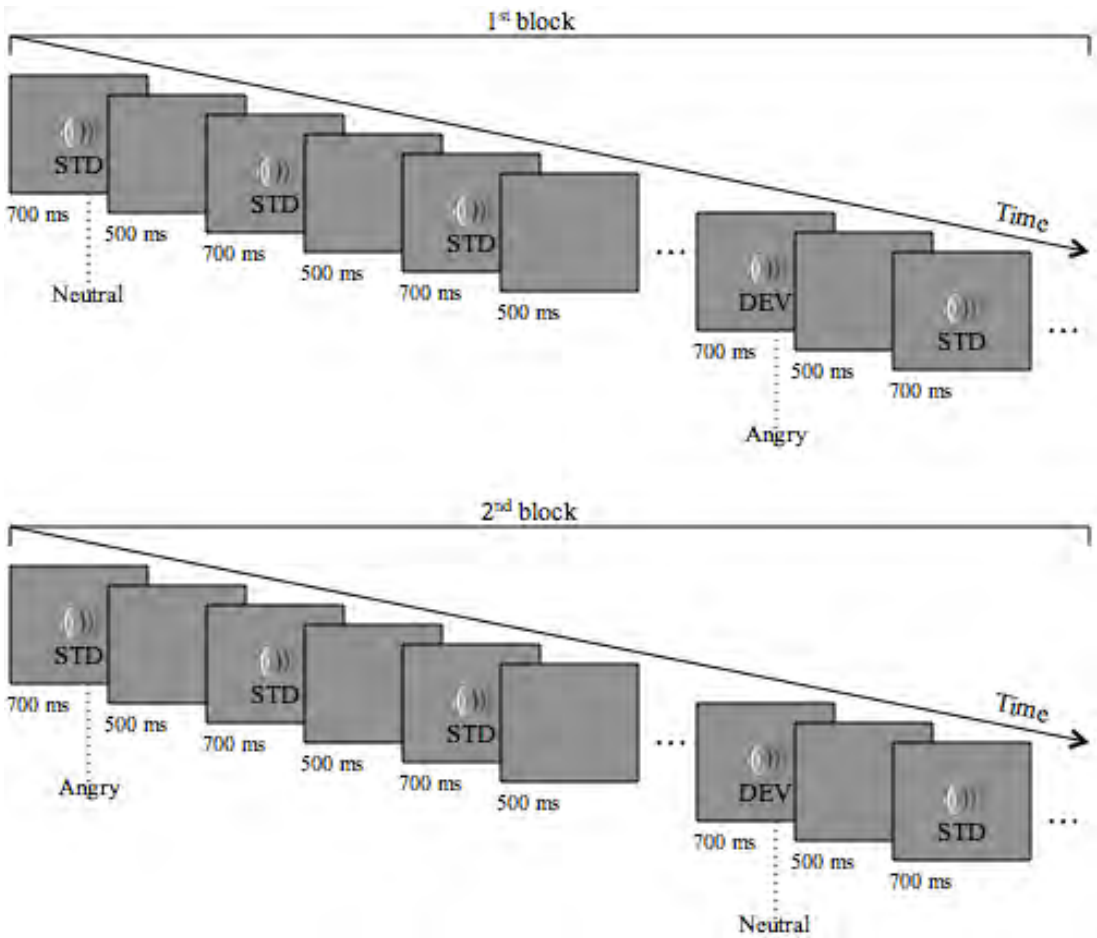

Figure 2. Schematic block sequence describing the timing of two blocks within an experimental condition.

	A		B		C		D	
	STD	DEV	STD	DEV	STD	DEV	STD	DEV
Block 1	Neutral	Angry	Angry	Neutral	Neutral	Happy	Happy	Neutral
Block 2	Angry	Neutral	Neutral	Angry	Happy	Neutral	Neutral	Happy
Block 3	Neutral	Happy	Happy	Neutral	Neutral	Angry	Angry	Neutral
Block 4	Happy	Neutral	Neutral	Happy	Angry	Neutral	Neutral	Angry

Figure 3. The counterbalancing was made through four blocks' schemes (A, B, C or D). The experiments were composed by four blocks and followed one of the four schemes. To each participant was attributed one of the four counterbalancing schemes.

