Universidade do Minho
Escola de Psicologia

Paula Maria dos Santos Castiajo

Emotional voice perception and its relationship with hallucination predisposition: An ERP investigation

dezembro de 2020

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Emotional voice perception and its relationship with hallucination predisposition: An ERP investigation

Tese de Doutoramento
em Psicologia Aplicada

Trabalho efetuado sob a orientação da
Professora Doutora Ana Patrícia Teixeira Pinheiro

dezembro de 2020

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Universidade do Minho, 18/12/2020

Assinatura: Paula Maria dos Santos Castro

Em memória do meu querido e muito amado Pai, que partiu antes do fim desta jornada e que sei que teria, mais uma vez, muito orgulho em mim!

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Perceção emocional na voz e a sua relação com a predisposição para alucinações: Uma investigação baseada em potenciais evocados

Resumo

Enquadramento: Alterações do processamento sensorial e cognitivo de emoções vocais têm sido associadas a alucinações verbais auditivas (AVA) nas perturbações psicóticas. No entanto, permanece por esclarecer se uma relação semelhante ocorre em indivíduos com elevada propensão para alucinações (PA). Um processamento emocional vocal alterado em indivíduos com elevada PA suportaria a hipótese do *continuum* da psicose. **Objetivo:** Esta Dissertação tem como objetivo principal investigar os correlatos eletrofisiológicos do processamento emocional vocal em indivíduos com elevada PA, e especificar as contribuições da valência e de pistas acústicas dos estímulos. Para garantir rigor no processo de avaliação do processamento emocional vocal com potenciais evocados (PE), dois estudos adicionais precederam os estudos de PE. Assim, foram realizados um total de quatro estudos nesta Dissertação. O Estudo 1 procurou adaptar e validar a LSHS (16-itens), um instrumento de despiste para a presença de alucinações em indivíduos não-clínicos, para a população portuguesa, e descrever as características fenomenológicas das experiências alucinatórias numa amostra não-clínica portuguesa. O Estudo 2 teve como objetivo identificar a quantidade mínima de informação acústica necessária para o reconhecimento de emoções em vocalizações não-verbais, e validar um conjunto de vocalizações emocionais não-verbais com duração variada. Nos estudos 3 e 4 foram analisadas as características e a dinâmica de componentes dos PE para, respetivamente: 1) examinar o impacto da PA na perceção emocional vocal, e especificar se o curso temporal do processamento da voz é afetado por manipulações de intensidade e duração do som; 2) clarificar de que forma a emoção e atenção interagem durante o processamento da voz em função da propensão para AVA, e examinar as contribuições da valência e intensidade do estímulo. **Resultados:** No Estudo 1, a adaptação Portuguesa da LSHS (16-itens) revelou uma estrutura de três fatores. Pensamentos intrusivos ou vívidos e alucinações relacionadas com o sono foram o tipo mais comum de alucinações. Contudo, fundamentalmente percebidas como experiências positivas, todos os tipos de alucinações foram descritos como incontroláveis e dominantes. No Estudo 2, a quantidade de informação acústica necessária para o reconhecimento de vocalizações não-verbais variou de acordo com o tipo de emoção: alegria (266 ms), nojo (296 ms) e tristeza (305 ms) foram corretamente identificados a partir de estímulos mais curtos do que raiva (342 ms) e medo (367 ms). No Estudo 3, elevada PA esteve associada a uma diminuição da amplitude de N1 e a um aumento da amplitude de P2 em resposta a vocalizações neutras mais longas e de intensidade sonora mais elevada (*vs.* positivas), e também a um aumento da amplitude de LPP para vocalizações negativas mais intensas e longas (*vs.* neutras). Estes resultados sugerem que a representação de saliência acústica em emoções vocais poderá estar alterada em função da PA. No Estudo 4, a amplitude da P3b foi geralmente maior para alvos vocais em participantes especificamente com AVA, independentemente da valência e intensidade das vocalizações, o que sugere dificuldades em distinguir informações vocais salientes (emocionais; intensas) de não salientes (neutras; suaves). **Conclusão:** Os estudos de potenciais evocados suportam a hipótese de saliência aberrante da psicose e a hipótese do *continuum* da psicose. **Palavras-chave:** Alucinações verbais auditivas; Emoção; Potenciais evocados; Propensão para alucinações; Voz.

Emotional voice perception and its relationship with hallucination predisposition: An ERP investigation

Abstract

Background: Altered processing of vocal emotions at both sensory and cognitive stages has been related to auditory verbal hallucinations (AVH) in psychotic disorders. However, whether a similar relationship occurs in individuals with high hallucination proneness (HP) remains to be clarified. Changes in vocal emotional processing in individuals with high HP would support the psychosis continuum hypothesis. **Objective:** This dissertation has as its main objective to investigate event-related potential (ERP) correlates of vocal emotional processing in individuals with high HP, and specify the contributions of stimulus valence and acoustic cues. To ensure a rigorous assessment of vocal emotional processing with ERPs, two additional studies preceded the main ERP experiments. Thus, a total of four studies were conducted in this Dissertation. Study 1 sought to adapt and validate the 16-item LSHS, a screening tool for the presence of hallucinations in non-clinical individuals, for the Portuguese population, and to describe the phenomenological characteristics underlying hallucinatory experiences in a Portuguese non-clinical sample. Study 2 aimed to identify the minimum amount of acoustic information necessary for recognition of emotions from non-verbal vocalizations, and to validate a set of non-verbal emotional vocalizations varying in duration. Studies 3 and 4 aimed to analyze the features and dynamics of the ERP components to, respectively: 1) examine the impact of HP on vocal emotional perception, and specify whether the time course of voice processing is affected by manipulations of sound intensity and duration; and 2) clarify how emotion and attention interact during voice processing as a function of AVH proneness, and examine the contributions of stimulus valence and intensity. **Results:** In Study 1, the Portuguese adaptation of the 16-item LSHS revealed a three-factor structure. Further, intrusive or vivid thoughts and sleep-related hallucinations were the most common type of hallucinations. Although, fundamentally perceived as positive experiences, all types of hallucinations were described as uncontrollable and dominating. In Study 2, the amount of acoustic information necessary for recognition of non-verbal vocalizations varied by emotion type: amusement (266 ms), disgust (296 ms), and sadness (305 ms) were correctly identified from shorter stimuli than anger (342 ms) and fear (367 ms). In Study 3, higher HP was associated with decreased N1 and increased P2 amplitudes in response to louder and longer neutral (*vs.* positive) vocalizations, as well as with a larger LPP to louder and longer negative (*vs.* neutral) vocalizations. These findings suggest that the representation of acoustic salience in vocal emotions may be altered as a function of HP. In Study 4, P3b amplitude was generally increased in response to vocal targets in participants specifically reporting AVH, irrespective of valence and intensity of vocalizations, which suggests difficulties in distinguishing salient (emotional; loud) from non-salient (neutral; soft) vocal information. **Conclusion:** The ERP studies support the aberrant salience hypothesis of psychosis and the continuum hypothesis of psychosis. **Keywords:** Auditory verbal hallucinations; Emotion; Event-related potentials; Hallucination proneness; Voice.

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List of Acronyms and Abbreviations

Amp	Amplitude
ANOVA	Analysis of variance
Aps	Action potentials
ATS	Anterior temporal sulcus
AVH	Auditory verbal hallucinations
AVH+	With auditory verbal hallucinations
AVH–	Without auditory verbal hallucinations
BSI	Brief Symptom Inventory
dB	Decibel
EEG	Electroencephalogram
e.g.	For example
ERP	Event-related potentials
F0	Fundamental frequency
fMRI	Functional magnetic resonance imaging
HEOG	Horizontal electrooculogram
Hz	Hertz
HP	Hallucination proneness
i.e.	That is
IFG	Inferior frontal gyrus
ISI	Inter-stimulus interval
KMO	Kaiser-Meyer-Olkin
LPP	Late Positive Potential
LSHS	Launay-Slade Hallucination Scale
MAV	Montreal Affective Voices
MMN	Mismatch negativity
MRI	Magnetic resonance imaging
ms	Milliseconds
mV	Millivolt
Neg	Negative
Neu	Neutral

Pos	Positive
PSPs	Post-synaptic potentials
PSYRATS	Psychotic Symptom Rating Scale
S	Seconds
SE	Standard error
SNR	Signal-to-noise ratio
SPQ	Schizotypal Personality Questionnaire
STD	Standard
STG	Superior temporal gyrus
ROI	Region of interest
TGT	Target
µV	Microvolt
VEOG	Vertical electrooculogram
VHs	Visual hallucinations
vs.	Versus

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PART I GENERAL INTRODUCTION

Chapter 1

1. Introduction

Schizophrenia is usually described as the most debilitating and chronic psychiatric disorder (Couture & Roberts, 2006; Fusar-Poli et al., 2007). Thus, detection of the first signs in those who are believed to be at high risk of converting to psychosis has been a priority in schizophrenia research (McGorry, et al., 2009). Risk factors for conversion can be found in first degree relatives of schizophrenia patients (genetic proneness) and non-clinical individuals with less severe negative and positive symptoms (clinical proneness) than those found in schizophrenia (Cornblatt et al., 2003). Auditory verbal hallucinations (AVH), i.e., the experience of hearing a voice when there is none (Woodruff, 2004), are within these symptoms that both psychotic patients and non-clinical individuals might share (Johns et al., 2004; van Os, Hanssen, Bijl, & Ravelli, 2000). Overall, epidemiological studies have shown that 5-28% of non-clinical individuals have had the experience of hearing voices (de Leede-Smith & Barkus, 2013; Johns et al., 2004; van Os, Hanssen, Bijl, & Ravelli, 2000; Tien, 1991), suggesting that these experiences might occur in a continuum between normal and pathological states (Baumeister, Sedgwick, Howes, & Peters, 2017). Phenomenologically, non-clinical AVH tend to be less severe than clinical AVH (Choong, Hunter, & Woodruff, 2007; Daalman et al., 2011; Larøi, 2012; de Leede-Smith & Barkus, 2013; Honig et al., 1998), although they seem to share common cognitive (Allen, Freeman, Johns, & McGuire, 2006; Brébion et al., 2016; Larøi, van der Linden, & Marczewski, 2004) and neural (Barkus, Stirling, Hopkins, Mckie, & Lewis, 2007; Diederen et al., 2012; Linden et al., 2010) mechanisms with clinical AVH. Thus, the experience of non-clinical AVH provides a unique opportunity to effectively establish the neural and cognitive mechanisms underlying AVH, with the advantage of avoiding confounding factors typically related to schizophrenia, i.e., medication, hospitalization, and concurrent presence of other symptoms such as negative symptoms (Badcock & Hugdahl, 2012).

Prodromal individuals (Addington et al., 2012; Toomey, Seidman, Lyons, Faraone, & Tsuang, 1999) also display similar deficits to schizophrenia patients (Pinheiro et al., 2013; 2014; Rossell & Boundy, 2005) in the perception of vocal emotions, which, in turn, seems to predict deficits in interpersonal functioning (Toomey, Seidman, Lyons, Faraone, & Tsuang, 1999). AVH have been related to a dysfunctional perception of vocal emotions in schizophrenia (Alba-Ferrara, Fernyhough, Weis, Mitchell, & Hausmann, 2012; Rossell & Boundy, 2005; Shea et al., 2007), which suggests that these deficits may contribute to the development of AVH (Alba-Ferrara, Fernyhough, Weis, Mitchell, & Hausmann, 2012). However, behavioral studies concerning the links between altered vocal emotional processing and the occurrence of positive-like symptoms (i.e., hallucinations and/or delusions) have shown divergent results, as some have found deficits in non-clinical individuals with positive-like symptoms (Addington et al., 2012; Amminger, Schäfer, Klier, et al., 2012; Amminger, Schäfer, Papageorgiou, et al., 2012) and others have not (Pinheiro, Farinha-Fernandes, Roberto, & Kotz, 2019). Few studies investigated the predictive value of vocal emotional processing impairments in a transition to psychosis (Allot et al., 2014; Corcoran et al., 2015), and none has used an electrophysiological method. Evidence using pure (neutral) tones (Lepock et al., 2018) has found that, similar to schizophrenia patients (Brown et al., 2000; Ford, 1999; Salisbury, Collins & McCarley, 2009), individuals at high-risk for psychotic disorder show deficits in both sensory processing (N1 component) and detection of salience (P2 component) of sounds (del Re et al., 2015), as well as in attention allocation to salient events of the environment [P3b component] (del Re et al., 2015; Hamilton et al., 2019; Özgürdal et al., 2008; van Tricht et al., 2011). Early sensory (N1, P2) and higher-order cognitive (P3b) processing of vocal emotions are also altered in schizophrenia patients (Pinheiro et al., 2013; 2104 Pinheiro & Niznikiewicz, 2019). However, the temporal dynamics of vocal emotional processing in individuals with hallucination proneness remains unclear. As event-related potentials (ERP) are examined before a behavioral response is made, they provide a direct measure of the sensory and cognitive processes under study. It is therefore crucial to clarify whether the occurrence of non-clinical hallucinations is related to both bottom-up sensory and higher-order cognitive changes in vocal emotional processing, and whether these putative changes are similar to those observed in schizophrenia patients. It is plausible that vocal emotional processing impairments and the experience of hallucinations in non-clinical individuals represent risk factors in the development of schizophrenia and, therefore, represent potential targets of early intervention in the disease (Kee, Horan, Mintz, & Green, 2004). Importantly, the putative observation of alterations in vocal emotional processing in non-clinical individuals with hallucinations may suggest the contribution of these

changes to the development of hallucinations also in non-clinical samples. This would support the hypothesis of a psychosis continuum (Baumeister, Sedgwick, Howes, & Peters, 2017).

In the current Dissertation, we will address these open questions using the ERP methodology. The excellent temporal resolution of ERP recording (in order of milliseconds – ms) is ideally suited for tracking brain changes during vocal emotional processing at both bottom-up sensory and higher-order cognitive processing stages. We hope to add to existing research by shedding light on how the processing of vocal emotions unfolds over time in non-clinical individuals varying in hallucination proneness.

1.1 Dissertation outline

This Dissertation's main goal was to examine how hallucination proneness affects the time course of vocal emotional processing reflected in distinct ERP indices. In this Chapter, we already provided a brief summary of the existing evidence on vocal emotional processing in non-clinical individuals with positive-like symptoms, and highlighted the advantage of using ERP methodology to unveil time-related changes in vocal emotional processing in individuals varying in hallucination proneness. To ensure more rigorously controlled ERP experiments, two additional studies aiming to validate a self-report instrument to measure hallucination proneness and a set of non-verbal emotional vocalizations varying in duration were conducted prior to the ERP experiments.

Chapter 2 presents a behavioral review on vocal emotional processing in the healthy population, followed by an introduction to the ERP technique. It describes the multi-stage model of vocal emotional processing and evidence from ERPs across the three stages of vocal emotional processing in the healthy population. This chapter is also dedicated to clarifying the contribution of attention to preserved processing of vocal emotions in the healthy population. Behavioral evidence on vocal emotional processing in psychotic voice-hearers and non-clinical individuals with positive-like symptoms, as well as the psychosis continuum hypothesis, are also emphasized in this chapter. Furthermore, Chapter 2 discusses ERP research on vocal emotional processing in psychotic voice-hearers and the contribution of attention to altered perception of vocal emotions in psychotic voice-hearers. The chapter finishes by specifying the main goals of this Dissertation.

Chapter 3 introduces Study 1 which aims to adapt and validate the Launay-Slade Hallucination Scale-Revised (LSHS – Larøi & van der Linden, 2005) for the Portuguese population (i.e., a well-known scale that taps into non-clinical hallucinatory experiences), and to describe the phenomenological

characteristics underlying hallucinatory experiences in the non-clinical Portuguese population. This study provides additional evidence for a link between hallucination proneness and anxious-depressive symptoms and schizotypal traits.

Chapter 4 is dedicated to Study 2. This study aims to probe the earliest time window at which emotions are accurately recognized from non-verbal vocalizations. Using distinct categories of emotion (anger, disgust, fear, amusement, sadness, and neutral), the study examines how much vocal information needs to be processed before an accurate emotional judgment is made. For this purpose, each vocalization was previously gated into seven distinct time intervals (from 100 to 700 ms).

Chapter 5 describes Study 3. The aims of this ERP study are 1) to examine whether individuals with high hallucination proneness exhibit alterations in vocal emotional perception at both early sensory (N1, P2) and higher-order cognitive (Late Positive Potential, LPP) processing stages and 2) to explore effects on vocal emotional perception by stimulus intensity (55 dB *vs.* 75 dB) and duration (500 ms *vs.* 700 ms) changes in high hallucination proneness. This study, and the next, include not only participants varying in hallucination proneness (low *vs.* high) selected from Study 1 (Chapter 3), but also a set of well-recognizable non-verbal emotional vocalizations varying in duration as probed by Study 2 (Chapter 4).

Chapter 6 presents Study 4 which aims to determine whether the interaction between vocal emotional processing and voluntary attention, reflected in P3b modulations, is affected by hallucination proneness. Effects of intensity (55 dB *vs.* 75 dB) change on the attentive processing of vocal emotions in hallucination proneness were also considered.

Finally, Chapter 7 is dedicated to the concluding remarks of the current Dissertation. To this end, it starts by looking at the main results. The most relevant and significant findings are then discussed. The last part of Chapter 7 summarizes the implications of the findings, followed by the limitations of the studies and recommendations for future research.

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Chapter 2

2. The perception of vocal emotions and its relationship with auditory verbal hallucinations (AVH): A review

2.1 Vocal emotional perception in the healthy population

The human voice is definitely the most important sound in a social environment. More than words, it carries socially relevant non-verbal information about the speaker, such as his/her identity, sex, age, and emotional state (Belin, Fecteau, & Bédard, 2004; Schirmer, Zysset, Kotz, & von Cramon, 2004). Non-verbal vocal emotional expressions, such as suprasegmental modulations of speech prosody (Schirmer, Striano, & Friederici, 2005) and short non-verbal vocalizations (Schröder, 2003), play an important role by complementing, supporting or contradicting verbalized information (Hybels & Weaver, 2007). Being able to detect and interpret emotions from the voice is a key determinant of adaptive social functioning (e.g., allows for the establishment and maintenance of interpersonal relationships and human bonding – Bozikas et al., 2006).

The perception of vocal emotions involves not only the recognition of a speaker's emotional state, but also the discrimination between voice signals – to determine whether different speakers convey the same or different emotions (Bänziger, Grandjean, & Scherer, 2009). Vocal emotional processing relies on a complex configuration of acoustic cues such as (fundamental frequency (F0) or pitch, intensity, rhythm, timbre and duration. Each vocal emotion is associated with a specific acoustic profile. For instance, happiness is characterized by fast speech rates and high F0 and intensity, whereas sadness is characterized by slow speech rates and low F0 and intensity – Schirmer & Kotz, 2006). It is the integration of each emotion acoustic profile that allows listeners to detect any vocal change that may signal a speaker's emotional state (Leitman, Wolf, Ragland, et al., 2010). Recognition accuracy for the six universal vocal expressions (happiness, sadness, anger, fear, disgust, and surprise) in both speech prosody (e.g., utterances: 73%; pseudo-utterances: 69% – Castro & Lima, 2010; utterances: 73% – Kan, Mimura, Kamijima, & Kawamura, 2004; pseudo-utterances: 73% – Liu & Pell, 2012) and vocalizations

(e.g., 73% – Belin, Fillion-Bilodeau, & Gosselin, 2008; 58% Sauter, Eisner, Calder, & Scott, 2010; 60% – Simon-Thomas, Keltner, Sauter, Sinicropi-Yao, & Abramson, 2009) is relatively high, although it may differ by emotion category. Specifically, emotional prosody recognition from speech is generally high for fear and happiness *vs.* anger and sadness, and low for disgust (Banse & Scherer, 1996; Juslin & Laukka, 2003; van Bezooijen, 1984). In the case of non-verbal vocalizations, sadness and disgust tend to achieve the highest accuracy (Hawk, van Kleef, Fischer, & van der Schalk, 2009; Lima, Castro, & Scott, 2013; Sauter, Eisner, Ekman, & Scott, 2010; Schröder, 2003), whereas fear, anger, and happiness tend to achieve the lowest accuracy (Sauter, Eisner, Calder, & Scott, 2010; Schröder, 2003 - but see Vasconcelos, Dias, Soares, & Pinheiro, 2017, in which amusement [laughter] was the most successfully recognized emotion). Studies comparing recognition accuracy with emotional prosody and non-verbal vocalizations show that fear, happiness, anger, sadness, contempt, and disgust are more easily recognized when expressed via vocalizations than via speech prosody (Hawk, van Kleef, Fischer, & van der Schalk, 2009). Recognition accuracy may also change as a function of changes in stimulus acoustic cues (e.g., intensity – Juslin & Laukka, 2001; Wang, Pan, Liu, & Chen, 2015; duration – Pell & Kotz, 2011; Rigoulot, Wassiliwizky, & Pell, 2013). Specifically, recognition accuracy of vocal emotions tends to increase when the signal intensity increases (Juslin & Laukka, 2001; Wang, Pan, Liu, & Chen, 2015). Furthermore, listeners need more acoustic information (i.e., longer vocal samples) to successfully classify happiness and disgust prosody, whereas neutral, fear, sadness, and anger are accurately recognized from short prosodic samples (e.g., Pell & Kotz, 2011; Rigoulot, Wassiliwizky, & Pell, 2013). The faster recognition of negative emotions such as fear, sadness, and anger may be explained by the relevance that a prompt response to vocal signals of threat, loss, and aggression plays in terms of survival (Pell & Kotz, 2011). Note, though, that the recognition of unpleasant prosodic cues was also found to be distinctly affected by stimulus duration: whereas increased temporal information was associated with more accurate recognition of sadness, decreased temporal information led to a more accurate recognition of anger (Bergmann, Goldbeck, & Scherer, 1988).

Taken together, the abovementioned studies shed important light on vocal emotional recognition in the healthy population. It is worth noting that behavioral measures do not provide the full picture of this dynamic process as they tap only into the higher-order evaluation processes that lead to a response (e.g., Paulmann & Pell, 2010). Due to their high temporal resolution, ERP measures are ideally suited for detecting processing changes: they track the time course of emotional cue processing from stimulus onset until a response is made, i.e., evaluating both bottom-up sensory and higher-order cognitive processing stages (Paulmann & Pell, 2010).