Participants were given a 15 minutes break after the presentation of the first block of a session. During the presentation of the MMN paradigm, the participants were asked to ignore the auditory stimuli and to pay attention to a silent movie, once they had to tell its story in the end of the session.

3.4 EEG Data Acquisition

Electrophysiological data were recorded using the ActiveTwo BioSemi system (BioSemi, Amsterdam, The Netherlands) with a 512 Hz sampling rate. Recordings were made using a custom 64 channel-cap according to the international 10/20 system and 2 flat-type electrodes placed on the left and right mastoids. Ocular artifacts were monitored through 3 flat-type facial electrodes: two electrodes placed at the canti of each eye (horizontal electrooculogram) and one electrode placed below the left eye (vertical electrooculogram).

Recordings were made in a sound attenuated and electrically shielded room. Subjects sat 100 cm away of a desktop computer and were instructed to relax and remain as still as possible to avoid eye and motor artifacts. The auditory stimuli were presented through a set of Sennheiser CX 300-II ear-canal phones with 19 to 21,000 Hz of frequency response and 113 dB of sound pressure.

3.5 EEG Processing

Off-line EEG analysis was conducted using BrainVision Analyser software (Brain Products GmbH, Munich, Germany). The algebraic sum of the left and right mastoids was used as offline reference for the EEG data. Individual epochs, time-locked to the onset of the stimuli, were extracted from the datasets. The epochs' segmentation started 100 ms before each vocalization onset and finished 1000s after stimulus onset. The EEG was corrected for blinks and eye movements using the method developed by Gratton, Coles and Donchin (1983). Specific epochs for individual channels were excluded in each trial, using the semiautomatic rejection, with artifacts (e.g., eye movements, blinks, muscle activity) identified by the following criteria: exceeding ± 100 mV of voltage. ERPs were composed by separately averaging each vocalization condition: 1) Neutral 1 (neutral in context of angry), 2) Angry, 3) Neutral 2 (neutral in context of happy), 4) Happy. At least, 85% of the segments passed the artifact rejection step and the following number of segments per condition was used as standards and deviants, respectively: Angry (913.77±72.30; 128.82±13.88), Neutral 1 (904.47±90.10; 132.29±9.74), Happy (907.53±93.25; 130.59±15.00), and Neutral 2 (907.77±110.72; 131.18±13.41). The activity of each vocalization, as a standard, was subtracted to the activity of the same vocalization as a deviant (Johnson, 1993). Mean amplitude and peak latency measurements were conducted for the negative deflection MMN occurring in a latency window from 140 to 240 ms after stimulus onset.

3.6 Statistical Analyses

Visual inspection of grand averages waveforms identified the distribution of MMN effects mainly over the fronto-central region.

Mean amplitudes and peak latencies were separately analyzed through Repeated Measures Analyses of Variance (ANOVAs) with emotion (neutral 1, angry, neutral 2, happy) and electrode (Fz, Cz) as within-subject factors. To investigate if there were MMN amplitude and peak latency differences between left and right hemispheres, Repeated Measures ANOVAs with emotion (neutral 1, angry, neutral 2, happy), electrodes (frontal, central) and hemisphere (left, right) as within-subjects factors were performed. Additionally, sex was included as between-subjects factor in an exploratory analysis of potential gender differences in MMN amplitude. Main effects were followed by pairwise comparisons, with Bonferroni correction.

Pearson correlations were computed to investigate the association between MMN amplitude (Fz, Cz), and BSI dimensions and indices, namely: Anxiety, Global severity, Interpersonal sensitivity, Somatization, Obsession-Compulsion, Depression, Hostility, Phobic anxiety, Paranoid ideation, Psychoticism, General Symptoms index and Positive symptoms index. Also, Pearson and Chi-Square tests were performed to investigate the association between MMN amplitudes and the three dimensions - valence, arousal and dominance - of the sounds' evaluation made by participants.

In an exploratory approach, Paired samples T-tests were performed to test differences of valence, arousal and dominance between the three vocalizations that participants evaluated after the end of the experiment. Also, a Repeated Measures ANOVA with emotion (neutral, angry and happy) and dimension (valence, arousal and dominance) as within-factors, and sex as between-factor was computed to investigate potential differences in ratings between men and women.

4. RESULTS

Figure 4. shows grand average waveforms for Neutral 1 (neutral in context of angry), Angry, Neutral 2 (neutral in context of happy) and Happy conditions, at frontal (Fz/1/2) and central (Cz/1/2) electrodes.

4.1 MMN Amplitude

Analysis of mean amplitude revealed a main effect of emotion [F (3, 48) = 8.219, p < 0.001]: MMN amplitude was more negative for Happy (p = 0.001) and Neutral 2 (p = 0.032) conditions compared with Angry, and no other significant differences were found between the four emotions. The additional hemispheric analysis involving F1/2 and C1/2 electrodes showed no significant effects or interactions involving the hemisphere factor.

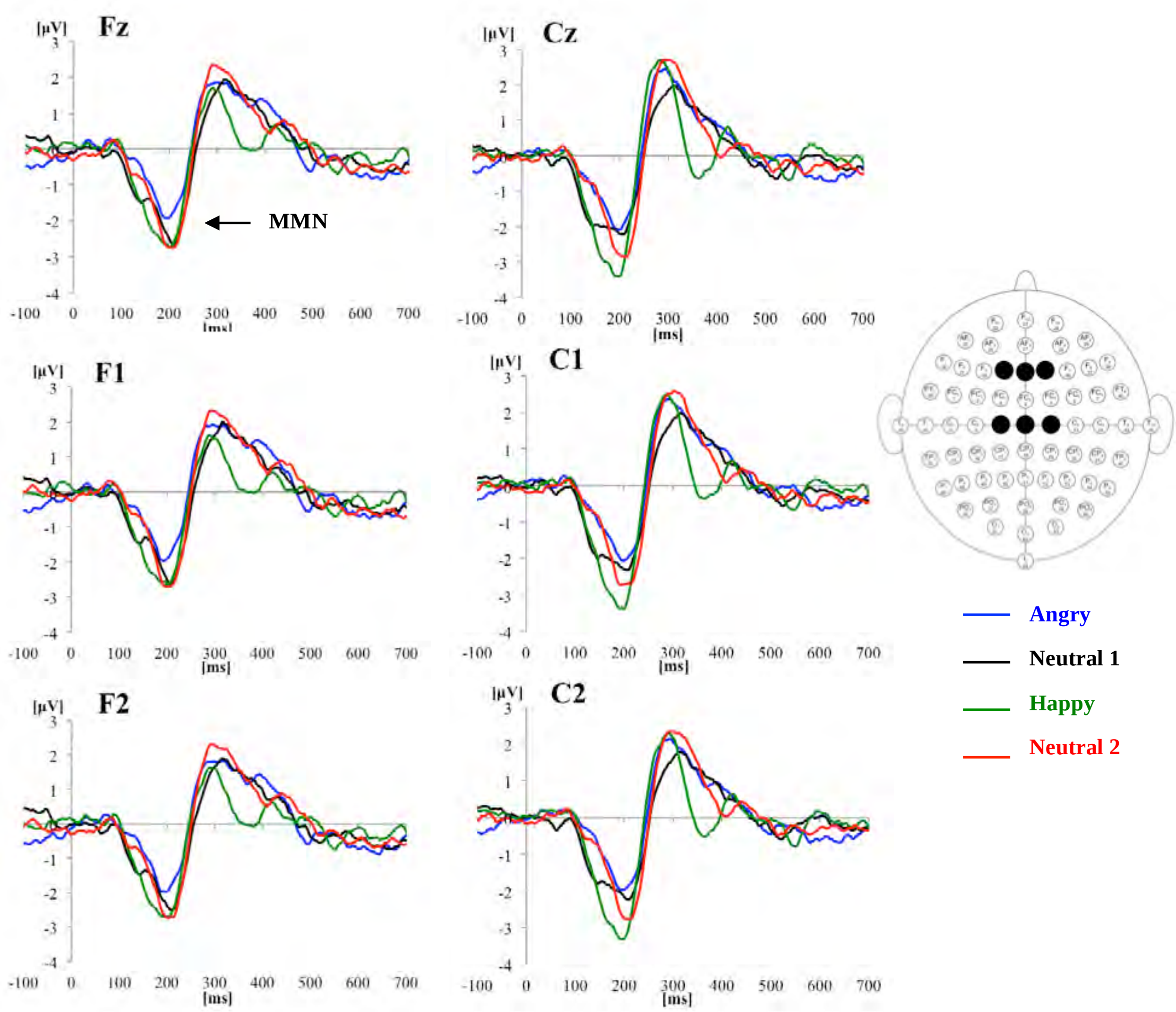

Figure 4. ERP waveforms to angry, neutral 1 (neutral in context of angry vocalizations), happy and neutral 2 (neutral in context of happy vocalizations) vocalizations at Fz, F1, F2, Cz, C1 and C2 electrode sites (the black spots in the Biosemi layout at the right side of the figure). MMN was more negative for Happy and Neutral 2 conditions compared with the Angry one.