2.1.1 Event-related potentials (ERP) technique

Neuroimaging techniques have been particularly effective in identifying spatial (magnetic resonance imaging – MRI), functional (functional magnetic resonance imaging – fMRI) and temporal (ERP) signatures of sensory, motor, emotional and cognitive processes, including those of vocal emotional processing (e.g., Frühholz, Ceravolo, & Grandjean, 2012; Liu et al., 2012; Paulmann & Kotz, 2008a; Pell et al., 2015; Pinheiro, Barros, Dias, & Kotz, 2017; Pinheiro, Barros, Vasconcelos, Obermeier, & Kotz, 2017; Sander & Scheich, 2005; Schirmer & Kotz, 2006; Schirmer, Kotz, & Friederici, 2005).

Brain's cortical and subcortical neurons generate continuous electrical activity, either by action potentials (APs) or post-synaptic potentials (PSPs), to communicate among themselves (Alcami & Pereda, 2019). Part of this electrical activity is associated with specific brain processing. When multiple neurons fire in synchrony, as the pyramidal cells responsible for PSPs generation, they produce electric fields at the scalp-level, which allows them to be detected by the electroencephalogram [EEG] (Beres, 2017). The EEG provides a non-invasive measurement of spontaneous (ongoing) and event-related brain activity (ERP) on a millisecond-by-millisecond basis by the placement of electrodes on the scalp (Luck, 2005).

As the name indicates, the ERP represents a sum of potentials (electrical activity) evoked by a specific event or stimulus. Two prior steps are thought to ensure the reliability of the ERP signal (i.e., the signal-to-noise ratio [SNR] – Luck, 2005): data pre-processing (e.g.., filtering data, artifact correction, artifact rejection, baseline correction), and an appropriate amount of trials per condition. ERP extraction from the EEG signal is obtained by averaging response epochs time-locked to a similar stimulus (Luck, 2005). The resulting averaged ERP waveform consists of a sequence of deflections (i.e., peaks, waves or components) characterized by their polarity (negative *vs.* positive), amplitude (magnitude [microvolts – μV] measured from the maximal peak of a given component), latency (time interval [milliseconds – ms] between stimulus onset and a maximal peak of a given component) and spatial distribution on the scalp [anatomical site of the generation] (Luck, 2005). Note, however, that due to the ERP low spatial resolution, only inferences about the spatial distribution of the associated ERP effect can be made (Luck, 2005). Whereas ERP waves that peak early (within the first 100 ms after stimulus onset) are termed sensory or exogenous components as they are high sensitive to stimulus physical parameters, ERP waves with later latencies (cognitive or endogenous components) reflect integrative and higher-order cognitive processing (Luck, 2005). By convention, any negative and positive component is identified with the letter "N" and "P", respectively, followed by a number (e.g., N1, P2, N2, P3) representing the distance from the stimulus

onset [0 ms] (Luck, 2005). ERP amplitude reflects the amount of resources allocated to a given process, while ERP latency represents the speed of processing (Polich, 2007).

Despite its low spatial resolution, the ERP has many advantages over behavioral and other neuroimaging measures (Luck, 2005). Compared to behavioral measures, ERP measures provide information about all stages of processing rather than just the response to a specific stimulus or event. In contrast to the MRI technique, the ERP enables the measurement of brain activity outside the scanner and without exposure to high-intensity magnetic fields. The main advantage of the ERP technique is the high temporal resolution at shorter time scales (ms) than fMRI [seconds, S] (Cohen, 2017; Luck, 2005). The greater temporal resolution allows determining the time it takes for the brain to respond to a specific stimulus or event (Cohen, 2017; Luck, 2005), and to inform about changes in the strength (amplitude), latency, and sources of responses (Murray, Brunet, & Michel, 2008).

Electrophysiological measures provide a powerful tool for probing the temporal dynamics of adaptive responses to a stimulus or event, being fitting to reflect the multistage model of vocal emotional processing. The following section describes the three-stage model of vocal emotional processing proposed by Schirmer and Kotz (2006), emphasizing the role of three ERP components presumed to reflect each stage of processing: N1, P2, and LPP.

2.1.2 The multi-stage model of vocal emotional perception

The perception of vocal emotions is currently conceptualized as a dynamic and multistage process, with each stage of the hierarchy representing a particular level of processing. (Belin et al., 2004; Ethofer et al., 2006; Schirmer & Kotz, 2006; Spreckelmeyer, Kutas, Urbach, Altenmüller & Münte, 2009). Schirmer and Kotz (2006) propose a three-stage model of vocal emotional processing, integrating both fMRI and ERP evidence: 1) sensory processing; 2) integration; and 3) cognition. These stages are reciprocally connected: sensory stages (bottom-up processes) impact on higher-order stages (top-down processes), and vice-versa (e.g. Ethofer et al. 2006). The first stage, sensory processing, reflects the automatic evaluation of the physical features of an auditory stimulus (i.e., extraction of the pitch, intensity, duration) by the auditory cortex (Luck, 2005), whereas the second stage, integration, involves the detection of the emotionality in the voice (emotion salience) by temporal regions of the brain (the bilateral superior temporal gyrus [STG] and the anterior temporal sulcus [ATS] – Kotz et al., 2003; Grandjean et al., 2005; Mitchell, Elliott, Barry, Cruttenden, & Woodruff, 2003). Frontal brain regions (the inferior frontal

gyrus (IFG) and the orbitofrontal cortex – Buchanan et al., 2000; Gandour et al., 2003; Wildgruber et al., 2005) are engaged in the cognitive evaluation of vocal emotions at later processing stages.

Specific ERP components provide temporally accurate information on the various stages of vocal emotional processing. The N1 (a negative evoked potential peaking approximately 100 ms after stimulus onset – Luck, 2005) reflects the sensory processing of the voice signal, whereas the P2 (a positive evoked potential peaking approximately 200 ms after stimulus onset – Luck, 2005) reflects the detection of the emotional salience of the voice (Paulmann & Kotz, 2008a; Paulmann & Kotz, 2008b; Schirmer & Kotz, 2006). The N1 and P2 reach maximum amplitudes at frontocentral and central electrode sites, respectively (Hyde, 1997). The early differentiation between neutral and emotional vocal cues is supported by N1 and P2 amplitude findings (Liu et al., 2012; Paulmann, Bleichner, & Kotz, 2013; Sauter & Eimer, 2009; Schirmer, Chen, Ching, Tan, & Hong, 2013). Later ERP components (e.g., P3 – Pinheiro, Barros, Dias, & Kotz, 2017; Pinheiro, Barros, & Pedrosa, 2015; Wambacq & Jerger, 2004; Wambacq, Shea-Miller, & Abubakr, 2004; LPP – Paulmann, Bleichner, & Kotz, 2013; Pell et al., 2015; Pinheiro et al., 2016; Sauter & Eimer, 2009; Schirmer, Chen, Ching, Tan, & Hong, 2013) reflect higher-order processes involved in the processing of vocal emotional details. The LPP, a centroparietal positivity that occurs at approximately 400-600 ms post-stimulus onset, is associated with the cognitive evaluation of the emotional significance of the voice (Thierry & Roberts, 2007). Typically, emotional vocal cues tend to elicit larger LPP amplitudes than neutral vocal cues (Pell et al., 2015; Pinheiro et al., 2016), suggesting that, as for visual cues (e.g., Hajcak, MacNamara, Foti, Ferri, & Keil, 2013; Schupp et al., 2000), enhanced sustained attention and cognitive resources are allocated to the processing of emotionally relevant vocal information. Summarized in the next section are the most noteworthy findings of research on N1, P2 and LPP correlates of vocal emotional processing in the healthy population.

2.1.3 Electrophysiological correlates of vocal emotional perception in the healthy population

Electrophysiological measures have provided important insights into the three stages of vocal emotional processing in the healthy population. It should be noted, however, that there have been some inconsistencies between studies. For example, whereas some ERP studies revealed that voice emotionality cannot be differentiated from voice neutrality at the first stage of vocal emotional processing (Paulmann & Kotz, 2008b; Schirmer, Chen, Ching, Tan, & Hong, 2013), others support an early

differentiation between emotional and neutral vocal information (Jessen & Kotz, 2011; Liu et al., 2012; Paulmann, Jessen, & Kotz, 2009). These studies demonstrated that the emotional qualities of a sound facilitate the sound sensory processing, i.e., positive and negative *vs.* neutral vocal cues were found to be associated with a less negative N1 amplitude (Jessen & Kotz, 2011; Liu et al., 2012; Paulmann, Jessen, & Kotz, 2009). Emotion-specific modulations of the N1 were also observed, such as decreased N1 amplitudes for vocalizations of happy *vs.* sad and angry *vs.* fearful (Pell et al., 2015; Jessen & Kotz, 2011). Differences in the N1 amplitude related to the emotional qualities of a sound (Jessen & Kotz, 2011; Liu et al., 2012; Paulmann, Jessen, & Kotz, 2009) may be accounted for by differences in the acoustic properties of the sounds. Specifically, the N1 amplitude was found to differ between emotional and neutral vocal cues only when sounds were acoustically more intense (Wang, Pan, Liu, & Chen, 2015). Short vocal samples seem also to facilitate the sensory processing of emotional information (Chang, Zhang, Zhang, & Sun, 2018). For instance Chang et al. (2018) observed decreased N1 amplitudes in response to short and long (*vs.* medium) vocal samples and short vocal samples of anger, sadness, and surprise *vs.* happiness. Differences between emotional and neutral vocal cues were reported not only in terms of amplitude but also in terms of latency. For example, Liu et al. (2012) observed an early N1 peak for emotional relative to neutral vocal cues. The observed latency difference suggests that emotional information is processed more quickly than neutral information.

Several studies suggest that ERP modulations by the emotional quality of the voice take place only at the second stage of processing (Paulmann, Bleichner, & Kotz, 2013; Paulman & Kotz, 2008b; Sauter & Eimer, 2010; Schirmer, Chen, Ching, Tan, & Hong, 2013). Specifically, emotional vocal cues were found to be distinguished from one another (Paulmann, Bleichner, & Kotz, 2013) and neutral vocal cues (Paulman & Kotz, 2008b; Sauter & Eimer, 2010; Schirmer, Chen, Ching, Tan, & Hong, 2013) within 200 ms after stimulus onset. P2 discrimination between emotional and neutral sounds tends to occur irrespective of emotional valence (anger, fear, disgust, happiness, surprise, and sadness), stimulus type (non-verbal vocalization or speech prosody – Pell et al., 2015), task-relevance (Kotz & Paulmann, 2007; Paulmann, Bleichner, & Kotz, 2013) and stimulus acoustic cues (Schirmer, Chen, Ching, Tan, & Hong, 2013). It is worth noting, however, that the direction of the P2 effects of valence is not consensual across studies: some revealed increased P2 amplitude to emotional *vs.* neutral sounds (Liu et al, 2012; Schirmer, Chen, Ching, Tan, & Hong, 2013), and others a reverse pattern (Paulmann & Kotz, 2008b). Changes in the P2 amplitude by stimulus valence may be related to changes in stimulus acoustic cues (Chang, Zhang, Zhang, & Sun, 2018; Wang, Pan, Liu, & Chen, 2015). Specifically, loud sounds were found to be required for effective discrimination between emotional and neutral information (Wang, Pan,

Liu, & Chen, 2015). Furthermore, increased P2 amplitudes were observed for vocal emotions of short (*vs.* medium and long) duration and happy and angry *vs.* surprised voices, especially in the short duration condition (Chang, Zhang, Zhang, & Sun, 2018). Furthermore, the P2 amplitude tends to increase to highly emotionally arousing sounds (Paulmann, Bleichner, & Kotz, 2013; Sauter & Eimer, 2010). P2 peak latencies were also found to differ by emotional valence, i.e., earlier P2 peaks were observed for happiness (laughter), followed by anger (growls) and sadness (sobs) vocalizations (Pell et al, 2015), suggesting a faster salience detection of positive *vs.* negative vocalizations.

The LPP is thought to reflect higher-order and complex cognitive encoding processes (Dillon, Cooper, Grent, Woldorff, & LaBar, 2006). LPP amplitude is typically modulated by the emotional quality of sounds (Paulmann, Bleichner, & Kotz, 2013; Pell et al., 2015; Pinheiro, Barros, & Pedrosa, 2015; Pinheiro et al., 2016). For instance, larger LPP amplitudes were observed for voice emotionality *vs.* voice neutrality, which suggests that the capacity to maintain attentional focus (i.e., sustained attention) on a specific sound may be facilitated by its emotional content (Pell et al., 2015; Pinheiro, Barros, & Pedrosa, 2015; Pinheiro et al., 2016). Emotion-specific modulations of the LPP were also demonstrated, such as increased LPP amplitude to threat-related sounds [anger] compared to non-threat-related sounds [happiness and sadness] (Paulmann, Bleichner, & Kotz, 2013; Pell et al, 2015). It seems likely that threat-related sounds may lead to deeper processing (reflected in increased LPP positivity) to allow a faster and adaptive response to them (Pell et al, 2015). Moreover, the LPP amplitude was found to increase for vocal emotions high in arousal *vs.* low in arousal (Paulmann, Bleichner, & Kotz, 2013).

2.1.4 The specific role of attention in preserved perception of vocal emotions in the healthy population: ERP evidence

The perception of vocal emotions depends greatly on top-down attentional processes (Frühholz & Grandjean, 2013). Attention to task-relevant stimuli, i.e., selective attention (Posner, 1991), may be elicited by the P3, a positive deflection occurring between 250 milliseconds (ms) and 500 ms post-stimulus onset (Duncan et al., 2009; Polich, 2007). The P3 represents two distinct attentional processes (Duncan et al., 2009; Kok, 2001; Polich, 2007): the frontocentral P3a reflects the automatic or bottom-up capture of attention by novel task-irrelevant stimuli; the centroparietal P3b indexes the voluntary or top-down allocation of attention to the target, i.e., task-relevant stimuli. Auditory oddball tasks, in which participants are instructed to discriminate an infrequent target stimulus from the frequent non-target

stimulus (P3b) and, if present, to ignore the rare non-target novel stimulus (P3a), are typically used to elicit the P3 in response to vocal emotions (e.g., Pinheiro, Barros, & Pedrosa, 2015; Pinheiro & Niznikiewicz, 2019; Schirmer, Simpson, & Escoffier, 2007).

Previous studies demonstrated that the P3 is modulated by the emotional quality of a vocal sound (Pinheiro, Barros, Dias, & Kotz, 2017: Pinheiro, Barros, & Pedrosa, 2015; Wambacq, Shea-Miller, & Abubakr, 2004). Specifically, larger P3b amplitudes were observed for happiness relative to both anger and neutral vocalizations (Pinheiro, Barros, Dias, & Kotz, 2017), and anger *vs.* neutral prosodic cues (Wambacq, Shea-Miller, & Abubakr, 2004). There is also evidence to suggest that emotional vocalizations capture attention more than neutral vocalizations as shown by increased P3a amplitudes to both happiness and anger *vs.* neutral vocalizations (Pinheiro, Barros, Dias, & Kotz, 2017; Pinheiro, Barros, & Pedrosa, 2015). Vocal emotional modulation of attention may result from changes in the acoustic properties of the voice that affect salience detection. For example, high (*vs.* low) voice intensity was associated with a larger P3a amplitude, indicating that voices acoustically more salient capture enhanced automatic attention (Schirmer, Simpson, & Escoffier, 2007). P3b amplitude to happy prosody was also shown to increase with increased intensity (Wang, Pan, Liu, & Chen, 2015). Taken together, these findings suggest that attention may change how vocal emotions are processed (Frühholz & Grandjean, 2013).

2.2 Vocal emotional perception in psychotic voice-hearers and non-clinical individuals with positive-like symptoms

Schizophrenia is a complex and debilitating mental disorder, affecting about 1% of the world's population (Saha, Chant, Welham, & McGrath, 2005). The peak period of schizophrenia onset occurs between late adolescence and early adulthood (Ali, 2009; Harrop & Trower, 2001), although it can arise later in life (Harris, & Jeste, 1988; Owen & Castle, 1999). Schizophrenia is characterized by the presence of severe psychopathological symptoms and cognitive dysfunction, with devastating effects on social function and daily activities (Green, Horan, & Lee, 2015). Schizophrenia symptoms fall into two main categories (Green, Horan, & Lee, 2015): positive or psychotic symptoms (e.g., hallucinations, delusions) and negative symptoms (e.g., avolition, blunted affect, anhedonia, and social withdrawal). Patients with schizophrenia may also have additional cognitive symptoms such as impaired executive functioning, impairment of short term working memory, poor problem-solving ability, slow processing speed, and attention deficit (Keefe & Fenton, 2007). AVH are the most common and characteristic symptoms of

schizophrenia, occurring in approximately 70% of patients (David, 1994; Johns et al., 2004). Attempting to understand the pathophysiology of AVH, four main cognitive neurobiological models have arisen in recent years: 1) impaired self-monitoring of inner speech; 2) language production; 3) aberrant memory; and 4) early automatic sensory processing errors (Upthegrove et al., 2016). According to the first and most prominent model, the occurrence of AVH derives from impaired self-monitoring that leads to impaired differentiation between self-generated [inner speech] and non-self-generated [external speech] speech (Bentall, 1990; Frith & Done, 1988; Moseley, Fernyhough, & Ellison, 2013). Schizophrenia's functional disability is further related to cognitive dysfunction (Green, Horan, & Lee, 2015), including attention, memory, executive functioning, and general intellectual abilities (Heinrichs & Zakzanis, 1998; Reichenberg & Harvey, 2007). These deficits are also observed in the prodromal phase of a psychotic disorder (Green et al., 2012; Pantlin & Davalos, 2016, i.e., the period before illness onset in which psychotic symptoms first arise (Addington et al., 2007).

It has been widely accepted that schizophrenia patients exhibit disrupted bottom-up processing of auditory stimuli (Javitt, 2009a; Leitman, Sehatpour, Higgins, et al., 2010), including the human voice (Bozikas et al., 2006; Pinheiro et al., 2013; 2014; Rossell & Boundy, 2005). The abnormalities seem to extend not only to the speech (Kuperberg, West, Lakshmanan, & Goff, 2008; Wang, Cheung, Gong, & Chan, 2011) and the identity (Alba-Ferrara, Weis, Damjanovic, Rowett, & Hausmann., 2012; Pinheiro, Rezaii, Rauber, & Niznikiewicz, 2016) dimensions of voice processing, but also to the emotional dimension (Alba-Ferrara, Fernyhough, Weis, Mitchell, & Hausmann, 2012; Bozikas et al., 2006; Edwards, Jackson, & Pattison, 2002; Hoekert, Kahn, Pijnenborg, & Aleman, 2007; Kucharska-Pietura, David, Masiak, & Phillips, 2005; Leitman et al., 2005; Pinheiro et al., 2013; 2014). Several studies demonstrated that schizophrenia patients are particularly impaired in their ability to extract emotional meaning from the voice signal, especially negative meaning (Bozikas et al., 2006; Edwards, Jackson, & Pattison, 2002; Pinheiro et al., 2013; 2014; Rossell & Boundy, 2005). Vocal emotion recognition deficits tend to be specifically aggravated in schizophrenia patients with AVH (e.g., Alba-Ferrara, Fernyhough, Weis, Mitchell, & Hausmann, 2012; Rossell & Boundy, 2005; Shea et al., 2007). Patients with AVH are also more likely than non-hallucinated patients to judge positive vocal expressions as negative (Rossell & Boundy, 2005), and neutral vocal expressions as emotional (Shea et al., 2007). Taken together, these findings indicate that schizophrenia patients who are less able to recognize vocal emotions are also more prone to experience AVH.

AVH are not exclusive of psychotic disorders, they can also occur in the (non-clinical) general population (de Leede-Smith & Barkus, 2013; Tien, 1991). Recent meta-analytic evidence suggests that

AVH occur in approximately 9.6% of persons without a clinical diagnosis (Maijer, Begemann, Palmen, Leucht, & Sommer, 2018). Studies comparing the phenomenology of the hallucinated voices revealed similarities, but also some differences between psychotic and non-clinical samples. Specifically, the perceived location (inside the head), loudness (less intense than one's voice), and source (external) of the hallucinated voices are among the phenomenological similarities that both psychotic patients and non-clinical individuals might share (Daalman et al., 2011). Differences in the phenomenology of AVH include the emotional valence, the perceived distress and control, and the frequency of the hallucinated voices (Choong, Hunter, & Woodruff, 2007; Daalman et al., 2011; de Leede-Smith & Barkus, 2013; Honig et al., 1998; Larøi & van der Linden, 2005; Larøi, 2012), i.e., non-clinical voice-hearers tend to perceive their AVH as less unpleasant, distressful and frequent, as well as more controllable than psychotic voice-hearers. Both clinical and non-clinical AVH are also thought to rely on similar cognitive (Allen, Freeman, Johns, & McGuire, 2006; Brébion et al., 2016; Larøi, van der Linden, & Marczewski, 2004) and neural (Barkus, Stirling, Hopkins, Mckie, & Lewis, 2007; Diederen et al., 2012; Linden et al., 2010) mechanisms. For example, psychotic and non-clinical voice-hearers are more likely than healthy controls to misattribute their speech to an external source (Brébion et al., 2016; Larøi, van der Linden, & Marczewski, 2004). Moreover, a common set of brain regions (bilateral inferior frontal gyri, insula, superior temporal gyri, supramarginal gyri, and postcentral gyri, left precentral gyrus, inferior parietal lobule, superior temporal pole, and right cerebellum) were found to be activated during the experience of clinical and non-clinical AVH (Diederen et al., 2012). Alterations in vocal emotional perception and recognition similar to those observed in schizophrenia patients with AVH were also observed in individuals at clinical (Addington et al., 2012; Amminger, Schäfer, Klier, et al., 2012; Amminger, Schäfer, Papageorgiou, et al., 2012) and genetic (Kee, Horan, Mintz, & Green, 2004; Tucker, Farhall, Thomas, Groot, & Rossell, 2013) high-risk of converting to psychosis and reporting positive-like symptoms (hallucinations and/or delusions). For example, first degree relatives of schizophrenia patients with AVH who were less capable of detecting changes in the intensity and pitch of pure tones (i.e., neutral sounds) were also found to be less able of recognizing vocal emotions, as well as more likely to experience AVH (Tucker, Farhall, Thomas, Groot, & Rossell, 2013). Furthermore, recognition accuracy of vocal emotions was found to be reduced in non-clinical individuals with positive-like symptoms (Addington et al., 2012; Amminger, Schäfer, Klier, et al., 2012; Amminger, Schäfer, Papageorgiou, et al., 2012).

The observed similarities between clinical and non-clinical AVH (Brébion et al., 2016; Daalman et al., 2011; Diederen et al., 2012; Larøi, van der Linden, & Marczewski, 2004) support the hypothesis of a psychosis continuum (Baumeister, Sedgwick, Howes, & Peters, 2017; van Os, Hanssen, Bijl, &

Ravelli, 2000; van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009). They further provide an outstanding opportunity to investigate the complexities of AVH in non-clinical samples free of uncontrollable confounding conditions (i.e., medication and hospitalization) commonly seen in psychotic patients (Badcock & Hugdahl, 2012). The hypothesis of a psychosis continuum is more extensively addressed in the following section.

2.2.1 The hypothesis of a psychosis continuum

Challenging the classic binary approach to psychiatry (sanity *vs.* insanity), the continuum approach suggests that psychotic symptoms lie on a continuum from non-clinical [psychotic-like symptoms] to clinical [psychotic symptoms] (Baumeister, Sedgwick, Howes, & Peters, 2017; van Os, Hanssen, Bijl, & Ravelli, 2000; van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009). The key difference between psychotic symptoms and psychotic-like symptoms is that whereas psychotic symptoms cause clinically significant distress that justifies a diagnosis, psychotic-like symptoms are not inevitably distressing and pathological (Hanssen, Bijl, Vollebergh, & van Os, 2003; van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009).

Evidence for the continuum hypothesis of psychosis derives from two-dimensional models: the quasi-dimensional approach (Meehl, 1989) assumes a continuum that ranges from aberrant personality traits (i.e., schizotypal symptoms) to clinically significant psychotic symptoms; the fully-dimensional approach (Claridge, 1997) assumes a continuum of increasing severity and persistence of symptoms between non-clinical and clinical populations (van Os, Hanssen, Bijl, & Vollebergh, 2001; van Os & Linscott, 2012). Hence, whereas the quasi-dimensional view of psychosis is supported by data derived from studies of schizotypal personality (e.g., Barrantes-Vidal, Grant, & Kwapil, 2015; Kwapil & Barrantes-Vidal, 2015; Rössler et al., 2007), the fully-dimensional view of psychosis provides insights into a diverse range of psychotic-like symptoms in the healthy population (e.g., Bradbury, Stirling, Cavill, & Parker, 2009; Brébion, Larøi, & van der Linden; 2010; Johns & van Os, 2001; Sommer et al., 2010; Rössler et al., 2007; van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009. From a fully-dimensional perspective, symptoms are distributed along a continuum of severity: 1) the least severe extreme includes briefly and attenuated psychotic-like symptoms observed in the non-clinical population (typically hallucinations and delusions); 2) the midline between extremes is characterized by persistent sub-clinical psychotic symptoms that do not cause functional impairment (i.e., prodromal stage); and 3) the most

severe extreme comprises diagnosed psychotic patients whose symptoms cause serious disability (Bradbury, Stirling, Cavill, & Parker, 2009; Brébion, Larøi, & van der Linden; 2010; Johns & van Os, 2001; Rössler et al., 2007; van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009). Furthermore, the experience of AVH in the general population without the need for care has been probed by testing: 1) individuals with AVH proneness who experience briefly and infrequent AVH that do not affect their daily functioning; and 2) non-clinical voice-hearers who experience frequent AVH of longer duration, often associated with other psychotic-like and mood symptoms (Johns et al., 2014). While the first subgroup is typically assessed using hallucination-proneness measures (e.g., the LSHS – Bradbury, Stirling, Cavill, & Parker, 2009; Morrison, Wells, & Nothard, 2002), screening interviews are often used to evaluate the experience of hearing voices in the second subgroup (e.g., Sommer et al., 2010).

Individuals who report psychotic-like symptoms are considered to be at clinical risk of developing a psychotic disorder (e.g., Kelleher and Cannon, 2011; Schaffner & McGorry, 2001) within a short time (i.e., the risk of transition is thought to be maximal after the first 24 months following clinical presentation – Cannon et al., 2008; Nelson et al., 2013). Of those, however, only a few will progress from a prodromal state to a diagnosable disorder (e.g., 35% – Cannon et al., 2008; 29% – Fusar-Poli et al., 2012; 20% – Nelson et al., 2013). Individuals at clinical risk for psychosis could be divided into three subgroups: those who will later develop psychosis; those who will remain symptomatic; and those who will become asymptomatic (Addington et al., 2011). Evidence supports no decline of functional abilities and no need for psychological healthcare in those who will never reach a clinical threshold for psychosis (Powers, Kelley, & Corlett, 2017). In general, the criteria to identify those most at risk of developing a psychotic disorder include 1) attenuated positive symptoms; 2) brief intermittent psychotic states; and 3) genetic risk (those with a schizotypal personality disorder or with a schizophrenia first-degree relative – Addington & Heinssen, 2012) coupled with recent functional decline (Miller et al., 2002; Yung & McGorry, 1996). The risk of developing a psychotic disorder is relatively higher in individuals who are clinically predisposed (i.e., 30% to 50% – Yung et al., 1998) relative to those genetically predisposed (i.e., 10% – Cornblatt & Obuchowski, 1997). Clinical states can be distinguishable from non-clinical states based on the severity, duration, and frequency of psychotic symptomatology in co-occurrence with other clinical conditions (i.e., anxiety, depressed mood, suspiciousness, disorganization, irritability, social withdrawal, poor functioning), and cognitive and behavioral changes (Yung & McGorry, 1996; Yung et al., 2003). Comorbidity has been shown to play a critical role in predicting the conversion to psychosis (Yung, Phillips, Yuen, & McGorry, 2004).

Despite these advances, it is still to be precisely identified the signs most likely to trigger the onset of psychosis and those that signal no clinical risk. Indeed, most of the predictive studies relied on single baseline measures (clinical, neurocognitive, neurobiological) to index the level of risk for the emergence of psychosis (Cannon et al., 2016; Fusar-Poli & Schultze-Lutter, 2016), and only a few have used a long-term follow-up design to determine the developmental trajectory of psychosis (e.g., Cannon et al., 2008; Fusar-Poli et al., 2017; Nelson et al., 2013; Klosterkötter, Hellmich, Steinmeyer, & Schultze-Lutter, 2001; Riecher-Rössler et al., 2009). Moreover, different studies have been producing different findings due to the use of different research tools and analytic approaches to measuring the risk of transition to psychosis (Schvarcz & Bearden, 2015). Therefore, improving the clinical prediction of psychosis has been a priority in clinical high-risk research. Instead of looking at the phenomenology of psychotic symptoms (i.e., state markers that represent the status of clinical manifestations in patients – Chen, Cinnamon, & Norton, 2006), the challenge has been to identify the behavioral and biological markers (trait markers) that may explain the emergence of psychosis (Bodatsch et al., 2011; Fusar-Poli, Radua, McGuire, & Borgwardt, 2011; Labad et al., 2015; Koutsouleris et al., 2011; Schmidt et al., 2013). Trait markers refer to any phenomenon that is present irrespective of variation in a clinical state and that is capable of persisting even during remission periods (Thompson, Bartholomeusz, & Yung, 2011). Examples of trait markers for psychotic disorders include 1) neurocognitive dysfunction (e.g., verbal memory – Brewer et al., 2005; Lencz et al., 2006; Seidman et al., 2010; spatial working memory – Bartók, Berecz, Glaub, & Degrell, 2005; Wood et al., 2003; visuospatial processing – Brewer et al., 2005; executive functioning – Koutsouleris et al., 2011; Lencz et al., 2006; Szöke et al., 2005); 2) disturbances in sensory information processing (Javitt, 2009a; Javitt, 2009b); 3) abnormal brain electrical activity (e.g., reduced Mismatch Negativity (MMN) amplitude, which suggests abnormal auditory deviance detection – Bodatsch et al., 2011; Michie, Innes-Brown, Todd, & Jablensky, 2002; decreased attention to auditory stimuli as reflected by decreased P3 amplitudes – Frommann et al., 2008); 4) structural and functional brain changes (gray matter reductions – Fusar-Poli, Radua, McGuire, & Borgwardt, 2011; Job et al., 2006; cortical volume loss – Sun et al., 2009; hyper or hypo-activated neural circuits – Whalley et al., 2006; brain connectivity abnormalities – Schmidt et al., 2013); 5) social functional disability (Cannon et al., 1997; Malmberg, Lewis, David, & Allebeck, 1998); 6) deficits in emotional perception (Kee, Green, Mintz, & Brekke, 2003; Kerr & Neale, 1993; Ross et al., 2001).

2.2.2 Electrophysiological correlates of vocal emotional perception in psychotic voice-hearers

It has been demonstrated that schizophrenia patients exhibit abnormalities in all the three stages of vocal emotional processing (Javitt, 2009a; Kantrowitz et al., 2011; Leitman et al. 2005; 2008; Pinheiro et al., 2013; 2014). ERP data provide evidence for abnormal processing of emotions from speech prosody at early sensory stages of processing (reflected in N1 and P2 amplitudes). Specifically, the N1 was found to be less negative in schizophrenia patients than in healthy controls for both emotional and neutral prosody (Pinheiro et al., 2013; 2014). Furthermore, compared to healthy controls, patients with schizophrenia showed larger P2 amplitudes in response to happy prosody (Pinheiro et al., 2013; 2014). Taken together, these findings suggest that the ability to extract emotional-related acoustic cues (N1) and salience (P2) from emotional prosody may be compromised in schizophrenia patients (Pinheiro et al., 2013; 2014). Reduced P2 amplitude to angry prosody was also found to be linked to a less accurate recognition of angry prosody in schizophrenia patients (Pinheiro et al., 2013). In good agreement with previous behavioral evidence (Leitman et al., 2008; 2011), this finding supports the contribution of early sensory processing deficits to higher-order cognitive impairments. In contrast, there is some evidence to suggest no significant differences between schizophrenia patients and healthy controls in the N1 and P2 responses to non-verbal emotional vocalizations (Müller, Kellermann, Seligman, Turetsky, & Eickhoff, 2012). Therefore, it seems that primitive sounds, such as screams and laughs, facilitate patients' extraction of vocal emotional information. To the best of our knowledge, no ERP study has directly examined how the LPP is modulated by emotional sounds in schizophrenia patients. Nevertheless, there is substantial behavioral evidence to support higher-level recognition impairments of vocal emotions in schizophrenia patients (e.g., Bozikas et al., 2006; Edwards, Jackson, & Pattison, 2002; Pinheiro et al., 2013; 2014; Rossell & Boundy, 2005). These deficits have been associated with patients' symptomatology, including the experience of AVH (Alba-Ferrara, Fernyhough, Weis, Mitchell, & Hausmann, 2012; Rossell & Boundy, 2005; Shea et al., 2007).

2.2.3 The specific role of attention in altered perception of vocal emotions in psychotic voice-hearers: ERP evidence

Behavioral evidence suggests that attention plays a key role in the interaction between impaired recognition of vocal emotions and the experience of AVH in schizophrenia patients (Alba-Ferrara, Fernyhough, Weis, Mitchell, & Hausmann, 2012). In particular, increased attentional bias towards threat-related vocal cues, which seems to be driven by patients' negative content of their hallucinated voices and by patients' subsequent negative mood, tends to increase the predisposition to AVH (Alba-Ferrara, Fernyhough, Weis, Mitchell, & Hausmann, 2012). Schizophrenia auditory-attentional processing abnormalities have also been reported at the electrophysiological level. Specifically, reduced P3 amplitude to pure (neutral) sounds (reflecting decreased attention to stimuli) is typically observed in schizophrenia patients (e.g., Ford, 1999; Hamilton et al., 2019; Jeon & Polich, 2003; Mathalon, Ford, Rosenbloom, & Pfefferbaum, 2000; Perlman et al., 2015; Turetsky, Siegel, Kohler, & Gur, 2009). Furthermore, the auditory P3 amplitude is also likely to be reduced before psychosis onset (i.e., in individuals at clinical and genetic risk for psychosis – Bramon et al. 2008; Frangou et al., 1997; Kidogami, Yoneda, Asaba, & Sakai, 1991) and during periods of symptomatic remission (e.g., van der Stelt, Lieberman, & Belger, 2005; Turetsky, Cannon, & Gur, 2000). Together, these studies provide support for the P3 as a trait marker for psychosis (e.g., Hamilton et al., 2019; van der Stelt, & Belger, 2007; Turetsky, Cannon, & Gur, 2000).

There is surprisingly little research on the P3 correlates of vocal emotional processing in schizophrenia (Chen, Liu, Weng, & Cheng, 2016; Pinheiro & Niznikiewicz, 2019). These studies suggest that the ability to voluntary orient attention (P3b) toward vocal emotions (Pinheiro & Niznikiewicz, 2019), as well as the automatic capture of attention (P3a) by vocal emotions (Chen, Liu, Weng, & Cheng, 2016), may be altered in schizophrenia patients. In particular, Pinheiro and Niznikiewicz (2019) revealed alterations in the voluntary attentional response to emotional prosodic targets in schizophrenia patients, i.e., reduced P3b amplitude to positive (happy) *vs.* negative (angry) vocal targets in patients relative to controls. Non-significant differences were observed in the P3b amplitude to negative vocal targets between patients and healthy controls. The observed reduction in the P3b response to happy prosody may reflect changes in the evaluation of positive emotional salience in schizophrenia patients (Pinheiro & Niznikiewicz, 2019). Decreased attention to high-pitched target tones (reflected in reduced P3b amplitudes) was further shown to compromise the identification of vocal emotions in schizophrenia patients (Jahshan, Wynn, & Green, 2013). Schizophrenia patients were also found to display larger P3a

amplitudes to both happy and angry prosody, and longer P3a latencies to angry prosody than healthy controls (Chen, Liu, Weng, & Cheng, 2016). These findings suggest that whereas both happy and angry prosody may automatically capture more attention in patients than healthy controls, the automatic attention toward angry prosody may be delayed in patients relative to healthy controls. Importantly, the P3a response to threatening voices was also found to differentiate patients from non-patients (Chen, Liu, Weng, & Cheng, 2016). Even though statistically non-significant, the relation between the P3a amplitude and the occurrence of positive symptoms was further demonstrated to be inversely proportional, i.e., to decrease with positive symptoms (e.g., hallucinations, delusions) increase (Chen, Liu, Weng, & Cheng, 2016).

2.3 Aims of the current Dissertation

In the preceding Chapter 1, we have pointed out the lack of research into the processing of vocal emotions in non-clinical individuals with high hallucination proneness, and have identified several questions that have not been addressed in the ERP research done to date. These questions were the motto for this Dissertation. Prior to the ERP experiments, two additional goals were established, dividing this Dissertation into two stages. In the first stage, we intended to validate the LSHS (Study 1) and a set of non-verbal emotional vocalizations varying in duration (Study 2) for the Portuguese population. In the second stage, we intended to explore the effects of hallucination proneness on early sensory (N1, P2) and higher-order cognitive (LPP) stages of vocal emotional processing (Study 3) and attention allocation (P3b) to vocal emotions (Study 4). Hence, the two first studies represent validation steps for rigorously controlled ERP experiments. The current Dissertation seeks to address the following questions:

1. What are the phenomenological characteristics underlying hallucinatory experiences in the non-clinical Portuguese population? (Study 1, Chapter 3)

2. How much voice signal is enough for a listener to successfully recognize emotions from non-verbal vocalizations? Does the amount of acoustic information for recognition vary by emotion type? (Study 2, Chapter 4)

3. Is the sensory and cognitive processing of vocal emotions affected by hallucination proneness? Are these potential changes associated with stimulus intensity and duration? (Study 3, Chapter 5)

4. Is the ability to selectively orient attention towards vocal emotions affected by hallucination proneness? Are these potential changes associated with stimulus intensity? (Study 4, Chapter 6)

Four studies were conducted to answer these questions. The ERP methodology was used in the two last experimental studies as we intended to provide evidence on the temporal dynamics of vocal emotional processing in non-clinical individuals varying in hallucination proneness.

The first study described in Chapter 3 aimed to examine the psychometric proprieties (sensitivity, internal validity, and internal consistency) of the 16-item LSHS version (Larøi, & van der Linden, 2005) among Portuguese college students, and to address hallucination phenomenology (prevalence, frequency, degree of control and emotional content). The aim here was also to clarify how hallucination proneness interacts with anxious-depressive symptoms and schizotypal traits in a small group of participants recruited from the LSHS validation study. In the second study (Chapter 4), the aim was to investigate whether differences in stimulus duration affect the recognition accuracy of non-verbal emotional vocalizations varying in valence (neutral, amusement, sadness, anger, disgust, and fear). Stimuli were divided into seven gate intervals ranging from 100 to 700 ms. Participants were asked to complete an explicit recognition task, categorizing each vocal stimulus based on a six-choice classification system. Indirectly, this study provides a set of vocalizations with distinct durations validated for the Portuguese population that may be a useful tool for ERP research using vocal emotional samples. The main goal of the third study (Chapter 5) was to determine whether early sensory (N1, P2) and higher-order cognitive (LPP) stages of vocal emotional processing are affected by hallucination proneness. Participants varying in hallucination proneness performed a task involving classification of emotional non-verbal vocalizations (positive, negative, neutral) differing in duration (500 ms *vs.* 700 ms) and intensity (55 dB *vs.* 75 dB) while the EEG signal was recorded. In the last study (Chapter 6) the goal was to determine whether attention allocation to vocal emotions is altered as a function of hallucination proneness and whether these putative changes are modulated by valence (positive *vs.* negative *vs.* neutral) and intensity (loud [75 dB] *vs.* soft [55 dB]). P3b responses were recorded while participants varying in hallucination proneness performed an active oddball task. Participants were presented with target vocalizations differing in valence (positive *vs.* negative *vs.* neutral) and intensity (55 dB *vs.* 75 dB) and were asked to silently count each block targets.

Using the ERP technique, the current Dissertation provides important insights into the temporal dynamics of vocal emotion perception in non-clinical individuals varying in hallucination proneness. We believe that our findings may be used as important clues for further research aiming to unveil hallucination proneness effects on vocal emotional perception. Studying the processing of vocal emotions in individuals with positive-like symptoms may also contribute to better understanding the neural and cognitive mechanisms underlying these experiences and the individual risk for psychotic disorders, as well as to inform clinical practice.

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PART II EMPIRICAL STUDIES

Chapter 3

3. On "hearing" voices and "seeing" things: Probing hallucination predisposition in a Portuguese non-clinical sample with the Launay-Slade Hallucination Scale-Revised[1]

3.1 Abstract

The experience of hallucinations is a hallmark of psychotic disorders, but they are also present in other psychiatric and medical conditions, and may be reported in non-clinical individuals. Despite the increased number of studies probing the incidence of non-clinical hallucinations, the underlying phenomenological characteristics are still poorly understood.

This study aimed to examine the psychometrics proprieties of the Portuguese adaptation of the 16-item Launay-Slade Hallucinations Scale (LSHS), the phenomenological characteristics of non-clinical hallucinatory experiences in a Portuguese sample, and the relationship between clinical symptoms and hallucination predisposition. Three-hundred-and-fifty-four European Portuguese college students completed the LSHS. Of those, 16 participants with high LSHS scores and 14 with low LSHS scores were further screened for clinical symptoms.

A three-factor solution for the LSHS Portuguese version proved to be the most adequate. Intrusive or vivid thoughts and sleep-related hallucinations were the most common. Although, fundamentally perceived as positive experiences, all types of hallucinations were described as uncontrollable and

[1]Publications derived from this study:

Peer reviewed publications in print or other media

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dominating. However, the more pleasant they were perceived, the more controllable they were assessed. In addition, hallucination predisposition was associated with increased clinical symptoms. These results corroborate the lower severity of hallucinations in the general population compared to psychotic individuals. Further, they support an association between clinical symptoms and increased vulnerability to hallucinations. Specifically, increased schizotypal tendencies and negative mood (anxiety and depression) may be related to increased psychotic risk.

Keywords: Hallucination predisposition; LSHS; Non-clinical hallucinations; Phenomenology; Psychometrics proprieties; Psychotic risk.

3.2 Introduction

Hallucinations represent one of the most intriguing phenomena (e.g., Allen, Larøi, McGuire, & Aleman, 2008), and have been in the spotlight of researchers from many disciplines for decades. Hallucinatory experiences, usually defined as perceptual experiences that occur in the absence of corresponding external sensory stimulation (Slade & Bentall, 1988), are a clinical manifestation of psychiatric disorders such as schizophrenia (Baethge, Baldessarini, Freudenthal, Streeruwitz, Bauer, & Bschor, 2005; Mueser, Bellack, & Brady, 1990). Even though the experience of hallucinations is considered a hallmark of psychotic disorders (e.g., David, 1994; Johns, Cannon, & Singleton, 2004), hallucinations may also be present in 10–15% of individuals with no clinical diagnosis (e.g., Badcock, Chhabra, Maybery, & Paulik, 2008; Barrett & Etheridge, 1992; Paulik, Badcock, & Maybery, 2006; Sommer et al., 2010). These findings provided support for a continuum model of psychotic experiences that extends not only across diagnostic categories, but also into the (non-clinical) general population (e.g., Bradbury, Stirling, Cavill, & Parker, 2009; Brébion, Larøi, & van der Linden, 2010; Johns & van Os, 2001). Three distinct states are thought to represent the phenotypic continuum of psychosis: (1) brief and attenuated psychotic experiences in the healthy population (typically hallucinations and delusions) observed in the least severe extreme; (2) persistent sub-clinical psychotic symptoms without functional impairment occurring from the least severe to the most severe extreme; and (3) psychotic disorders with symptoms that cause clinically significant distress and functional impairment occurring in the most severe extreme (van Os et al., 2009). Of note, non-clinical cases represent the largest proportion of the full continuum (van Os et al., 2009). Differences between clinical and non-clinical psychotic symptoms seem

to be quantitative rather than qualitative (e.g., Larøi, 2012; Larøi & van der Linden, 2005a). Indeed, the onset of psychosis is often preceded by an increased frequency of non-clinical psychotic symptoms (e.g., Dominguez, Wichers, Lieb, Wittchen, & van Os, 2011; Hanssen, Bak, Bijl, Vollebergh, & Os, 2005; Larøi, 2012; Larøi & van der Linden, 2005a) in co-occurrence with clinical conditions such as anxiety, depressed mood, suspiciousness, disorganization, irritability, social withdrawal, poor functioning, and cognitive and behavioral changes (e.g., Yung & McGorry, 1996; Yung et al., 2003). The occurrence of non-clinical hallucinations represents a risk factor for conversion to full psychosis (e.g., Kelleher & Cannon, 2011), even though it is not necessarily followed by a psychotic diagnosis (Johns & van Os, 2001; Verdoux et al., 1999).