There were no statistically significant differences between men and women in MMN amplitude, both in the midline and hemispheric analyses.

4.2 MMN Peak Latency

Analysis of MMN peak latencies showed no main effects or interactions in both midline and hemispheric analyses. There were no statistically significant differences between men and women in MMN latency, both in the midline and hemispheric analyses.

4.3 Correlation Analysis

Concerning the associations tested between the neurocognitive, the BSI and the MMN amplitude data, the analyses showed no statistically significant associations.

4.4 Ratings of Sounds' Affective Dimensions

Paired samples T-tests revealed significant differences between the sounds rated by participants in each of the dimensions assessed. Concerning valence, there were significant differences between: neutral and angry [t (16) = 4.955, p < 0.001], with higher valence for neutral than for angry stimulus; neutral and happy [t (16) = -11.279, p < 0.001], with higher valence for happy than for neutral stimulus; and, angry and happy [t (16) = -8.144, p < 0.001], with higher valence for happy than for angry stimulus. Considering the arousal dimension, differences were observed between: neutral and angry sounds [t (16) = -10.783, p < 0.001], with higher arousal for angry than for neutral stimulus; and, neutral and happy [t (16) = -7.467, p < 0.001], with higher arousal for happy than for neutral stimulus. For the dominance dimension, the significant differences were the following: neutral vs. angry [t (16) = 8.054, p < 0.001], with higher control for neutral than for angry stimulus; angry vs. happy [t (16) = 9.114, p < 0.001], with higher control for happy than for angry stimulus. The repeated Measures ANOVA did not show a significant interaction between gender and any of the dimensions rated (valence, arousal and dominance) (p > 0.05).

5. DISCUSSION

The present electrophysiological study examined how valence has a role on the emotional nonlinguistic vocalizations processing when they are unattended. As far as our knowledge goes, this work provided, for the first time, ERP evidence in favor of the automatic discrimination between emotional and neutral, and between positively and negatively valenced vocalizations. Mainly, it was observed the following: an increase in MMN amplitude for Happy and Neutral 2 (neutral in context of happy) conditions compared to the Angry one, at midline electrodes.

The question of what neural processes stay behind the division, or borderline between, the conscious perception has been one of the most intriguing and debated issue of cognitive neuroscience (Näätänen, 2011). One can wonder how much of the auditory experience escape to our consciousness and by what means it reaches our attention. It is in this context that MMN acquires a significant biological role as an automatic brain mechanism of echoic memory updating and deviance detection (Näätänen, 2003). MMN ensures the alarm function of the brain through a quick and reliable evaluation of the eliciting events, and the subsequent cascade of steps leading to cognitive processing.

In what respects to the possible modulation effect of valence over earlier stages of processing, the results run against the predefined hypothesis: the MMN amplitude for angry vocalizations was significantly smaller relatively to the happy ones. The present finding challenges two previous views about emotional stimuli processing: first, that there is a negativity bias in the processing of these stimuli (Smith, Cacioppo, Larsen & Chartrand, 2003), and second, that angry stimuli had a facilitated processing given to its signaling function for survival. Our results point to the fact that, in a temporal window where it is believed that there is no intervention of cognitive processes, the brain is able to distinguish between positive and negative vocalizations and so, valence modulates MMN amplitude; also, they demonstrate that deviance detection mechanisms are more allocated to happy vocalizations. In a close study of Schirmer and colleagues (2005), the authors showed that happy syllables elicit shorter MMN latencies; in our results the effect of positive valence was found over MMN amplitude conversely to latency. We suggest that the mood of participants could potentially account for the observed results. The mood was not tested before the experiment takes place. Nevertheless, the analyses of BSI data revealed that the healthy controls sample did not have positive symptomatology and that BSI scores were not correlated with the MMN amplitudes. Thus, we hypothesized that participants mood was more positive than what is found in clinical samples. Accordingly with this possible explanation, there are studies showing advantages in positive information processing (Unkelbach, Fiedler, Bayer, Stegmuller & Danner, 2008), demonstrating a priming effect of mood over the encoding of mood-congruent stimuli (Kiefer, Schuch, Schenck & Fiedler, 2007) and suggesting that happy emotionality has influence over early sensory auditory processing stages (Spreckelmeyer et al., 2009).