Hallucinations may occur in different sensory modalities (e.g., auditory, visual, olfactory, tactile, and gustatory). Nonetheless, auditory hallucinations are the most common, especially in patients with schizophrenia (David & Busatto, 1998). They are often perceived as "voices" talking to each other (auditory verbal hallucinations – AVHs; Mueser, Bellack, & Brady, 1990; Nayani & David, 1996). AVHs have been consistently reported in 70% of schizophrenia patients (e.g., David, 1994; Johns, Cannon, & Singleton, 2004), as well as in other clinical disorders such as affective psychosis, depression, bipolar, or posttraumatic stress disorder (e.g., Asaad, 1990; Tien, 1991). However, the experience of "hearing voices" may also occur in 5–28% of the normal population (e.g., Jonhs et al., 2004; de Leede-Smith & Barkus, 2013; Tien, 1991). Nonetheless, there are important (e.g., phenomenological) differences between clinical and non-clinical AVHs (e.g., Badcock et al., 2008; Brébion, Larøi, & van der Linden, 2010; Choong, Hunter, & Woodruff, 2007; de Leede-Smith & Barkus, 2013; Larøi et al., 2012). Particularly, AVHs occur with increased frequency and duration in psychotic compared to non-psychotic individuals (de Leede-Smith & Barkus, 2013). Moreover, AVHs are perceived as more uncontrollable and unpleasant in psychotic individuals (de Leede-Smith & Barkus, 2013). The loudness (a little softer than the self-voice), attribution (external source), and location of the hallucinated voice (inside the head) are the main similarities shared by clinical and non-clinical individuals (de Leede-Smith & Barkus, 2013).

Visual hallucinations (VHs) are the second most common type of hallucinations in psychotic patients (prevalence of 24–72%; Cummings & Miller, 1987), even though their prevalence might be underestimated (Thomas et al., 2007). VHs may also occur in a wide range of clinical conditions, such as ophthalmologic diseases, neurologic disorders, toxic and metabolic disorders, and psychiatric disorders (e.g., schizophrenia, affective psychosis and bipolar disorder; Cummings et al., 1987; Waters et al., 2014), as well as in non-clinical individuals (Johns & van Os, 2001; Tien, 1991). Although, visual

hallucinations are much less common in non-clinical compared to clinical samples, they seem to be more prevalent than auditory hallucinations in healthy individuals (Ohayon, 2000; Tien, 1991).

Whereas most of the studies have focused on auditory and visual forms of hallucinations (e.g., Cummings & Miller, 1987; Langdon, Jones, Connaughton, & Fernyhough, 2009; McCarthy-Jones et al., 2014; Sanjuan, Gonzalez, Aguilar, Leal, & Os, 2004; Stephane, Thuras, Nasrallah, & Georgopoulos, 2003; Teeple, Caplan, & Stern, 2009), fewer studies examined hallucinations in other sensory modalities (e.g., Lewandowski, DePaola, Camsari, Cohen, & Ongur, 2009; Mueser, Bellack, & Brady, 1990; Thomas et al., 2007). Despite their rare frequency, olfactory, gustatory, and tactile hallucinations have been additionally reported in both psychotic (Lewandowski et al., 2009) and non-clinical samples (Tien, 1991). Nonetheless, auditory and visual forms represent the major risk factors for a psychiatric diagnosis (de Leede-Smith & Barkus, 2013; Ohayon, 2000).

In the last decades, a growing number of studies probed the pathophysiological mechanisms underlying the experience of hallucinations in non-clinical samples (e.g., Barrett & Etheridge, 1992; Paulik, Badcock, & Maybery, 2007; Posey & Losch, 1983; Vercammen & Aleman, 2010; Young, Bentall, Slade, & Dewey, 1986). While it is important to consider that non-clinical hallucinations are typically less severe than clinical hallucinations (e.g., de Leede-Smith & Barkus, 2013), the study of this phenomenon in a non-clinical population is particularly advantageous as it avoids confounding effects of medication and hospitalization that are often ascribed to clinical samples (e.g., Kühn & Gallinat, 2010).

The existing studies have most commonly selected participants from university settings (e.g., Fonseca-Pedrero et al., 2010; Larøi, & van der Linden, 2005b; Morrison, Wells, & Nothard, 2000; Paulik, Badcock, & Maybery, 2006). In this context, the Launay-Slade Hallucination Scale (LSHS; Launay & Slade, 1981), and its subsequent revised versions (e.g., Bentall & Slade, 1985; Morrison, Wells, & Nothard, 2000; Morrison, Wells, & Nothard, 2002; Larøi, & van der Linden, 2005b), has been the most commonly used instrument to probe hallucination predisposition. Of note, non-clinical individuals with higher LSHS scores were found to share phenomenological, cognitive, neuropsychological, and psychophysiological similarities with psychotic patients with hallucinations (Bentall, Claridge, & Slade, 1989; de Leede-Smith & Barkus, 2013). The LSHS original English version (Launay & Slade, 1981) consists of 12 items in a true or false response format. Items were subsequently rephrased by replacing negatively formulated content with positive content in the first modified version of the scale (Bentall & Slade, 1985). Aiming to increase response variability, Bentall and Slade (1985) also replaced the true-or-false response format with a 5-point Likert scale. As previous versions of the LSHS did not address visual hallucinatory experiences, subsequent versions by Morrison et al. (2000; 2002) have incorporated additional items

that tap into visual forms of hallucinations (Morrison, Wells, & Nothard, 2000; Morrison, Wells, & Nothard, 2002). These studies have also removed the "unsure" option with the aim of preventing the tendency to choose the midpoint option of the scale (Morrison et al., 2000, 2002). Due to the lack of items probing the experience of hallucinations other than in the auditory and visual modalities, two Belgian versions of the LSHS, including 17 and 16 items, respectively, were developed (Larøi, Marczewski, & van der Linden, 2004; Larøi, & van der Linden, 2005b). Compared to the LSHS first Belgian version (Larøi et al., 2004), the subsequent Belgian version (Larøi and van der Linden, 2005b) has only two modifications: an item was excluded due to its extremely low response rating ("In the past I have heard the voice of God or one of his messengers speaking to me"); and the item "Sometimes, when I look at things such as chairs and tables, they are unreal or strange" was replaced with "Sometimes I have seen things or animals when nothing was in fact there." This replacement aimed to provide a more appropriate visual hallucination item, considering the lack of this type of items in the LSHS version of Morrison et al. (2000). From all the LSHS adaptations, the two versions developed by Larøi et al. (2004), Larøi and van der Linden (2005b) are the most complete, as they include items that tap into distinct forms of hallucinations (auditory, visual, olfactory, tactile, hypnagogic, and hypnopompic), and as those items are further assessed in other relevant dimensions (e.g., frequency, degree of control, and affective content).

Although, an exploratory factor analysis of the LSHS has shown that hallucination predisposition is better represented by a multi-factor structure (e.g., Larøi et al., 2004; Paulik et al., 2006; Waters, Badcock, & Maybery, 2003), the number and type of dimensions that characterize this predisposition are not consensual: two factor (e.g., Fonseca-Pedrero et al., 2010; Morrison et al., 2000; Serper, Dill, Chang, Kot, & Elliot, 2005), three-factor (e.g., Aleman, Nieuwenstein, Boecker, & de Haan, 2001; Paulik, Badcock, & Maybery, 2006; Waters, Badcock, & Maybery, 2003), four-factor (e.g., Cangas, Langer, Moriana, 2009; Larøi et al, 2004; Levitan, Ward, Catts, & Hemsley, 1996; Vellante et al., 2012), and five-factor (e.g., Larøi & van der Linden, 2005b) dimensions were proposed. Whereas some of these inconsistencies may be accounted for by differences in LSHS versions or response formats, and by differences in the samples (clinical and non-clinical) examined, study discrepancies were reported even when using the same LSHS version. For example, using the LSHS developed by Bentall and Slade (1985), Serper et al. (2005) found a two-factor solution ("subclinical factor" and "clinical factor"), whereas Aleman et al. (2001) and Waters et al. (2003) obtained a three-factor solution. These two later three factor solutions also differed from each other ("tendency toward hallucinatory experiences," "subjective externality of thought," and "vivid daydreams"; "vivid mental events," "hallucinations with a religious theme," and "auditory and visual perceptual hallucinatory experiences," respectively). Moreover, whereas

a five-factor solution was found in the LSHS adaptation of Larøi and van der Linden (2005b), a four-factor structure was proposed by the Italian adaptation of the Belgian version (Vellante et al., 2012). Despite the controversy surrounding this topic, there is substantial evidence that all LSHS versions are especially reliable, having adequate psychometric properties (e.g., Cella, Cooper, Dymond, & Reed, 2008; Waters et al., 2003) and temporal stability (e.g., Morrison et al., 2002). Moreover, the LSHS is a versatile instrument that can be used to measure hallucination predisposition in both non-clinical (e.g., Larøi et al., 2004; 2005b; Morrison et al., 2000; Waters et al., 2003) and clinical individuals (e.g., Levitan et al., 1996; Serper et al., 2005). As such, it was adapted to many languages, including Dutch (Aleman et al., 2001), Spanish (Fonseca-Pedrero et al., 2010), French (Larøi et al., 2004; Larøi & van der Linden, 2005b), and Italian (Vellante et al., 2012). The validation and adaptation of the LSHS in different languages represent a cross-cultural validation of the hallucination predisposition construct (Hui & Triandis, 1985).

Note that the adaptation of a scale or survey to a specific language and cultural context requires specific statistical analyses that determine whether the instrument has adequate measurement properties to be used not only in the target population, but also in cross-cultural studies. Three important indices are considered in the evaluation of the quality of an assessment instrument: (1) sensitivity (i.e., the ability to discriminate between individuals — discrimination, and to detect individual changes over time — responsiveness to change; Kirshner, & Guyatt, 1985), (2) validity (i.e., the ability to capture the construct under study — construct validity, and to produce reliable empirical knowledge — internal validity; Kimberlin & Winterstein, 2008), as well as (3) consistency and reliability (i.e., the ability to consistently produce the same result if the instrument is administered again — stability, and to achieve agreement between items — internal consistency; Kimberlin & Winterstein, 2008).

3.2.1 Aims and hypotheses of the current study

The current study aimed to validate and adapt the LSHS version developed by Larøi and van der Linden (2005b) for the Portuguese population, by examining its psychometric proprieties (sensitivity, internal validity, and internal consistency). In addition, the psychometric results of the Portuguese LSHS adaptation were compared with the Belgian LSHS original validation. The decision to use this LSHS version was motivated by the fact that it comprises items concerning several types of hallucinatory experiences (auditory, visual, olfactory, and tactile), and a response format that allows measuring

additional relevant aspects of these experiences (e.g., frequency, degree of control, affective content of the hallucinatory experience). We expected to find a five-factor structure in the Portuguese adaptation of the LSHS, similarly to Larøi and van der Linden (2005b).

In a second step, we sought not only to describe the phenomenological characteristics of non-clinical Portuguese hallucinatory experiences (e.g., prevalence, frequency, degree of control, affective content of the hallucinatory experience), but also to examine the relationship between them (Larøi & van der Linden, 2005b). Differences between males and females, which were not tested in the previous adaptations of the scale, were also examined. The analysis of sex differences was motivated by previous evidence demonstrating that women are more commonly affected by non-clinical hallucinations when compared to men (Maric, Krabbendam, Vollebergh, de Graaf, & van Os, 2003; Tien, 1991; Young, Bentall, Slade, & Dewey, 1986). Consequently, we hypothesized that non-clinical hallucinations would be more prevalent in female relative to male participants. Moreover, based on previous findings (Johns, Hemsley, & Kuipers, 2002; Larøi & van der Linden, 2005b), we predicted that unpleasant experiences would be related to attributions of lower controllability over the end and reappearance of these experiences, as well as with higher frequency ratings.

Following Larøi and van der Linden (2005b), the third aim of the current study was to clarify whether the hallucinatory experiences were related to the use of alcohol or drugs. In addition, we aimed to determine the association between LSHS ratings and anxious-depressive symptomatology and schizotypal tendencies. These later measures were not included in the study of Larøi and van der Linden (2005b). Previous studies have shown that the presence of both anxious-depressive symptomatology and schizotypal tendencies (Barkus, Stirling, Hopkins, McKie, & Lewis, 2007; de Leede-Smith & Barkus, 2013; Paulik, Badcock, & Maybery, 2006; Smith et al., 2006) might indicate increased hallucination predisposition. Therefore, we hypothesized that the prevalence of hallucinatory experiences would be higher in individuals reporting more clinical symptoms.

3.3 Methods

3.3.1 Participants

A total sample of 354 European Portuguese college students (mean age = 24.13, *SD* = 6.61 years, ranging from 18 to 64 years; 266 females) participated in the study. Participants were recruited,

via email, from several universities located in the north, center and south of Portugal, following a sampling procedure commonly used in prior studies with college students (e.g., Jones & Fernyhough, 2009; Richardson & Garavan, 2009; Stainsby & Lovell, 2014). The education level varied from 12 to 21 years (*M* = 14.52, *SD* = 1.83). Data from the 354 participants who responded to the questionnaire were all included in the data analyses. At the time participants answered the questionnaire, 328 were students, whereas 26 had recently finished their undergraduate or graduate studies. Considering the nature of this recruitment method, a specific response rate could not be determined.

Of those, 16 participants (mean age = 23.50, *SD* = 8.53 years, ranging from 18 to 53 years; 11 females) with high LSHS scores (mean score = 35.13, *SD* = 8.03, ranging from 25 to 51 points), and 14 participants mean age = 21.40, *SD* = 5.24 years, ranging from 18 to 37 years; 13 females) with low LSHS scores (mean score = 14.57, *SD* = 4.69, ranging from 7 to 20 points) were further screened for clinical symptoms.

The study protocol was approved by the local ethics committee ('Subcomissão de Ética para as Ciências da Vida e da Saúde' – CECVS–064/2014, from the University of Minho). Informed written consent was obtained for each participant prior to their involvement in the study.

3.3.2 Materials

The Portuguese adaptation of the Belgian modified version of the LSHS (Larøi & van der Linden, 2005b, originally developed by Launay & Slade, 1981) was used to assess hallucination predisposition in college students.

The translation and adaptation of the modified version of the LSHS (Larøi & van der Linden, 2005b) for the European Portuguese language was carried out using the back-translation procedure. This procedure involves three independent steps. First, the original Belgian version (Larøi & van der Linden, 2005b who translated the scale from French into English) was translated into European Portuguese by a native speaker who was highly proficient in the use of the English language. Subsequently, the European Portuguese version was back translated into the original English language by three other subjects who were blind to the original version. Finally, all the translations as well as the original version were reviewed to verify semantic, idiomatic, experiential and conceptual equivalence, and after discussing any potential discrepancies, a consensus was reached regarding the final version of the Portuguese LSHS.

The LSHS current version includes 16 items tapping into different forms of hallucinations (auditory, visual, olfactory, tactile, hypnagogic, and hypnopompic), which are measured using a 5-point Likert scale, from 0 to 4 (0 = "definitely does not apply to me," 1 = "possibly does not apply to me," 2 = "unsure," 3 = "possibly applies to me," and 4 = "definitely applies to me"). The total score ranges between 0 and 64, with higher scores indicating higher hallucination predisposition. Consistent with the first Belgian LSHS version (Larøi et al., 2004), this version includes five additional items that were not part of the LSHS short versions (Launay & Slade, 1981; Bentall & Slade, 1985; Morrison et al., 2000, 2002): an item related to olfactory hallucinatory experiences ("In the past, I have smelled a particular odor when there was nothing there"), an item related to tactile hallucinatory experiences ("I have had the feeling of touching something or being touched and then found that nothing or nobody was there"), an item related to the experience of feeling the presence of someone close who has already died ("On certain occasions I have had the feeling of the presence of someone close who has deceased"), an item which is simultaneously related to visual, auditory and tactile sensory experiences ("Sometimes, immediately prior to falling asleep or upon awakening, I have had the experience of having seen or felt or heard something or someone that wasn't there or the feeling of being touched even though no one was there"), and an item that addresses sensations of flying and floating, and out-of-body experiences ("Sometimes, immediately prior to falling asleep or upon awakening, I have had a sensation of floating or falling or that I left my body temporarily"). Responses such as "possibly applies to me" or "definitely applies to me" (3 or 4 points) were subsequently rated on a 5-point Likert scale measuring frequency of occurrence (from 0 = "it occurs very rarely" to 4 = "it occurs very often"), degree of control (over the end of the experience, varying from 0 = "it's very easy to cease the experience" to 4 = "it's very difficult to cease the experience"; and over the beginning of the experience, varying from 0 = "it's very easy to avoid the experience" to 4 = "it's very difficult to avoid the experience," and affective content of the experience (from 0 = "the experience is very negative" to 4 = "the experience is very positive"). Moreover, participants who responded "possibly applies" or "definitely applies" (3 or 4 points) to at least one item were further invited to complete five complementary items on a true-or-false response format. These questions aimed to clarify whether the hallucinatory experiences concerned them personally or not, whether these experiences involved other close persons and past events, and if the hallucinatory experiences occurred during stressful events or under the influence of drugs or alcohol. The Portuguese translation of the LSHS items is presented in Appendix A.

In order to collect additional relevant information, hallucination predisposition items were interspersed with several fillers items: seven items concerning psychopathology and schizotypal

tendencies (e.g., “I feel more upset or angry than usual,” “I am rarely sad or depressed,” “I describe myself as an anxious person,” “People usually describe me as an odd person”), and 10 items selected from the Marlow–Crowne Social Desirability Scale (Crowne & Marlow, 1960; e.g., “I am always friendly, even with people who are unpleasant,” “Sometimes, I feel resentful for not having things the way I like”). Clinical filler items were based on questionnaires commonly used in clinical assessments such as the Brief Symptom Inventory (BSI, Derogatis & Spencer, 1982) and the Schizotypal Personality Questionnaire (SPQ; Raine, 1991). All filler items were randomly distributed through the LSHS questionnaire, and responses were provided by using the same scoring scale (5-point Likert scale).

The BSI and the SPQ were used to assess clinical symptoms in both high and low LSHS participants, in a second stage of the study. The Portuguese adaptation of the BSI (Derogatis & Spencer, 1982; adapted by Canavarro, 1999) was used to examine the presence of psychological distress and psychiatric disorders. The BSI is a self-report questionnaire with 53 items distributed across nine subscales (Somatization, Obsessive-Compulsive, Interpersonal Sensitivity, Depression, Anxiety, Hostility, Phobic Anxiety, Paranoid Ideation, and Psychoticism) and three additional scales (Global Severity Index, Positive Symptoms Total, and Positive Symptoms Distress Index) that capture global psychological distress. Items are evaluated on a 5-point Likert scale, ranging from 0 (“not at all”) to 4 (“extremely”). Total scores range between 0 and 24 for three subscales (Obsessive-Compulsive, Depression, and Anxiety), 0 and 20 for four subscales (Hostility, Phobic Anxiety, Paranoid Ideation, and Psychoticism), 0 and 16 for one subscale (Interpersonal Sensitivity), and 0 and 28 for one subscale (Somatization). Moreover, scores ≥ 1.7 in the Positive Symptoms Distress Index (PSDI) may indicate emotional distress.

The Portuguese adaptation of the SPQ (Raine, 1991, adapted by Santos, 2011) was used to assess schizotypal traits. The 74-item self-rated SPQ comprises three factors (Cognitive-Perceptual, Interpersonal, and Disorganized). These factors in turn include distinct subscales: the Cognitive-Perceptual (Ideas of Reference, Odd Beliefs, Unusual Perceptual Experiences, and Suspiciousness), and Interpersonal (Excessive Social Anxiety, No Close Friends, Constricted Affect, and Suspiciousness) factors include four subscales, whereas the Disorganized factor includes two subscales (Odd or Eccentric Behavior and Odd Speech). Items are rated using a dichotomous response format (“yes,” “no”). Total scores range between 0 and 74: the higher the number of “yes” responses, the more severe the schizotypal traits.

3.3.3 Procedure

Data were collected from April 2014 to February 2015. College students were invited via email to participate in a study in which they were asked to respond to a questionnaire about perceptual experiences, by accessing a website in a HTLM format, specifically developed for that purpose. To encourage survey participation, a voucher was drawn. The online survey began by introducing the goal of the study and providing specific instructions about the questionnaire. Prior to the presentation of the questionnaire, participants were reminded about confidentiality and rights. Those who were interested in participating in the study ensured their participation by providing online informed consent. After providing socio-demographic information (age, sex, education level), participants were asked to complete the questionnaire. During the presentation of the questions, items remained at the center of the computer screen until a response was made. Answers were automatically saved after the participants' selection using the mouse. There was no time limit to complete the questionnaire.

Participants were subsequently assigned to one of two groups on the basis of hallucination predisposition by a median split. Those with high LSHS scores (≥ 20 points) and those with low LSHS scores (≤ 20 points), and who agreed to enroll in a second stage of the study, were asked to complete the BSI and the SPQ in a face-to-face assessment session. To encourage participation, vouchers or course credits were provided.

3.3.4 Data analyses

Statistical analyses were performed using the IBM SPSS Statistics 22.00 (SPSS, Corp., USA) software package. First, psychometric properties of the LSHS Portuguese adaptation were examined by assessing its sensitivity, internal validity and internal consistency, and reliability. A frequency analysis for each item was conducted to determine whether all response categories were represented in this sample (sensitivity). The factor structure of the questionnaire was performed through Principal Component Analysis using Varimax rotation (internal validity). We confirmed whether data were based on the Kaiser-Meyer-Olkin (KMO) criteria and Bartlet's test of sphericity. Only factors with eigenvalues greater than 1 were retained. Subsequently, three Principal Component Analysis were conducted to determine the best solution for the Portuguese version of the questionnaire: (1) an unforced factor analysis with a cut-off point of 0.30 for factor loadings; (2) a forced five-factor solution with factor loadings above 0.50, as suggested in the original factor analysis (Larøi & van der Linden, 2005b); and (3) a forced analysis with

Promax rotation in order to extract four factors loading > 0.30, as proposed in a subsequent Italian adaptation (Vellante et al., 2012) of the revised scale presented by Larøi and van der Linden (2005b). For the forced five- and four-factor solutions, items loading above the established saturation values (0.50 and 0.30, respectively) on more than one factor were retained in the same factors of the previous studies. The reliability was quantified by measuring the internal consistency of the questionnaire with item-total score correlations (correlation of each item with the total of the remaining items), as well as with Cronbach's alpha coefficients (internal consistency and reliability). The Cronbach's alpha coefficient was calculated for the total score, as well as for each factor, and values ≥ 0.70 were considered acceptable. Items were considered to have adequate consistency if their item-total correlation fell between 0.275 and 0.75 (Pedhazur & Schmelkin, 1991).

Second, descriptive analyses were conducted to describe the phenomenological characteristics of the hallucinatory experiences (prevalence, frequency of occurrence, perceived degree of control, and affective content of the hallucinatory experience for each factor and for each item) and other specific aspects related to them (whether the hallucinatory experiences concerned participants personally, if they involved relatives or friends, events already experienced and stressful events or difficulties, as well as if they occurred under the influence of drugs or alcohol).

Third, an exploratory data analysis was conducted using the Shapiro–Wilk test, the Kolmogorov–Smirnov test, and measures of skewness and kurtosis. This analysis revealed that data for some of the variables under study (prevalence, frequency, valence, and control) were not normally distributed. Nonetheless, a direct comparison of results between non-parametric and parametric tests revealed identical results. In such a case, it has been suggested to report the results from parametric tests as they have more statistical power than non-parametric tests (Fife-Schaw, 2006). Therefore, parametric tests were selected as no discrepancies were observed between parametric and non-parametric test results, and considering prior simulation studies (Elliott & Woodward, 2007; Ghasemi & Zahediasl, 2012) that indicate that parametric tests perform well with non-normal distributions if the sample size is large enough ($N > 30$). Hence, differences between males and females in hallucinatory experiences were examined using independent samples t-tests, whereas Pearson correlation coefficients were used to probe the relationship between the affective content of the hallucinatory experiences and the perceived degree of control over the experiences (means for the items tapping into the perceived control over the beginning *vs.* end of the experiences were calculated separately), as well as between the affective content of the hallucinatory experiences and their frequency of occurrence.

Finally, independent samples t-tests were used to probe differences between individuals with high *vs.* low hallucination predisposition in clinical symptomatology. Additionally, the relationship between LSHS and clinical scores was assessed using Pearson correlation coefficients. Parametric statistical tests were used as the normality assumption was verified.

3.4 Results

3.4.1 Psychometric properties of the Portuguese adaptation of the LSHS

3.4.1.1 Sensitivity

The Portuguese version of the LSHS was found to have appropriate sensitivity as all items were successful in discriminating between the five response categories. Nonetheless, whereas participants tended to select higher values (3 and 4 points) in five of the items (1, 2, 3, 7, and 12) and unsure values (2 points) in one of the items (5), 10 items (4, 6, 8, 9, 10, 11, 13, 14, 15, and 16) were more likely to receive lower values (0 points).

3.4.1.2 Internal validity

In the first Principal Component Analysis (unforced analysis) a three-factor structure explaining 53% of the total variance was found. The first factor yielded the highest proportion of explained variance (24.13%), and included 7 items. The second factor accounted for additional 17.40% of the total variance and was composed of 3 items, whereas the third factor, explaining 11.47% of the variance, included 6 items. For this factorial solution, the Bartlet's test of sphericity was statistically significant ($p < 0.001$), and the Kaiser-Meyer-Olkin (KMO) index was close to 1 (0.88), which reflects goodness-of-fit of the factor analysis. Eigenvalues for the three factors were all > 1. Items that loaded above 0.30 on more than one factor were retained in the factor that included other similar items. **Table 1** displays the factor analysis of the Portuguese version of the LSHS, which resulted in a three-factor structure.

Table 1. Three-factor structure of the Portuguese adaptation of the LSHS.

	Factor		
Item	1	2	3
4. In the past, I have had the experience of hearing a person's voice and then found that no one was there.	**.67**		
8. I often hear a voice speaking my thoughts aloud.	**.34**	.55	
9. I have been troubled by hearing voices in my head.	**.67**		
10. On certain occasions, I have seen the face of a person in front of me, but there was no one.	**.73**		
14. In the past, I have smelt a particular odor when there was nothing there.	**.55**		
15. I have had the feeling of touching something or being touched and then found that nothing or no one was there.	**.79**		
16. Sometimes I have seen things or animals when nothing was in fact there.	**.76**		
5. The sounds I hear in my daydreams are generally clear and distinct.		**.78**	
6. The people in my daydreams seem so true to life that I sometimes think that they are.		**.73**	
7. In my daydreams I can hear the sound of a tune almost as clearly as if I were actually listening to it.		**.73**	
1. Sometimes a passing thought will seem so real that it frightens me.		.50	**.44**
2. Sometimes my thoughts seem as real as actual events in my life.		.51	**.55**
3. No matter how hard I try to concentrate on my work unrelated thoughts always creep into my mind.			**.74**
11. Sometimes, immediately prior to falling asleep or upon awakening, I have had the experience of having seen or felt or heard something or someone that wasn't there or the feeling of being touched even though no one was there.	.64		**.38**
12. Sometimes, immediately prior to falling asleep or upon awakening, I have had a sensation of floating or falling or that I left my body temporarily.			**.56**
13. On certain occasions I have had the feeling of the presence of someone close who has deceased.	.46		**.37**
Eigenvalue	5.58	1.78	1.11
Explained variance (%)	24.13	17.40	11.47
Cronbach α	0.82	0.74	0.71

However, this three-factor structure was not in accordance with the five-factor structure proposed by the authors of the original questionnaire (Factor I: "Sleep-related hallucinations," Factor II: "Vividness

of daydreams," Factor III: "Intrusive or vivid thoughts," Factor IV: "Auditory hallucinations," and Factor V: "Visual hallucinations"). To extract the same number of factors, a second factor analysis was conducted. Even though the forced five-factor solution accounted for a greater amount of the total variance (64.35%) than the unforced three-factor solution (53%), the fourth and the fifth factors obtained eigenvalues below 1 (0.95 and 0.87, respectively). Moreover, three items loaded below 0.50 (1, 8, and 15) in the current five-factor solution, and therefore were excluded. Factor I explained 19.22% of the variance and included four items; Factor II accounted for 15.75% of the variance and included three items; Factor III, explaining 10.15% of the total variance, retained two items; Factor IV accounted for 9.90% of the variance and retained two items; and Factor V explained the lowest proportion of variance (9.32%), and included two items. Whenever possible, items loading above 0.50 on more than one factor were included in the same factor of the original structure. Retained items and corresponding factor loadings, as well as comparative results between this study and the original study (Larøi & van der Linden, 2005b), are presented in **Table 2**.

Table 2. Five-factor structure of the Portuguese adaptation of the LSHS and the Belgian original five-factor structure.

Item	Portuguese Five-Factor					Belgian Five-Factor				
	1	2	3	4	5	1	2	3	4	5
4.	.72								.68	
8.	.43[a]								.63	
9.	.72								.73	
10.	.76									.71
16.	.67									.65
5.		.79					.73			
6.		.66					.69			
7.		.79					.79			
11.			.70			.71				
12.			.67			.72				
15.			.45[a]			.73				
13.				.71		.58				
14.				.62						
1.					.42[a]			.64		
2.					.61			.70		
3.					.80			.65		
Eigenvalue	5.58	1.78	1.11	0.95[b]	0.87[b]	5.03	1.96	1.83	1.61	1.46
Variance %	19.22	15.75	10.15	9.90	9.32	29.00	10.00	9.00	7.00	4.00
Cronbach α	0.79	0.74	0.58[c]	0.49[c]	0.50[c]	0.74	0.72	0.68	0.76	–

[a]Items loading less than 0.50 were excluded. This occurred for three items (1, 8 and 15).

[b]Eigenvalues below 1.

[c]Cronbach α values below 0.70. **Note.** It was not possible to determine a Cronbach's α coefficient for Factor 5 in the Belgian LSHS version as this factor contained only two items.

Following the Italian validation of the revised LSHS version (Vellante et al., 2012), a final forced Principal Components Analysis was conducted to extract four factors. The four-factor solution for the Portuguese adaptation of the questionnaire proposed by Vellante et al. (2012) explained 58.92% of the total variance. The percentage of variance explained by each factor was 34.90% for Factor I (3 items), 11.14% for Factor II (4 items), 6.96% for Factor III (6 items), and 5.92% for Factor IV (3 items). All items saturated above 0.30 in the same factors of the Italian study. However, only the first three factors showed eigenvalues > 1. Factor loadings and comparative results between the Portuguese study and the Italian study are listed in **Table 3**.

Table 3. Four-factor structure of the Portuguese adaptation of the LSHS and the Italian four-factor structure of the Belgian LSHS version.

	Portuguese Four-Factor				Italian Four-Factor			
Item	1	2	3	4	1	2	3	4
8.	.47				.51			
9.	.76				.64			
10.	.81				.94			
4.		.33						.31
5.		.82						.75
6.		.73						.83
7.		.80						.77
11.			.78			.75		
12.			.66			.67		
13.			.46			.68		
14.			.66			.59		
15.			.73			.76		
16.			.80			.39		
1.				.67			.74	
2.				.77			.88	
3.				.74			.62	
Eigenvalue	5.58	1.78	1.11	0.95[a]	6.71	1.82	1.22	0.89
Variance %	34.90	11.14	6.96	5.92	41.90	11.50	7.60	5.60
Cronbach α	0.62[b]	0.71	0.77	0.64[b]	0.85	0.85	0.83	0.86

[a]Eigenvalues below 1.
[b]Cronbach α values below 0.70.

Based on the three Principal Components Analysis, a three-factor solution proved to be the most adequate. Therefore, the Portuguese version of the LSHS includes a total of 16 items, distributed by the 3 factors that emerged from the analysis. Factor I was named "Auditory, visual, olfactory, and tactile

hallucinations" as it encompasses the seven items related to the four types of hallucinations; Factor II was named "Vividness of daydreams" and comprises the three same items of the original version; and Factor III was named "Intrusive or vivid thoughts and Sleep-related hallucinations." This last factor comprises six items that were distributed by two independent factors in the original version ("Intrusive or vivid thoughts" and "Sleep-related hallucinations"). Even though the items were regrouped into 3 factors in the Portuguese version of the LSHS only, the 15 items of the original five-factor version were kept. Moreover, item 14 (concerning the olfactory sensory modality) was retained in the current version, although it was excluded from the Belgian study as its saturation value was not within the acceptable interval (> 0.50). The following analyses were only run on the final three-factor structure of the Portuguese LSHS.

3.4.1.3 Internal consistency and reliability

A Cronbach's alpha of 0.87 was found for the global score. **Table 1** shows Cronbach's alpha values for each factor of the Portuguese version of the LSHS, with values ranging between a minimum of 0.71 for Factor III and a maximum of 0.82 for Factor I. These values indicate a high internal consistency and reliability. Moreover, an item-total correlation above 0.30 was found for all items (0.31–0.62 range), revealing a high item-total consistency (see **Table 4**). Taken together, these results confirm the internal consistency of the Portuguese adaptation of the LSHS.

Table 4. Mean scores, standard deviations, item-total correlations and alpha levels after item elimination from the LSHS Portuguese adaptation ($N = 354$).

Item	Mean	*SD*	Item-Total Correlation	Alpha if Item was deleted
1. Sometimes a passing thought will seem so real that it frightens me.	1.95	1.30	0.50	0.86
2. Sometimes my thoughts seem as real as actual events in my life.	2.16	1.27	0.55	0.86
3. No matter how hard I try to concentrate on my work unrelated thoughts always creep into my mind.	2.63	1.14	0.31	0.87
4. In the past, I have had the experience of hearing a person's voice and then found that no one was there.	0.93	1.26	0.54	0.86
5. The sounds I hear in my daydreams are generally clear and distinct.	1.64	1.19	0.50	0.86

Item	Mean	*SD*	Item-Total Correlation	Alpha if Item was deleted
6. The people in my daydreams seem so true to life that I sometimes think that they are.	1.22	1.20	0.54	0.86
7. In my daydreams I can hear the sound of a tune almost as clearly as if I were actually listening to it.	1.64	1.36	0.47	0.86
8. I often hear a voice speaking my thoughts aloud.	1.95	1.30	0.49	0.86
9. I have been troubled by hearing voices in my head.	0.49	0.90	0.49	0.86
10. On certain occasions, I have seen the face of a person in front of me, but there was no one.	0.45	0.89	0.59	0.86
11. Sometimes, immediately prior to falling asleep or upon awakening, I have had the experience of having seen or felt or heard something or someone that wasn't there or the feeling of being touched even though no one was there.	1.14	1.32	0.55	0.86
12. Sometimes, immediately prior to falling asleep or upon awakening, I have had a sensation of floating or falling or that I left my body temporarily.	2.16	1.51	0.45	0.86
13. On certain occasions I have had the feeling of the presence of someone close who has deceased.	0.84	1.19	0.45	0.86
14. In the past, I have smelt a particular odor when there was nothing there.	0.78	1.13	0.48	0.86
15. I have had the feeling of touching something or being touched and then found that nothing or no one was there.	0.73	1.09	0.58	0.86
16. Sometimes I have seen things or animals when nothing was in fact there.	0.55	0.93	0.62	0.86

3.4.2 Phenomenological features of the hallucinatory experiences

3.4.2.1 Prevalence, frequency of occurrence, perceived degree of control, and affective content

Hallucinatory experiences were reported by 10% of the sample (the cut-off point at the upper 90th percentile was 35 points). **Table 5** shows the prevalence, frequency of occurrence, perceived degree of

control, and affective content of the hallucinatory experiences for each of the three LSHS factors. Factor III (Intrusive or vivid thoughts and Sleep-related hallucinations) received the highest prevalence and frequency of occurrence ratings (42% and 33%, respectively), followed by Factor II (Vividness of daydreams; 26% and 21%, respectively), and Factor I (Auditory, visual, olfactory and tactile hallucinations; 10% and 8%, respectively). In contrast, few participants described their vivid hallucinatory experiences as very rare (2% for Factor III, 1% for Factor I, and 0.6% for Factor II). Regarding the perceived degree of control, 39% (Factor III), 24% (Factor II), and 10% (Factor I) of participants rated these experiences as being poorly controllable, while very few considered them as being highly controllable (1%, 0.7%, and 0.5%, respectively). Finally, hallucinatory experiences were described as more pleasant than unpleasant: Factor III experiences were characterized as the most pleasant (35%), followed by those included in Factor II (24%) and Factor I (9%), whereas only 2% (Factor III) and 0.3% (Factor II and Factor I) of participants associated their experiences with unpleasant emotions.

Independent samples t-tests revealed that neither the LSHS total scores nor the factor score for all the phenomenological characteristics of the hallucinatory experiences (prevalence, frequency of occurrence, degree of control, and affective content) were significantly different as a function of participant's sex ($p > 0.50$ for all cases).

Of note, the prevalence of hallucinatory experiences was not correlated with the use of alcohol or drugs ($r = 0.04$, $p = 0.50$).

Table 5. Overall number of participants and (percentages) for each LSHS factor according to prevalence, frequency of occurrence, perceived degree of control and affective content.

Factor	Prevalence[a]	Frequency[b] (rare-often)	Control[c] (low-high)	Affective content[d] (negative-positive)
I.	36 (10%)	5-28 (1%-8%)	34-2 (10%-0.5%)	2-32 (0.5%-9%)
II.	92 (26%)	2-76 (0.6%-21%)	84-3 (24%-0.7%)	1-86 (0.3%-24%)
III.	148 (42%)	9-116 (2%-33%)	137-5 (39%-1%)	7-126 (2%-35%)

[a]Percentage of participants who answered "possibly applies to me" or "definitely applies to me" (3 or 4 points).
[b]Percentage of participants who answered 1 "it occurs very rarely" (rare) and 5 "it occurs very often" (often).
[c]Low control is represented by the percentage of participants who answered "it is very difficult to cease the experience" and "it is very difficult to avoid the experience", whereas high control is represented by the percentage of participants who answered "it is very easy to cease the experience" and "it is very easy to avoid the experience".
[d]Percentage of participants who answered "the experience is very negative" (negative) and "the experience is very positive" (positive).

Table 6 illustrates the overall prevalence, frequency of occurrence, and perceived degree of control for each item of the LSHS. In general, prevalence of hallucinatory experiences reported by the participants ranged between a minimum of 5% for item 9 and a maximum of 70% for item 3. Moreover experiences described in items 1, 2, 3, 7, and 12 received the highest prevalence and frequency of occurrence ratings, whereas experiences described in items 9, 10, and 16 were the least prevalent and frequent. Experiences described in items 1, 2, 3, 7, and 12 were perceived as the most difficult to control.

Considering the items associated with Factor I (items 4, 8, 9, 10, 14, 15, and 16), auditory hallucinations (13%) were reported as more prevalent than olfactory (11%), tactile (10%), and visual hallucinations (6%). The highest ratings of frequency and low control for the four types of hallucinations (Factor I) were also observed in the case of auditory hallucinations (10% and 12%, respectively), followed by olfactory and tactile hallucinations (8% for both and 10% for both, respectively), and visual hallucinations (4% and 5%, respectively).

Table 6. Overall number of participants and (percentages) for each of the 16 LSHS items according to prevalence, frequency of occurrence and perceived degree of control.

Item	Prevalence[a]	Frequency[b] (rare-often)	Control[c] (low-high)
1.	146 (41%)	5-118 (1%-33%)	137-3 (39%-0.8%)
2.	172 (49%)	3-139 (0.8%-39%)	162-3 (46%-0.8%)
3.	249 (70%)	1-206 (0.3%-58%)	233-8 (66%-2%)
4.	65 (18%)	13-45 (4%-13%)	57-6 (16%-2%)
5.	90 (25%)	4-73 (1%-21%)	81-4 (23%-1%)
6.	67 (19%)	1-62 (0.3%-17%)	63-0 (18%-0%)
7.	119 (34%)	2-93 (0.6%-26%)	107-5 (30%-1%)
8.	53 (15%)	1-48 (0.3%-14%)	52-1 (15%-0.3%)

Item	Prevalence[a]	Frequency[b] (rare-often)	Control[c] (low-high)
9.	19 (5%)	4-13 (1%-4%)	18-1 (5%-0.3%)
10.	20 (6%)	3-13 (0.8%-4%)	18-1 (5%-0.3%)
11.	79 (22%)	14-53 (4%-15%)	73-3 (21%-0.8%)
12.	192 (54%)	22-141 (6%-40%)	171-12 (48%-3%)
13.	52 (15%)	7-39 (2%-11%)	49-2 (14%-0.6%)
14.	40 (11%)	5-29 (1%-8%)	37-1 (10%-0.3%)
15.	36 (10%)	4-29 (1%-8%)	34-0 (10%-0%)
16.	22 (6%)	2-16 (0.6%-4%)	20-1 (6%-0.3%)

[a]Percentage of participants who answered "possibly applies to me" or "definitely applies to me" (3 or 4 points).
[b]Percentage of participants who answered 1 "it occurs very rarely" (rare) and 5 "it occurs very often" (often).
[c]Low control is represented by the percentage of participants who answered "it is very difficult to cease the experience" and "it is very difficult to avoid the experience", whereas high control is represented by the percentage of participants who answered "it is very easy to cease the experience" and "it is very easy to avoid the experience".

3.4.2.2 Other phenomenological features

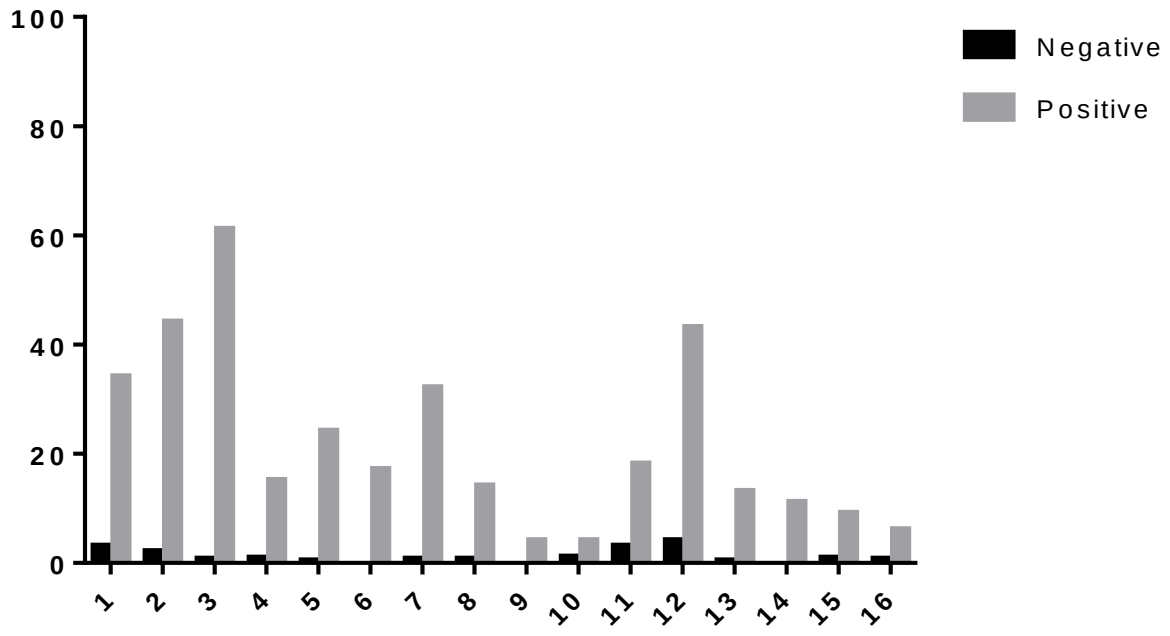
Overall, a great number of participants described their experiences as concerning them personally (65%), involving relatives or friends (41%), and personally experienced events (38%). Hallucinatory experiences related to previous experiences occurred recently in 16% of participants, between 1 and 5 years ago in 15% of participants, and more than 5 years ago in 7% of participants. Moreover, 42% of participants reported that their experiences occurred during stressful events or difficulties. Finally, a small percentage of participants (5%) described their hallucinations as being experienced under the influence of alcohol or drugs.