Also, we could argue the possible role pitch had on modulating MMN amplitude. It was already recognized that there is a memory-based comparison of pitch, at a preattentive level (Jacobsen & Schröger, 2001), and that this acoustic parameter is among the auditory cues that play a role in the perception of emotion from nonverbal vocal cues (Sauter, Eisner, Calder & Scott, 2010). Attending to the direction of the differences in pitch found between stimuli (Neutral = 190.57 Hz; Angry = 248.32 Hz; Happy = 322,02 Hz), we point this acoustic parameter as one potentially modulation factor of the deviance detection mechanisms observed.

Also, we put the hypothesis of not only valence, per se, accounting for an explanation of MMN amplitude discrepancies between the two emotional vocalizations. Significant differences were found between happy and neutral vs. angry dominance ratings in the evaluations of sounds made by participants. Dominance refers to the subjective sense of power over an eliciting event (Osgood, 1975). We believe that, along with valence, the observed dominance ratings reinforced the relevance of stimuli and modulated the MMN response for both happy and neutral (in context of happy) vocalizations. We showed for the first time that brain recognizes added social relevance to happy vocalizations relatively to angry ones, by means of the auditory change detection mechanisms that are engaged (Schirmer et al., 2007).

Concerning the first hypothesis highlighted for this study, we weren't able to show that emotional stimuli were easily discriminated comparatively with neutral. We demonstrate the opposite, finding larger MMN amplitudes for Neutral 2 condition comparatively with Angry. This evidence is not in line with previous related studies showing greater MMN for emotional comparatively with neutral vocal expressions (Schirmer et al., 2005), and the same pattern obtained through perceptual and cognitive ERP components when digitized sounds (Liu et al., 2012a) and non-linguistic vocalizations (Liu et al., 2012b) are processed. Our finding means that there is a greater deviance detection response for neutral vocalizations when they appear in the context of happy ones, relatively to the response observed for angry sounds. Previously, Thierry and Roberts (2006) also found an effect of neutrality in an early processing stage, when comparing neutral with unpleasant digitized sounds. Additionally, the discrepancies in pitch between standards and deviants in the Neutral 2 condition were much stronger than in the Neutral 1 condition, what is suggested to explain the statistical differences found in neutral 2 condition relatively to angry condition. Our results also suggest that arousal could potentially be inversely correlated with MMN amplitude.

No statistically significant differences were found between the two neutral conditions, despite the visual inspection of grand average waveforms pointing to the opposite. This finding indicates that the emotional valence of the underlying contexts (angry vs. happy) in which neutral vocalizations appeared do not modulate the MMN amplitude for neutral stimuli as expected. Accordingly, the results demonstrate that the deviance detection mechanisms allocated to neutral vocalizations processing are not dependent on contextual characteristics of the stimuli.

The present results point that even when auditory processing is occurring implicitly, the brain does not bypass emotional information. We wonder if the unexpected findings are due to specific constraints of Portuguese population. A larger and a homogeneous sample in terms of sex would be desirable. Despite the spatial constraints of ERP technique, topographic maps would help to unfold possible differences between electrode sites. Future studies should explore the differential electrophysiological processing of distinct types of positive and negative non-verbal vocalizations. Additional studies are needed to continue to address this research topic, using both ERP and fMRI methodologies to foster more experimental data on the automatic tagging and cognitive processing of non-verbal vocalizations.

6. GENERAL CONCLUSION

In summary, the results of our experiment show that auditory automatic change detection mechanisms are more pronounced for positive comparatively to negative vocalizations, and to neutral (when in happy vocalizations context) relatively to negative vocalizations. This finding suggests that MMN underlies an advantageous brain mechanism for detecting events' emotionality even in circumstances where attentional resources are not allocated to the main task. More studies are needed to investigate how different types of emotional non-verbal vocalizations are automatically and cognitively processed by the brain.

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