3.4.2.3 Relationship between the affective content of the hallucinatory experiences, perceived degree of control, and frequency of occurrence

Figure 1 summarizes the percentage of participants who rated their experiences as being pleasant *vs.* unpleasant. All experiences were perceived as more pleasant than unpleasant. Pleasant ratings ranged between a minimum of 4% for items 9 and 10, and a maximum of 61% for item 3, whereas unpleasant ratings ranged between a minimum of 0% for items 6, 9, and 14, and a maximum of 4% for item 12.

The perceived degree of control, both in terms of ceasing the experience ($r = 0.53$, $p < 0.001$) and preventing the reappearance of the experience ($r = 0.60$, $p < 0.001$), was significantly correlated with the affective content of the hallucinatory experiences: the more pleasant the experiences were described, the more controllable they were perceived. A strong correlation between the affective content of the hallucinatory experiences and the frequency of occurrence was also found ($r = 0.62$, $p < 0.001$), which suggests that these experiences tend to be described as more pleasant as more often they occur.

Figure 1. Percentage of negative and positive affective ratings for each LSHS item.



3.4.3 Relationship between LSHS scores and clinical scores (anxious depressive symptomatology and schizotypal tendencies)

Clinical scores differed significantly between the two subsamples (see **Table 7**), with individuals with high hallucination predisposition showing higher scores than individuals with low hallucination predisposition in both clinical measures (BSI and SPQ).

Moreover, the prevalence of hallucinatory experiences was strongly correlated with clinical symptomatology (BSI Obsessive-Compulsive, $r = 0.46$, $p = 0.011$; BSI Depression, $r = 0.43$, $p = 0.017$; BSI Anxiety, $r = 0.45$, $p = 0.012$; BSI Hostility, $r = 0.41$, $p = 0.024$; BSI Positive Symptom Distress Index, $r = 0.50$, $p = 0.005$) and schizotypal tendencies (SPQ Total Score; $r = 0.43$, $p = 0.016$). Participants who reported having more hallucinations presented increased anxiety and depressive symptoms, as well as schizotypal tendencies.

Table 7. Mean values and standard deviations of the LSHS, BSI and SPQ considering higher hallucination predisposition and lower hallucination predisposition subsamples separately.

	Higher Hallucination Predisposition ($n = 16$)		Lower Hallucination Predisposition ($n = 14$)		
Clinical Measures	*M*	*SD*	*M*	*SD*	*t*
LSHS Total Score	35.13	8.03	14.57	4.69	-8.69***
BSI Somatization	2.85	2.73	1.20	1.20	-2.20*
BSI Obsessive-Compulsive	4.50	2.75	2.35	1.82	-2.54*
BSI Interpersonal Sensitivity	1.80	1.40	0.93	0.93	-2.05*
BSI Depression	3.81	1.94	1.65	1.10	-3.80**
BSI Anxiety	4.01	2.35	2.00	1.66	-2.80**
BSI Hostility	3.20	2.15	1.80	1.64	-2.06*
BSI Phobic Anxiety	1.20	1.30	0.54	0.90	-1.90+
BSI Paranoid Ideation	2.95	2.40	1.91	1.80	-1.40
BSI Psychoticism	1.75	1.91	0.63	0.84	-2.12*
BSI Positive Symptoms Distress Index	1.46	0.31	1.26	0.27	-1.90+
SPQ Cognitive-Perceptual Factor	11.00	4.83	6.93	4.10	-2.50*
SPQ Interpersonal Factor	11.69	5.20	7.60	3.82	-2.50*
SPQ Disorganized Factor	4.94	3.04	2.60	1.55	-2.73*
SPQ Total Score	24.31	7.14	14.71	6.10	-3.98***

***$p < .001$; **$p < .010$; *$p < .050$; +$p < .10$.

3.5 Discussion

The current study aimed to translate, adapt and validate the 16-item Launay-Slade Hallucinations Scale (Larøi & van der Linden, 2005b) for the Portuguese population. Further, the phenomenology of hallucinations was explored in a sample of European Portuguese college students, as well as the relationship between hallucinatory experiences and the use of alcohol and drugs, following Larøi & van der Linden (2005b). An additional goal was to probe the relationship between hallucinatory experiences and anxious-depressive symptoms and schizotypal traits.

3.5.1 The dimensional structure of the Portuguese LSHS

The results demonstrate that the Portuguese adaptation of the LSHS is characterized by high internal validity, as well as by high internal consistency and reliability. The exploratory factor analysis showed that a three-factor structure is the most adequate solution for the LSHS Portuguese version (Factor I: "Auditory, visual, olfactory, and tactile hallucinations," Factor II: "Vividness of daydreams," and Factor III: "Intrusive or vivid thoughts and Sleep-related hallucinations"). The original five-factor solution proposed by Larøi and van der Linden (2005b), as well as the subsequent Italian four-factor solution (Vellante et al., 2012), did not meet the standards of fit in the current study. Our results provide further evidence for the multifactorial structure of hallucination predisposition measured by the LSHS (e.g., Fonseca-Pedrero et al., 2010; Larøi et al, 2004; Levitan et al., 1996; Morrison et al., 2000; Paulik et al., 2006; Serper et al., 2005; Vellante et al., 2012), even though the number of factors that better represent these experiences vary consistently across studies (e.g., Aleman et al., 2001; Larøi et al., 2004; 2005b; Serper et al., 2005; Vellante et al., 2012; Waters et al., 2003). As most of these studies have used shorter versions of the LSHS (e.g., Aleman et al., 2001; Bentall & Slade, 1985; Launay & Slade, 1981; Morrison et al., 2000; 2002; Serper et al., 2005), a comparison of the current results was only possible with the studies of both Larøi and van der Linden (2005b) and Vellante et al. (2012).

Important discrepancies between the Belgian validation and our study were observed. First, in the current study auditory and visual hallucinations were combined into a single factor (Factor I), whereas intrusive or vivid thoughts and sleep-related hallucinations were combined as one factor (Factor III). Each of these experiences (auditory hallucinations, visual hallucinations, intrusive or vivid thoughts and sleep-related hallucinations) emerged as four separate factors in the original study of Larøi and van der Linden

(2005b; Factor IV, Factor V, Factor III, and Factor I, respectively). Nevertheless, we replicated the combination of auditory and visual hallucinations into a single factor, previously reported in the Italian adaptation of this LSHS version (Vellante et al., 2012). This suggests that hallucinatory experiences in the auditory and visual modalities share phenomenological similarities (e.g., automatic nature, occurrence during waking hours). On the other hand, intrusive thoughts have been found to be associated with hypnagogic or hypnopompic hallucinations (Jones, Fernyhough, & Meads, 2009; McCarthy-Jones, Barnes, Hill, Marwood, Moseley, & Fernyhough, 2011; Schmidt & Gendolla, 2008), which might explain why both hallucinatory experiences emerged as a single factor (Factor III) in the current study.

Second, olfactory and tactile sensory modalities of hallucinations were also combined with auditory and visual hallucinations in the current study, resulting in a multisensory factor. This combination is in contrast with Larøi and van der Linden (2005b): whereas the item concerning olfactory hallucinations (item 14) was excluded, the tactile hallucinations item (item 15) was part of Factor I ("Sleep-related hallucinations"). Tactile hallucinations are most likely to occur while falling asleep (hypnagogic experiences) or waking up (hypnopompic experiences; Ohayon, 2000; Cheyne, 2001). However, they can also be experienced during waking hours (e.g., Tien, 1991). In the current study, the combination of four sensory modalities of hallucinations (auditory, visual, olfactory, and tactile) into a single factor (Factor I "Auditory, visual, olfactory, and tactile hallucinations") is consistent with the observation that all these experiences occur in a state of complete awareness (wakefulness hallucinations; e.g., Tien, 1991; Ohayon, 2000).

A similar finding between the current and the original study (Larøi & van der Linden, 2005b) was only evident in Factor II ("Vividness of daydreams"), as it includes the same items indicated by Larøi and van der Linden (2005b). This suggests that experiences reported in Factor II might be more easily differentiated from other forms of hallucinations. As for the internal consistency and reliability of the questionnaire, the analysis yielded satisfactory results. The current indices (alpha coefficient and item-total correlations) reached similar values to those described in the original study, suggesting a high reliability of the LSHS Portuguese version.

3.5.2 Phenomenological aspects of hallucinations in Portuguese non-clinical individuals

Overall, 10% of the sample reported significant hallucinatory experiences (LSHS score > 35). This finding fits well with previous observations reporting an incidence of 10–15% of hallucinators with no

clinical diagnosis (e.g., Badcock, Chhabra, Maybery, & Paulik, 2008; Barrett & Etheridge, 1992; Paulik, Badcock, & Maybery, 2006; Sommer, Daalman, Rietkerk, Diederen, Bakker, Wijkstra, & Boks, 2010). In the current sample, the experiences were neither under the influence of alcohol and drugs, as only 5% of participants described their hallucinations as being experienced under the influence of alcohol or drugs, and occurred similarly in male and female participants. The experience of hallucinations was associated with stressful events (42%), in line with previous studies (e.g., Crowe et al., 2011; Larøi, 2012; Moskowitz & Corstens, 2008). Even though in a small proportion of cases (24%), hallucination predisposition was also associated with stressful events in the study of Larøi and van der Linden (2005b). Despite variability in the prevalence and frequency ratings of hallucinatory experiences in the current sample, intrusive or vivid thoughts and hypnagogic and hypnopompic hallucinations (i.e., experiences occurring between waking and sleeping or during sates of altered awareness) were the most common (42%) and frequent (33%), whereas wakefulness hallucinations (i.e., experiences occurring during waking hours or states of complete awareness) were the least prevalent (10%) and frequent (8%). A closer inspection of each item of Factor I ("Auditory, visual, olfactory, and tactile hallucinations") indicated that auditory hallucinations were relatively common in the Portuguese sample (18% for item 4; 15% for item 8), although not as common as in the Belgian sample (Larøi & van der Linden, 2005b; 34% and 19%, respectively). At the same time, auditory hallucinations were a less prevalent experience in the current sample (13%) than in previous reports with clinical groups (~70% in schizophrenia; 20–50% in bipolar disorder; and 40% in posttraumatic stress disorder; Choong, Hunter, & Woodruff, 2007). Consistent with this finding, epidemiological studies suggest that patients are more likely to report auditory hallucinations than non-psychotic individuals (e.g., Johns et al., 2004; de Leede-Smith & Barkus, 2013; Tien, 1991). Moreover, the presence of hypnagogic and hypnopompic hallucinations is higher in non-clinical individuals than in patients (de Leede-Smith & Barkus, 2013), whereas patients experience wakefulness hallucinations more often than non-clinical individuals (Cheyne, 2001; Jones, Fernyhough, & Meads, 2009; Ohayon, 2000).

As visual hallucinations tend to be the most common form of wakefulness hallucinations in non-clinical groups (Larøi et al., 2005b; Ohayon, 2000; Simon et al., 2009; Sommer et al., 2010; Tien, 1991), we did not expect to observe that auditory hallucinations (13%) were more prevalent than visual hallucinations (6%). Interestingly, olfactory (11%) and tactile (10%) hallucinations were also more prevalent when compared with visual hallucinations. Consistent with previous studies, differences between sensory modalities of hallucinations in non-clinical individuals were minimal (Johns et al., 2001; Tien, 1991). These results corroborate the multimodal nature of non-clinical hallucinations (e.g., Johns et al., 2004; de Leede-Smith & Barkus, 2013; Tien, 1991).

Regarding the perceived control over the hallucinations, all types of hallucinatory experiences were rated as highly uncontrollable and dominating. Specifically, intrusive or vivid thoughts and hypnagogic and hypnopompic hallucinations were perceived as uncontrollable experiences by a greater number of participants (39%). Furthermore, auditory hallucinations were perceived as more difficult to control (12%) than olfactory (10%), tactile (10%), and visual (5.5%) hallucinations. This finding agrees with previous studies (Larøi & van der Linden, 2005b), and additionally suggests that the inability to control such experiences might be comparable to that described by clinical individuals (Chadwick & Birchwood, 1994).

Regarding the emotional content of hallucinatory experiences, wakefulness hallucinations were predominantly perceived as pleasant experiences by Portuguese participants (9%), whereas they were perceived more frequently as unpleasant by Belgian participants (34%). In addition, intrusive or vivid thoughts and hypnagogic and hypnopompic hallucinations were also perceived as more pleasant (35%) than the other hallucinatory experiences in the current study. Also, only 0.7% of participants perceived auditory hallucinations as unpleasant in this study. Nevertheless, auditory hallucinations were also rated as positive experiences by a significant number of participants (23%) in the study of Larøi and van der Linden (2005b). In line with these results, prior studies demonstrated that positive emotional reactions to hallucinatory experiences tend to be more common among non-clinical individuals (de Leede-Smith & Barkus, 2013), whereas the opposite is observed in psychotic patients (e.g., de Leede-Smith & Barkus, 2013; Pinheiro, Rezaii, Rauber, & Niznikiewicz, 2016).

As expected, the perceived emotional content of hallucinatory experiences and the degree of control over those experiences were associated. Specifically, the more pleasant the hallucinatory experiences were perceived, the more controllable they were judged. A relationship between both variables was also found in the original study (Larøi & van der Linden, 2005b), but in the opposite direction (i.e., unpleasant experiences were associated with a lower degree of control). Nevertheless, it is reasonable to expect that pleasant experiences are more easily controllable than unpleasant experiences. Consistent with Larøi and van der Linden (2005b), hallucinatory experiences were also described as more pleasant as more often they tend to occur. The perceived pleasantness may result from the increased familiarity associated with frequent hallucinatory experiences (Larøi et al., 2005b; Nayani & David, 1996). In sum, the current findings corroborate previous observations of less severe hallucinatory experiences in non-clinical compared to clinical individuals (e.g., de Leede-Smith & Barkus, 2013). Note that these experiences were, at the same time, less unpleasant than those reported in Larøi and van der Linden

(2005b), which lends support to the existence of a continuum of severity even in the non-clinical experience of hallucinations (Taylor, Freeman, & Ronald, 2016).

3.5.3 Relationship between hallucination predisposition and clinical symptoms

Individuals with higher hallucination predisposition presented more anxious-depressive and schizotypal symptomatology. This result fits well with evidence showing that healthy individuals who experience hallucinations may share psychophysiological similarities with psychotic patients, including feelings of anxiety and depression (Bentall, Claridge, & Slade, 1989; de Leede-Smith & Barkus, 2013; Yung et al., 2006; Yung, Nelson, Baker, Buckby, Baksheev, & Cosgrave, 2009). Moreover, the current findings add support to the observation that the presence of both anxious depressive symptomatology and schizotypal tendencies is related to hallucinatory experiences (Barkus, Stirling, Hopkins, McKie, & Lewis, 2007; de Leede-Smith & Barkus, 2013; Paulik, Badcock, & Maybery, 2006; Smith et al., 2006; Tien & Eaton; 1992; Yung & McGorry, 1996). However, the direction of the association needs further examination in future studies: individuals with increased psychopathological symptoms may be more vulnerable to hallucinatory experiences, or vice versa. Importantly, the combination of psychotic symptoms (e.g., hallucinations and schizotypal tendencies) and negative mood (e.g., anxiety and depression) may place individuals at more risk for a subsequent conversion to psychosis (e.g., Armando et al., 2010; de Leede-Smith & Barkus, 2013; Jones, Murray, Rodgers, & Marmot, 1994; Yung et al., 2006). This is particularly evident in schizophrenia, in which symptoms of depression (e.g., Leff, Tress, & Edwards, 1988) and anxiety (e.g., Cosoff & Hafner, 1998; Turnbull & Bebbington, 2001) are frequent comorbidities.

3.6 Limitations

Some limitations should be considered when interpreting the current findings. First, the sample is comprised of college students who were motivated to participate in the study, and hence it is not representative of the general (non-clinical) population. Second, the factor structure of the LSHS Portuguese version was obtained only via exploratory factor analyses, and not confirmed by confirmatory factor analyses. Finally, regarding the relationship between the hallucinatory experiences and

psychopathological and schizotypal tendencies, the observed association results from a correlational analysis, which does not allow inferences about causality.

3.7 Conclusion

The current study shed further light on hallucinatory experiences in the non-clinical population. Portuguese non-clinical individuals were not only more likely to experience intrusive or vivid thoughts and hypnagogic and hypnopompic hallucinations relative to the other five types of hallucinations (auditory, visual, olfactory, tactile, and vividness of daydreams hallucinations), but also to perceive their hallucinatory experiences as less unpleasant than what is commonly reported in individuals with a psychotic disorder. Of note, the current results demonstrate that hallucination predisposition is related to clinical symptomatology (schizotypal tendencies and negative mood), which may represent increased psychotic risk.

The psychometric proprieties of the LSHS here examined suggest that this scale is a reliable and valid questionnaire to objectively assess hallucinatory experiences in the non-clinical population. Therefore, the adaptation of the LSHS for the Portuguese population represents a useful tool not only for further research intended to clarify the phenomenology of hallucinations in non-clinical individuals, but also for comparative research probing the effects of culture on hallucinatory experiences.

3.8 References

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Chapter 4

4. Decoding emotions from non-verbal vocalizations: How much voice signal is enough?[2]

4.1 Abstract

How much acoustic signal is enough for an accurate recognition of non-verbal emotional vocalizations? Using a gating paradigm (7 gates from 100 to 700 ms), the current study probed the effect of stimulus duration on recognition accuracy of emotional vocalizations expressing anger, disgust, fear, amusement, sadness and neutral states. Participants (N = 52) judged the emotional meaning of vocalizations presented at each gate.

Increased recognition accuracy was observed from gates 2 to 3 for all types of vocalizations. Neutral vocalizations were identified with the shortest amount of acoustic information relative to all other types of vocalizations. A shorter acoustic signal was required to decode amusement compared to fear, anger and sadness, whereas anger and fear required equivalent amounts of acoustic information to be accurately recognized.

[2]Publications derived from this study:

Peer reviewed publications in print or other media

Castiajo, P., & Pinheiro, A. P. (2019). Decoding emotions from nonverbal vocalizations: How much voice signal is enough?. *Motivation and Emotion, 43*(5), 803-813. doi: https://doi.org/10.1007/s11031-019-09783-9

Poster Presentations Presented at Scientific Meetings

Castiajo, P., & Pinheiro, A. P. (2017, September). Temporal signatures of vocal emotional recognition. Poster session presented at the 47th European Brain & Behaviour Society Meeting (EBBS), Bilbao, Spain.

Castiajo, P., & Pinheiro, A. P. (2017, May). How quickly do listeners recognize emotions from nonverbal vocalizations?. Poster session presented at the 12th Nacional Meeting of the Portuguese Association of Experimental Psychology (APPE), Porto, Portugal.

Castiajo, P., & Pinheiro, A. P. (2017, March). How much time do we need to recognize vocal emotions?. Poster session presented at the International Convention of Psychological Science (ICPS), Vienna, Austria.

Castiajo, P., & Pinheiro, A. P. (2016, June). How accurately do listeners recognize emotions from nonverbal short vocalizations?. Poster session presented at the scientific meeting 3rd International Conference of the European Society of Cognitive and Affective Neuroscience, Porto, Portugal.

Castiajo, P. & Pinheiro A. P. (2016, April). Are emotions effectively conveyed through short nonverbal vocalizations?: A follow-up on the Portuguese adaptation of the Montreal Affective Voices (MAV). Poster session presented at the 11th Nacional Meeting of the Portuguese Association of Experimental Psychology (APPE), Lisbon, Portugal.

These findings confirm that the time course of successful recognition of discrete vocal emotions varies by emotion type. Compared to prior studies, they additionally indicate that the type of auditory signal (speech prosody *vs.* non-verbal vocalizations) determines how quickly listeners recognize emotions from a speaker's voice.

Keywords: Duration; Emotion; Gate; Non-verbal vocalizations; Recognition.

4.2 Introduction

The voice is likely the most important sound category in a social environment. It carries not only verbal information, but also socially relevant cues about the speaker, such as his/her identity, sex, age, and emotional state (Belin, Fecteau, & Bédard, 2004; Schirmer, Zysset, Kotz, & Von Cramon, 2004). Vocal emotions can be communicated either through suprasegmental modulations of speech prosody (Schirmer, Striano, & Friederici, 2005) or short non-verbal vocalizations (Schröder, 2003), also known as affective bursts (Belin, Fillion-Bilodeau, & Gosselin, 2008). Both speech prosody (Banse & Scherer, 1996; Juslin & Laukka, 2001) and non-verbal vocalizations (Sauter, Eisner, Calder, & Scott, 2010) rely on a shared acoustic code (e.g., duration, fundamental frequency [F0], intensity) serving the expression of emotional meaning. Nonetheless, compared to speech prosody, non-verbal vocalizations are considered to represent more primitive expressions of emotions and an auditory analogue of facial emotions (Belin et al., 2004). The ability to accurately infer vocal emotions of social partners – both prosody and non-verbal vocalizations – is critical during communication, specifically in predicting the intentions and behaviors of others (Juslin & Laukka, 2003). Whereas the time needed to accurately recognize vocal emotions from speech prosody has been specified (Pell & Kotz, 2011), it remains to be clarified how much temporal information is necessary for an accurate decoding of emotions from non-verbal vocalizations, the focus of the current study.

4.2.1 Decoding of emotions from non-verbal vocalizations versus speech prosody

Vocal expressions are inherently dynamic and their temporal structural determines how emotional meaning is decoded. A robust body of evidence demonstrates that emotions are perceived and recognized

in a categorical manner during voice perception (Cowie & Cornelius, 2003; Juslin & Laukka, 2003; Laukka, 2005), supporting categorical approaches to emotion (Ekman, 1992; Scherer & Ellgring, 2007). Several studies probed how accurately listeners decode vocal emotions either from speech prosody (van Bezooijen, 1984; Juslin & Laukka, 2001; Pell, 2002; Scherer, 1989) or non-verbal vocalizations (Belin et al., 2008; Lima, Castro, & Scott, 2013; Sauter, Eisner, Calder, & Scott, 2010; Schröder, 2003; Vasconcelos, Dias, Soares, & Pinheiro, 2017). These studies showed that accuracy varies by emotion category. Specifically, speech prosodic cues expressing fear and happiness are commonly less accurately recognized than anger and sadness, whereas disgust tends to be associated with the lowest recognition accuracy (Banse & Scherer, 1996; Juslin & Laukka, 2003; van Bezooijen, 1984). In the case of non-verbal vocalizations, sadness and disgust are associated with the highest accuracy (Hawk, van Kleef, Fischer, & Van Der Schalk, 2009; Lima, Castro, & Scott, 2013; Sauter, Eisner, Ekman, & Scott, 2010; Schröder, 2003), whereas fear, anger and happiness tend to be the least accurately decoded vocal emotions (Sauter, Eisner, Calder, & Scott, 2010; Schröder, 2003 - but see Vasconcelos et al., 2017, in which amusement [laughter] was the most successfully recognized emotion). Although scarce, studies that have directly compared recognition accuracy in emotional prosody and non-verbal vocalizations revealed that fear, happiness, anger, sadness, contempt, and disgust are more easily recognized in vocalizations than in speech prosody (Hawk et al., 2009).

4.2.2 The time course of emotion recognition in speech prosody

Emotion-specific differences in voice processing may be explained by differences in their underlying acoustic properties (Juslin & Laukka, 2001; Sauter, Eisner, Calder, & Scott, 2010). The expression and comprehension of vocal emotions rely on a complex configuration of acoustic cues, such as duration, fundamental frequency (F0), and intensity (Schirmer & Kotz, 2006). For instance, happy prosody is characterized by high F0 and intensity and fast speech rate, whereas sad prosody is characterized by low F0 and intensity, as well as by slow speech rate (Banse & Scherer, 1996; Juslin & Laukka, 2003; Sobin & Alpert, 1999). The event-related potential (ERP) studies that probed the time course of vocal emotional perception indicate that neutral and emotional cues are rapidly differentiated within 200 ms after stimulus onset (Liu et al., 2012; Paulmann & Kotz, 2008; Pinheiro et al., 2013; Pinheiro et al., 2014; Schirmer, Simpson, & Escoffier, 2007). By examining emotional priming effects (typically reflected in faster and/or more accurate responses to targets preceded by congruent rather

than incongruent primes – Murphy & Zajonc, 1993), some of these ERP studies demonstrated that the implicit recognition of emotional prosody occurs very rapidly (i.e., 300 ms after prime-target onset: Bostanov & Kotchoubey, 2004; 400 ms after prime-target onset: Paulmann & Pell, 2010; Schirmer, Kotz, & Friederici, 2002, 2005). Despite an early differentiation of neutral and emotional acoustic cues at the brain level, listeners may need more or less acoustic information (i.e., longer vocal samples) to explicitly categorize specific discrete emotions. The studies of Pell and Kotz (2011) and Rigoulot, Wassiliwizky, and Pell (2013) with prosodic pseudo-utterances demonstrated that neutral expressions (510 ms and 654 ms, respectively), fear (517 ms and 427 ms, respectively), sadness (576 ms and 612 ms, respectively) and anger (710 ms and 672 ms, respectively) are recognized at shorter gate intervals than happiness (977 ms and 811 ms, respectively) and disgust (1486 ms and 1197 ms, respectively). Using a restricted number of emotion categories, Cornew, Carver, and Love (2010) observed similar findings with neutral (444 ms), angry (723 ms) and happy (802 ms) prosodic stimuli. The remarkable capacity to recognize negative emotions such as fear, sadness and anger with shorter amounts of acoustic information may be explained by the relevance that a prompt response to vocal signals of threat, loss, and aggression plays in terms of survival (Pell et al., 2011). Nonetheless, changes in speech rate may affect the recognition of negative prosodic cues: whereas a slow speech rate (associated with a longer stimulus duration) was associated with a more accurate recognition of sadness, a faster speech rate (associated with a shorter stimulus duration) led to a more accurate recognition of anger (Bergmann, Goldbeck, & Scherer, 1988).

As all studies mentioned above (Bergmann et al., 1988; Cornew et al., 2010; Pell et al., 2011; Rigoulot et al., 2013) probed the effects of duration on vocal emotional recognition using speech prosody, it remains to be clarified how much temporal information is necessary for the accurate decoding of emotions from non-verbal vocalizations. As for speech prosody, it is reasonable to expect that different amounts of voice information are required to recognize discrete emotional states expressed through vocalizations without verbal content. Similarities in the temporal patterns of vocal emotional recognition in speech prosody and non-verbal vocalizations would support a general mechanism involved in emotional decoding irrespective of stimulus type.

4.2.3 Rapid decoding of emotions in non-verbal vocalizations versus speech prosody

A more recent ERP study shed light on whether the processing of emotional prosody *vs.* non-verbal vocalizations relies on the same neurocognitive mechanisms. Pell and collaborators (2015) showed

that the perception of non-verbal vocal emotions takes precedence over prosodic emotional cues (Pell et al., 2015). Earlier N100 and P200 peak latencies were observed for happy (laughter) non-verbal vocalizations compared to happy prosody, as well as earlier P200 peak latencies for non-verbal vocalizations expressing anger compared to angry prosody. In contrast, no differences were observed in the N100 and P200 peak latencies for sadness as a function of stimulus type (Pell et al., 2015). Latency differences between emotion categories were also observed in the study of Pell et al. (2015): the N100 peaked earlier for happy (laughter) compared to both angry and sad non-verbal vocalizations, whereas the P200 peaked earlier for happy (*M* = 216 ms), followed by angry (*M* = 224 ms) and sad vocalizations (*M* = 235 ms). The earlier ERP response to laughter relative to other emotional categories corroborates the high distinctiveness of this vocal expression (Edmonson, 1983; Kipper & Todt, 2001). Despite the contributions of these ERP studies, they do not specify the minimum duration of vocal information that is necessary for above-chance emotional recognition of non-verbal vocalizations. Whereas ERPs track the time course of emotional cue processing from stimulus onset until a response is made (i.e., evaluating both bottom-up sensory and higher-order cognitive processing stages), behavioral measures tap into the higher-order evaluation processes that lead to a response (e.g., Paulmann & Pell, 2010).

4.2.4 The current study and hypotheses

How much voice signal is enough for a listener to successfully recognize discrete emotional meaning? Does the time course of emotional recognition differ when the voice signal carries (speech prosody) or not (non-verbal vocalizations) verbal content? Using a gating paradigm, the current study examined the minimum stimulus duration necessary for an accurate recognition of emotions in non-verbal vocalizations, extending previous studies (Pell et al., 2011). Non-verbal vocalizations were selected from the Montreal Affective Voices (MAV, Belin et al., 2008; validation for the Portuguese population by Vasconcelos et al., 2017) as the MAV is a standardized battery widely used in studies of emotion recognition (e.g., Collignon et al., 2010; Naranjo et al., 2011; Paquette, Peretz, & Belin, 2013). For a more direct comparison with previous studies testing speech prosody (Pell et al., 2011), MAV vocalizations conveying basic emotions, i.e. anger, disgust, fear, amusement, sadness, and neutral states were selected to determine the earliest time window at which emotions are accurately recognized. Auditory gates were defined and represented specific time increments: stimuli were divided into seven gate intervals ranging from 100 ms to 700 ms (i.e., the first gate started at the beginning of the

vocalization and the last corresponded to the entire stimulus duration). Furthermore, participants were asked to categorize the vocalizations based on a six-choice classification system (neutral, amusement, sadness, disgust, anger, and fear). Two types of analyses were performed: first, recognition accuracy was computed for each type of vocalization at each gate duration; second, the gate at which the emotion was accurately recognized (without classification changes at longer gate durations) was identified for each type of vocalization (i.e., emotion identification points were computed).

As for speech prosody (Pell et al., 2011), we hypothesized that emotional recognition accuracy would increase as a function of increased gate duration (i.e., increased stimulus length). Moreover, we hypothesized that an accurate identification of discrete emotions would occur at different gate intervals. Specifically, two alternative hypotheses were formulated. Considering EEG (electroencephalogram) evidence showing an earlier latency of ERP components within 200 ms post-stimulus onset in response to laughter compared to both angry and sad vocalizations (Pell et al., 2015), the recognition of laughter was expected to require less acoustic information than the recognition of negative vocalizations, reflected in an earlier identification point. However, if emotion recognition in non-verbal vocalizations follows a similar time course to speech prosody (Cornew, Carver, & Love, 2010; Pell & Kotz, 2011; Rigoulot, Wassiliwizky, & Pell, 2013), negative vocalizations should be identified at shorter gates compared to positive vocalizations. This would be consistent with an evolutionary approach to emotions (e.g., Ito, Larsen, Smith, & Cacioppo, 1998; Nesse, 1990; Pell et al., 2011): negative vocal expressions are considered highly salient cues since they might communicate possible threats in the environment (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001). Therefore, a rapid detection and recognition of negative emotions is critical for survival (Pell et al., 2011). Given the lower acoustic variation of neutral vocalizations, we hypothesized they would be recognized at shorter gates compared to emotional vocalizations (Pell & Kotz, 2011). These hypotheses were tested with mixed-effects models since they avoid spurious effects and have more power compared to traditional methods such as the analysis of variance (ANOVA; Jaeger, 2008).

4.3 Method

4.3.1 Participants

The best procedure to determine sample size when using mixed-effects modeling remains to be specified (Maas & Hox, 2005; McNeish & Stapleton, 2016). Hence, and since the current study relies on

a similar gating paradigm to the one described by Pell and Kotz (2011) with speech prosody (*N* = 49), a similar number of participants was included in the current study. Fifty-two participants (mean age = 23.42, *SD* = 7.80 years, age range 18-49 years; 27 females) completed the study. The education level ranged from 12 to 20 years (*M* = 13.87, *SD* = 1.99). All participants reported no hearing difficulties and were native speakers of European Portuguese. They provided written informed consent (see Appendix B) and received course credit for their participation. The study was approved by a local Ethics Committee (University of Minho, Braga, Portugal).

4.3.2 Stimuli

Fifty-eight non-verbal vocalizations expressing anger (*n* = 10), disgust (*n* = 10), fear (*n* = 8), amusement[3] (*n* = 10), sadness (*n* = 10) and neutral states (*n* = 10) were selected from the MAV. The MAV includes 90 non-verbal emotional vocalizations (e.g., laughter, growls, cries or screams) uttered by five male and five female speakers (five female and five male vocalizations of each emotional category). These speakers were instructed to produce short emotional interjections using the vowel /a/[4]. Despite cultural differences in decoding accuracy for different MAV emotional categories (increased for sadness – 86%, and decreased for pain – 51% – Belin et al., 2008; increased for sadness – 79%, and decreased for fear – 25% – Koeda et al., 2013; increased for amusement – 90%, and decreased for anger – 29.5% – Vasconcelos et al., 2017), all these studies yielded high levels of accuracy[5] . In the current study, the number of male and female vocalizations was the same for each emotional category.

First, the duration of the selected MAV stimuli was shortened (*n* = 50) or increased (*n* = 8) to 700 ms[6]: whereas shortening stimulus duration involved cutting the endpoint of its waveform, stimulus duration was gradually increased to 700 ms by adding less variable segments of the sound to its waveform ensuring that its emotionality was not changed (based on a pilot study with three experienced voice

[3]Based on existing studies arguing for a clear distinction between different types of positive non-verbal vocalizations (e.g., achievement/triumph, amusement, contentment, sensual pleasure and relief - Sauter & Scott, 2007; amusement, interest, relief, awe, compassion, sensory pleasure, enthusiasm and triumph –Simon-Thomas, Keltner, Sauter, Sinicropi-Yao, & Abramson, 2009), the term 'happiness' used in the MAV was replaced with 'amusement' in the current study as it more accurately matches the stimuli (laughter) included in this battery.

[4]The lower acoustic variability of the MAV sounds, compared to other stimulus batteries (e.g., Lima, Castro, & Scott, 2013), is ideal for the study of the effects of stimulus duration on vocal emotional recognition: when presented with stimuli with lower acoustic variation, listeners may rely more on duration for their emotional judgments than on other acoustic properties of the voice.

[5]68.2% for the chance level at 12.5% – Belin et al., 2008; 51.1% for the chance level at 12.5% – Koeda et al., 2013; 62.8% for the chance level at 11.1% – Vasconcelos et al., 2017.

[6]The maximum duration of the gate (700 ms) was chosen to allow the use of the current vocalizations in ERP studies probing the time course of vocal emotional processing. In studies using this methodology, differences in stimulus duration across conditions may affect sensory ERP components such as the N1 (Stapells, 2002), and potentially confound the interpretation of later processing stages involved in the cognitive evaluation of the stimulus.

researchers). Therefore, two vocalizations of fear were excluded as their too short duration prevented further acoustic manipulations. To test whether the manipulated vocal samples still conveyed the intended emotional meaning, they were first judged by a sample of participants who did not participate in the current study (*N* = 38; mean age = 21.68, *SD* = 3.74 years, age range 18-33 years; 23 females). Hits were defined as the number of times a vocalization received the highest intensity ratings in the corresponding scale. The overall mean recognition accuracy was quite high (68.67% for a chance level of 25%). Recognition accuracy rates were identical to those described for the original (non-manipulated) stimuli of the MAV (Belin et al., 2008; Vasconcelos et al., 2017).

After this pilot experiment, the 700 ms vocalizations were divided into 7 gates with decreasing durations from 700 ms to 100 ms, yielding a total of 406 vocalizations. To control for differences in the perceived loudness across stimuli, vocalizations were individually normalized to a peak intensity of 70 dB. Manipulation of stimulus duration and intensity was performed with Praat software (Boersma & Weenink, 2005, www.praat.org).

4.3.3 Procedure

An auditory gating task was used, in which listeners were presented with increasing (cumulative frequency) amounts of vocal emotional information. Data were collected on desktop computers equipped with headphones. Superlab software (Cedrus Corporation, 1991) was used for stimulus presentation and response recording. Stimuli were equally distributed across two sets (each included vocalizations produced by male and female speakers, representing the five emotion categories and a neutral category – 203 stimulus in each set) to avoid fatigue effects: 50% of participants rated set 1 and 50% rated set 2. Hence, five samples of anger, amusement, disgust, sadness, and neutral expressions and four samples of fear presented in the seven gate durations were included in each set (29 vocalizations x 7 gates). Whenever one set included three female and two male samples of an emotion category, the other set included three male and two female samples of the same emotion type. This was true for anger, amusement, disgust, sadness and neutral expressions. As for fear, each set included two female and two male samples at each gate duration. Following Pell and Kotz (2011), the order of stimulus presentation began with gate 1 and ended with gate 7. Each gate duration comprised stimuli of the six categories that were randomized across participants. Before the beginning of the experiment, instructions were provided on the computer screen. Participants were instructed to rate the emotion category of each vocalization

by choosing one of six possible options (0 = neutral, 1 = amusement, 2 = sadness, 3 = anger, 4 = disgust, and 5 = fear). A training trial with two extra stimuli was provided at the beginning of the experiment. Each experimental session lasted approximately 45 minutes. Three additional seven-point scales were used to assess the approachability (1= totally avoiding, 7 = totally approaching the stimulus), intensity (1= not at all intense, 7 = extremely intense), and authenticity (1= not at all authentic, 7 = extremely authentic) of each vocalization. As the focus of the current study was on the effects of stimulus duration on recognition accuracy, these additional ratings are presented in Appendix C.

4.3.4 Data analyses

Recognition accuracy. Accuracy was calculated as the proportion of correct categorizations for each emotion category in each gate. For example, for anger, a proportion of 0.50 indicates that 5 out of 10 vocalizations of anger were correctly classified as anger.

Emotion identification points: An emotional identification point was defined as the first gate duration at which an emotion was accurately recognized if 1) it was again correctly identified at the next gate duration; and if 2) it was not more than once incorrectly identified at all following (longer) gate durations (Pell et al., 2011; Salasoo & Pisoni, 1985). Emotion identification points ranged from gates 1 to 6. Trials that did not fulfill the abovementioned criteria were discarded. For example, gate 2 was assigned to the following categorization of amusement: neutral, amusement, amusement, amusement, sadness, amusement and amusement. Emotion identification points were separately estimated for each vocalization when judged by each participant (5 categories x 5 items + 1 category x 4 items x 52), yielding a total of 1508 identification points or 260 identification points for anger, disgust, amusement, sadness and neutral categories, and 208 identification points for fear. Subsequently, we calculated the distribution of correct identification points and discarded trials for each emotion type at each gate duration (see **Table 9**).

Accuracy data were analyzed with linear mixed-effects models using the lmer4 (Bates, Maechler, Bolker, & Walker, 2014) and lmerTest (Kuznetsova, Brockhoff, & Christensen, 2016) packages in the R environment (R3.4.3. GUI 1.70), which were used to estimate fixed and random coefficients. This type of statistical analysis allows examining the effects of variables that may vary either between subjects, within subjects, or both between and within subjects, representing a more efficient way to account for variance at different levels (Hoffman & Rovine, 2007).

4.4 Results

4.4.1 Recognition accuracy

Table 8 displays the overall recognition accuracy for each type of vocalization at each gate duration. The overall mean recognition accuracy was 0.34 at gate 1, 0.39 at gate 2, 0.71 at gate 3, 0.78 at gate 4, 0.80 at gate 5, 0.84 at gate 6, and 0.85 at gate 7. All vocalizations were recognized with above-chance accuracy from gates 1 to 7 (the chance-level performance was 16.66% for a 6-alternative forced choice task), except sadness at gate 1.

The hypothesis that emotional recognition accuracy would increase as a function of increased gate duration was first tested with a mixed-effects model including recognition accuracy as outcome, participants as random effects, and emotion category and gate duration as fixed effects. A significant interaction effect between emotion category and gate duration (estimated difference = .969, $p < .001$) indicated that accuracy across gates differed significantly according to emotion type. To account for the effect of set (sets 1 and 2), this dichotomous variable was also added to the model as a fixed effect. The set had no significant effect on the recognition accuracy of all types of vocalizations, except anger (estimated difference = .978; $p = .035$) and disgust (estimated difference = -.094; $p = .006$). The analysis was also replicated using approachability, intensity and authenticity as covariates: the pattern of results for the interaction did not change with the inclusion of these variables.

Table 8. Proportion of correct responses for each type of vocalization at each gate duration.

	Recognition Accuracy						
	Gate duration (ms)						
Emotion	G1[a]	G2[b]	G3[c]	G4[d]	G5[e]	G6[f]	G7
Category	100	200	300	400	500	600	700
Anger	0.36 (0.24)	0.38 (0.25)	0.52[b] (0.24)	0.52 (0.25)	0.53 (0.21)	0.61[c,d,e] (0.22)	0.62[c,d,e] (0.27)
Disgust	0.33 (0.23)	0.33 (0.26)	0.66[b] (0.17)	0.77[c] (0.17)	0.82[c] (0.15)	0.87[c,d] (0.18)	0.83[c,d] (0.22)
Fear	0.29 (0.23)	0.34 (0.25)	0.65[b] (0.24)	0.69 (0.24)	0.65 (0.26)	0.70 (0.28)	0.78[c,d,e,f] (0.24)
Amusement	0.25 (0.22)	0.32[a] (0.20)	0.88[b] (0.14)	0.95[c] (0.11)	0.97[c] (0.08)	0.98[c] (0.07)	0.98[c] (0.06)
Sadness	0.17 (0.20)	0.28[a] (0.18)	0.73[b] (0.18)	0.89[c] (0.13)	0.91[c] (0.13)	0.95[c,d] (0.10)	0.94[c] (0.09)
Neutral	0.62 (0.31)	0.68 (0.35)	0.82[b] (0.29)	0.88 (0.25)	0.91[c] (0.22)	0.90[c] (0.21)	0.92[c] (0.22)

Note. Standard deviation is shown in parentheses.
[a]Significantly different from gate 1; [b]Significantly different from gate 2; [c]Significantly different from gate 3; [d]Significantly different from gate 4; [e]Significantly different from gate 5; [f]Significantly different from gate 6.

Subsequently, the effects of gate on recognition accuracy were tested for each emotion category separately. The model included recognition accuracy as outcome, participants as random effect, and gate as fixed effect. The recognition of each type of vocalization improved significantly at successive gate intervals (see **Table 8**): recognition of amusement improved from gates 1 to 2 (estimated difference = .065, $p = .017$), 2 to 3 (estimated difference = .142, $p < .001$) and 3 to 4 (estimated difference = .065, $p = .017$); recognition of sadness improved from gates 1 to 2 (estimated difference = .112, $p < .001$), 2 to 3 (estimated difference = .565, $p < .001$) and 3 to 4 (estimated difference = .158, $p < .001$); recognition of anger improved from gates 2 to 3 (estimated difference = .135, $p < .001$) and 5 to 6 (estimated difference = .081, $p = .025$); recognition of disgust improved from gates 2 to 3 (estimated difference = .327, $p < .001$) and 3 to 4 (estimated difference = .112, $p < .001$); recognition of fear improved from gates 2 to 3 (estimated difference = .313, $p < .001$) and 6 to 7 (estimated difference = .077, $p = .049$); recognition of neutral vocalizations improved from gates 2 to 3 (estimated difference = .446, $p < .001$).

4.4.2 Emotion identification points

This set of analyses aimed to estimate the exact gate duration at which each vocalization was first recognized by each participant, with no identification changes at subsequent gates. **Table 9** illustrates the distribution of correct identification points and discarded trials for each vocalization at each gate. **Figure 2** displays the minimum duration, expressed in milliseconds, required to identify each category of non-verbal vocalizations, without further changes at subsequent gates.

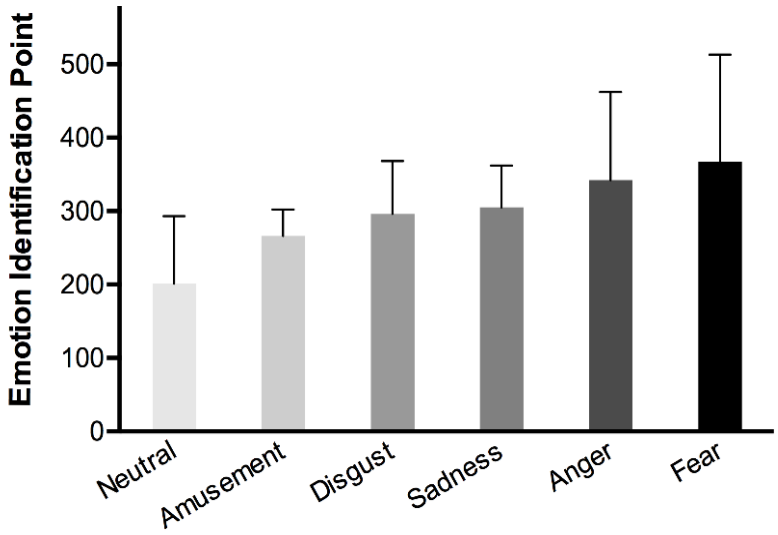
The hypothesis that the accurate identification of discrete emotions would occur at different gate intervals was tested with a mixed-effects model including identification points as outcome, participants as random effect and emotion category as fixed effect. The effect of set was also tested but, as no significant effect was found, it was not considered in the final model. Three participants who failed to identify the intended meaning from any of the angry vocalizations, and two participants who responded incorrectly to all neutral vocalizations were excluded from these analyses as the means for both types of vocalizations could not be estimated. Of note, after excluding these participants from the statistical model, we still ensured an equal number of participants per condition. A total of 47 participants (mean age = 23.23, *SD* = 7.18 years, age range 18-46 years; 23 females) was included in the analysis of identification points.

Table 9. Distribution of correct identification points and discarded trials for each type of vocalization at each gate duration.

	Identification Points							
	Gate duration (ms)							
Emotion Category	G1 100	G2 200	G3 300	G4 400	G5 500	G6 600	Total Correct	Total Incorrect
Anger	40 (15.38%)	16 (6.15%)	39 (15%)	17 (6.54%)	15 (5.77%)	36 (13.85%)	163 (62.69%)	97 (37.31%)
Disgust	50 (19.23%)	28 (10.77%)	85 (32.70%)	24 (9.23%)	16 (6.15%)	23 (8.85%)	226 (86.93%)	34 (13.07)
Fear	32 (15.38%)	17 (8.17%)	57 (27.40%)	11 (5.29%)	11 (5.29%)	34 (16.35%)	162 (77.88%)	46 (22.12%)
Amusement	47 (18.08%)	30 (11.53%)	150 (57.69%)	21 (8.08%)	4 (1.54%)	4 (1.54%)	256 (98.46%)	4 (1.54%)
Sadness	22 (8.46%)	40 (15.38%)	116 (44.62%)	42 (16.16%)	16 (6.15%)	8 (3.08%)	244 (93.85%)	16 (6.15%)
Neutral	130 (50%)	33 (12.70%)	43 (16.54%)	18 (6.92%)	9 (3.46%)	5 (1.92%)	238 (91.54%)	22 (8.46%)

Note. Mean percentage values are shown in parentheses.

Figure 2. Mean time values (ms) required to recognize each type of vocalization.



Note. The mean values considered only correctly identified vocalizations for each emotion category. Therefore, incorrect judgments were not considered (5 exemplars of neutral, anger, sadness, amusement, and disgust and 4 exemplars of fear). Error bars represent standard deviations.

The amount of acoustic information needed to recognize emotions from non-verbal vocalizations differed significantly by emotion type. Neutral vocalizations were identified with the shortest amount of acoustic information relative to all types of vocal emotions (fear: estimated difference = 166.45, $p < .001$; anger: estimated difference = 141.24, $p < .001$; sadness: estimated difference = 103.97, $p < .001$;

disgust: estimated difference = 95.21, $p < .001$; amusement: estimated difference = 65.35, $p < .001$). Positive vocalizations (amusement) required a shorter acoustic signal than negative vocalizations (fear: estimated difference = 101.10, $p < .001$; anger: estimated difference = 75.89, $p < .001$ and sadness: estimated difference = 38.62, $p = .041$). **Figure 3** illustrates the estimated differences between emotion categories.

Figure 3. Schematic diagram representing the estimated differences between emotions.



Note. Solid and dashed lines represent significant and non-significant *p*-values, respectively.
*$p \leq .05$.

4.5 Discussion

Clarifying how fast listeners decode vocal emotions is critical for our understanding of the mechanisms underlying emotional voice perception and communication. Vocal expressions change over time and these dynamic changes dictate how emotion-specific meaning is encoded and decoded. The current study probed how accurately listeners recognize emotional meaning communicated through short non-verbal vocalizations and determined the exact amount of acoustic information required for an accurate emotion recognition. A gating paradigm with precise time increments (100 ms) was used to investigate these questions. Our findings demonstrate that emotions are very rapidly decoded even when the voice signal does not contain verbal information, in good agreement with previous studies (Liu et al., 2010; Pell et al., 2015; Sauter & Eimer, 2010). Significant improvements in recognition occurred from gates 2 to 3, when listeners were exposed to at least 200 ms voice samples. Further, the current findings support the observation that discrete vocal emotions unfold at different rates and are recognized at different points in time. Specifically, neutral vocalizations were recognized with a shorter acoustic signal than emotional vocalizations. When comparing recognition for the different discrete emotions, we observed that the recognition of amusement (laughter) required the shortest acoustic signal, whereas anger and fear required the longest acoustic signal for successful recognition.

4.5.1 Decoding emotions from short non-verbal vocalizations

Vocal emotions rely on temporally-unfolding acoustic representations. An incremental increase of recognition accuracy was observed with longer vocal samples for all emotion categories. Specifically, the recognition of non-verbal vocal emotions was found to rapidly improve in the 200-300 time window. Of note, gate 3 (300 ms duration) was enough for the accurate recognition of more than 50% vocal samples of all emotion categories (see **Table 8**). Hence, the acoustic modulations occurring within the first 300 ms after vocalization onset seem to be the most critical time window for explicit decisions about a speaker's emotional state. This observation agrees with the time window showing effects of emotional salience detection in ERP studies (i.e., within 200 ms after voice onset – P50: Liu et al., 2012; N100 and P200: Pinheiro et al., 2013; P200: Sauter & Eimer, 2010). Although not as critical, acoustic changes in later time windows facilitated emotional recognition in general, as more acoustic information was available to listeners.

Extending previous research with speech prosody (Pell et al., 2011; Rigoulot et al., 2013), the current results indicate differences in the rate at which the recognition of discrete emotions improves from one gate to the next. Specifically, amusement (266 ms), disgust (296 ms) and sadness (305 ms) were identified at shorter gate intervals compared to anger (342 ms) and fear (367 ms) (see **Figure 2** and **Figure 3**). In addition, significant differences were observed between amusement and sadness, with the first being identified with less acoustic information.

The earliest recognition of amusement at the behavioral level agrees with previous EEG evidence showing an earlier or facilitated discrimination of laughter compared to vocalizations expressing anger and sadness (Pell et al., 2015). The high acoustic distinctiveness of laughter (e.g., frequency parameters, duration or distribution of spectral energy – e.g., Edmonson, 1983; Kipper & Todt, 2001) may enhance the salience of this vocal emotion (e.g., Pinheiro, Barros, Dias, & Kotz, 2017; Pinheiro, Barros, Vasconcelos, Obermeier, & Kotz, 2017) and explain its earlier identification point (Kipper & Todt, 2001) compared to the other emotion categories.

Following amusement, listeners were also able to decode sadness from shorter voice samples. The social function played by the two vocal emotions (Belin, 2006; Latinus & Belin, 2011; Meneses & Díaz, 2017) may account for the earlier identification points observed in the current study. Particularly, spontaneous laughter (e.g., amused laughter, joyful laughter) facilitates cooperative behavior (Gervais & Wilson, 2005; Greatbatch & Clark, 2003). Laughter may also elicit emotional contagion (Mehu & Dunbar,

2008), which is critical in social bonding (Gervais & Wilson, 2005; Vettin & Todt, 2004). Sadness (reflected in crying vocalizations) may promote the development of social bonds by stimulating in others the willingness to provide assistance and emotional support (Hendriks, Croon, & Vingerhoets, 2008; Vingerhoets, Bylsma, & Rottenberg, 2009). Further, listeners seem to be innately predisposed to rapidly respond to crying and laughing sounds (Barr, Chen, Hopkins, & Westra, 1996; Caron, 2002) as both represent a child's primary means of communication (Barr et al., 1996; Scheiner, Hammerschmidt, Jürgens, & Zwirner, 2002). The identification of disgust was also possible when shorter vocal samples were presented to the listeners. This could be related to the survival value associated with the fast identification of disgusting sounds, which might signal a threat for the organism such as rotten food (Zimmer, Höfler, Koschutnig, & Ischebeck, 2016). Although the rapid detection of vocal expressions of anger and fear also has an adaptive value, the tendency to misinterpret anger as fear and vice-versa (Belin et al., 2008; Vasconcelos et al., 2017) may explain why a longer acoustic signal was required for their accurate identification.

Supporting our hypothesis and a prior study with speech prosody (Pell & Kotz, 2011), neutral vocalizations were accurately recognized at gate 1 (100 ms), with accuracy levels significantly higher (62%) than those achieved by all emotional categories (see **Table 8**). Plausibly, the smaller acoustic variation of neutral vocal cues (Belin et al., 2008) facilitated their identification at shorter gates. Additional acoustic cues provided by longer gates did not seem to add crucial information for its recognition.

4.5.2 Decoding emotions from short non-verbal vocalizations versus speech prosody

Our results also provide support for differences in recognition accuracy according to stimulus type (with *vs.* without verbal content). In general, the non-verbal vocalizations used in the current study yielded higher accuracy ratings than the prosodic pseudo-utterances in the study of Pell and collaborators (2011). Emotion-specific differences are also observed when contrasting accuracy for speech prosody (from shorter to longer duration: fear, sadness, anger, happiness and disgust – Pell et al., 2011) and non-verbal vocalizations (from shorter to longer duration: amusement, disgust, sadness, anger and fear – the current study).

The earlier recognition points in the current study suggest that shorter amounts of acoustic information are required for an accurate recognition of emotions in vocalizations relative to prosodic pseudo-utterances (between 266 and 367 ms in the current study *vs.* between 510 and 1486 ms in the

study of Pell et al., 2011). This finding agrees with previous evidence demonstrating an earlier and preferential detection of emotions from non-verbal vocalizations relative to speech prosody (Pell et al., 2015). This difference might be justified by the fact that non-verbal vocalizations served a communicative function long before the emergence of language (Belin et al., 2004). Compared to speech prosody, vocalizations seem to rely on less complex (Juslin & Laukka, 2003) and more automatic (Lima, Anikin, Monteiro, Scott, & Castro, 2018) decoding mechanisms that could promote a faster behavioral response (Pell et al., 2015). Moreover, whereas speech prosody demands the concurrent processing of segmental and suprasegmental cues (which may require more processing resources), the processing of emotions in vocalizations relies on non-verbal information only (Pell et al., 2015). These features may explain why accurate emotion recognition is achieved with less acoustic information when the listener is exposed to vocalizations compared to speech prosody. Further, they may account for differences in the time course of emotion recognition when the voice signal contains (speech prosody) or not (non-verbal vocalizations) concurrent verbal information. Of note, both neutral vocalizations and neutral speech prosody were identified from shorter acoustic events compared to all vocal emotions. This suggests that stimulus type (speech prosody *vs.* non-verbal vocalizations) only affects the time course of vocal emotional (not neutral) recognition.

In good agreement with previous evidence (Hawk et al., 2009; Pell et al., 2015), the current findings suggest that emotions are more reliably and rapidly detected from non-verbal vocalizations than from emotional prosody. Research on vocal emotional processing may thus benefit from the use of non-verbal vocal emotions. This could be especially advantageous in the case of emotion recognition training programs. For example, Schlegel and colleagues (2017) conducted a video-based emotion recognition training program with non-clinical adults by combining distinct types of emotional information (facial, postural, gestural and speech prosody). They found that whereas training improved the performance of young and middle-aged adults, no improvement was observed in older adults (Schlegel, Vicaria, Isaacowitz, & Hall, 2017). Even though there is some evidence indicating that the recognition of emotional information declines with age (Ruffman, Henry, Livingstone, & Phillips, 2008), it is plausible that the simultaneous processing of segmental and suprasegmental information (emotional prosody) increased task demands and contributed to the null effects observed in older participants. Therefore, the use of emotional non-verbal vocalizations, which have been found to be universally recognized (Laukka et al., 2013; Sauter, Eisner, Ekman, & Scott, 2010), may be of particular relevance to emotion recognition intervention programs.

4.6 Limitations

Despite the strengths of the current study, some limitations should be considered. First, the use of a forced-choice task may have inflated recognition accuracy as listeners' judgments were restricted to the number of available options. Future studies should use a free-response format to determine whether spontaneous judgements produce similar accuracy levels for each type of vocalization as a function of gate. Second, besides laughter, no other types of positive vocal emotions (e.g., achievement, sensual pleasure, relief) were examined in the current study. As a result, it remains to be clarified whether the recognition of different types of positive vocalizations relies on different amounts of acoustic information. Third, the generalization of the current results is limited by the cultural specificities of this sample. Future studies should test the role of sociocultural differences in the time course of vocal emotional recognition. Finally, our conclusions are constrained by the gate durations used in the current study, which were defined by 100 ms increments. Further studies are required to examine whether accuracy varies by emotion type with gates shorter than 100 ms.

4.7 Conclusion

The current study adds to emotional prosody research by shedding light on the time required to decode basic emotions from non-verbal vocalizations. Acoustic modulations occurring within the first 300 ms after stimulus onset represented the most critical time window for explicit identification of emotions from non-verbal vocalizations. Further, the amount of vocal information that is necessary to decode the emotional meaning of non-verbal vocalizations varied as a function of emotion category: the recognition of amusement relied on the shortest acoustic signal, whereas the recognition of anger and fear required longer acoustic samples. As for speech prosody, these results provide further support for the notion that critical acoustic-based emotional cues unfold over the course of a non-verbal vocalization at different time points. Specifically, they suggest a facilitated decoding of amusement (laughter), which may be related to its social significance and acoustic distinctiveness in non-verbal social communication. The time course for recognition of a speaker's emotional state has received little attention so far. This study provides the starting point for further research aiming to unveil temporal effects on vocal emotional perception.

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Chapter 5

5. Acoustic salience in emotional voice perception and its relationship with hallucination proneness[7]

5.1 Abstract

Auditory verbal hallucinations (AVH) are reported in approximately 70% of psychotic patients, but they may also occur in 9.6% of the healthy general population. AVH have been related to altered processing of vocal emotions at both sensory and higher-order processing stages in psychotic patients. However, it remains to be clarified whether individuals with high hallucination proneness (HP) exhibit a similar pattern of alterations. Here, we investigated the impact of HP on vocal emotional perception and specified whether manipulations of acoustic cues such as sound intensity and duration, related to salience changes, affect the time course of voice processing reflected in event-related potentials (ERP) of the electroencephalogram. Participants varying in HP performed a task involving the categorization of emotional non-verbal vocalizations (neutral, anger, and amusement) differing in duration and intensity. ERP results demonstrated interactive effects of HP, valence, and acoustic cues on both early (N1, P2) and late (Late Positive Potential – LPP) processing stages. Higher HP was associated with decreased N1 and increased P2 amplitudes in response to louder and longer neutral (vs. positive) vocalizations, as well as with a larger LPP to louder and longer negative (vs. neutral) vocalizations. Together, these findings suggest that HP is associated with changes in the processing of vocal emotions that might be related to altered salience of acoustic representations of emotions. Together with prior studies with psychotic

[7]Publications derived from this study:

Peer reviewed publications in print or other media

Castiajo, P. & Pinheiro, A. P. (in press). Acoustic salience in emotional voice perception and its relationship with hallucination proneness. *Cognitive, Affective, & Behavioral Neuroscience*.

patients, these findings show that altered perception of vocal emotions may additionally contribute to the experience of hallucinations in non-clinical samples.

Keywords: Auditory verbal hallucinations; Emotion; Event-related potentials; Hallucination proneness; Voice.

5.2 Introduction

Auditory verbal hallucinations (AVH), the experience of hearing a voice when there is none, represent the most common type of hallucinations in schizophrenia, with an estimated prevalence of 70% (Johns et al., 2004). However, they also occur in approximately 9.6% of persons without a clinical diagnosis (Maijer, Begemann, Palmen, Leucht, & Sommer, 2018). Studying the experience of hearing voices in non-clinical individuals may provide critical insights into the neural and cognitive mechanisms underpinning AVH, with the advantage of avoiding potential confounds associated with medication and hospitalization in psychotic patients (Badcock & Hugdahl, 2012).

Similarities in the cognitive (Brébion et al., 2016; Larøi, van der Linden, & Marczewski, 2004) and neural (Diederen et al., 2012; Linden et al., 2010) mechanisms underpinning AVH in psychotic and non-clinical participants have been identified, supporting the notion of a psychosis continuum, i.e. that psychotic-like experiences are distributed in the general population along a continuum of severity (Baumeister, Sedgwick, Howes, & Peters, 2017; van Os, Hanssen, Bijl, & Ravelli, 2000; van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009). For instance, both psychotic and non-clinical persons reporting AVH are more likely than healthy controls to misattribute inner speech to an external source (Brébion et al., 2016; Larøi, van der Linden, & Marczewski, 2004). Phenomenological similarities were also noted, namely the perceived location (inside the head), loudness (less intense than one's own voice), and source (external) of AVH (Daalman et al., 2011). However, compared to psychotic patients with AVH, non-clinical voice hearers tend to perceive their hallucinatory experiences as more controllable (Choong, Hunter, & Woodruff, 2007; Daalman et al., 2011; de Leede-Smith & Barkus, 2013), as well as less frequent (Daalman et al., 2011; Larøi & van der Linden, 2005; Larøi, 2012). AVH may also differ in verbal content, which tends to be more negative in psychotic patients (e.g., commands or criticisms about what the patient is doing – Larøi et al., 2012 Nayani et al., 1996) than in non-clinical voice hearers (e.g., hearing a voice calling a person's name when no one is there – de Leede-Smith & Barkus, 2013). From a dimensional perspective of psychotic-like experiences (van Os, Hanssen, Bijl, & Vollebergh, 2001; van

Os & Linscott, 2012), the experience of AVH in the general population without need for clinical care has been typically examined by testing: 1) individuals with AVH proneness who experience briefly and infrequent AVH that do not affect their daily functioning; and 2) non-clinical voice-hearers who experience frequent AVH of longer duration, often associated with other psychotic-like and mood symptoms (Johns et al., 2014). While the first subgroup is typically assessed using general hallucination-proneness measures (e.g., the Launay-Slade Hallucination Scale [LSHS] – Bradbury, Stirling, Cavill, & Parker, 2009; Morrison, Wells, & Nothard, 2002), screening interviews targeting the specific experience of hearing voices are often used to identify the second subgroup (e.g., Sommer et al., 2010).

Voices (including hallucinated voices) carry not only verbal information, but also critical non-verbal information about the speaker, such as their identity and emotional state (Belin, Besterlmeyer, Latinus, & Watson, 2011). Neuroimaging evidence suggests that these three types of vocal information are processed in partially dissociated cortical regions (Belin et al., 2011; Belin, Fecteau, & Bédard, 2004). In schizophrenia patients reporting positive symptoms, behavioral and brain changes were found in the processing of speech information (Kuperberg, West, Lakshmanan, & Goff, 2008), voice identity (Alba-Ferrara, Weis, Damjanovic, Rowett, & Hausmann., 2012; Pinheiro, Rezaii, Rauber, & Niznikiewicz, 2016) and vocal emotions (Alba-Ferrara, Fernyhough, Weis, Mitchell, & Hausmann, 2012; Giannitelli et al., 2015; Pinheiro et al., 2013; 2014; Rossell & Boundy, 2005; Weisgerber et al., 2015). Specifically, schizophrenia patients with AVH were found to be less accurate in the recognition of negative relative to positive vocalizations (Rossell & Boundy, 2005) and showed reduced activation of the amygdala and hippocampus when listening to cries compared to laughs (Kang et al., 2009).

5.2.1 Vocal emotional perception in AVH along the psychosis continuum

Alterations in the processing of vocal emotions are recognized as an important feature of schizophrenia (Bozikas et al., 2006; Edwards, Pattison, Jackson, & Wales, 2001; Hooker & Park, 2002; Leitman et al., 2007; Pinheiro et al., 2013; 2014), being observed before illness onset (Addington et al., 2012; Amminger, Schäfer, Klier, et al., 2012; Amminger, Schäfer, Papageorgiou, et al., 2012) and aggravated in patients with AVH (e.g., Alba-Ferrara, Fernyhough, Weis, Mitchell, & Hausmann, 2012; Rossell & Boundy, 2005; Shea et al., 2007). Compared to non-hallucinating patients, psychotic patients reporting AVH were found to be less accurate at recognizing emotional prosodic cues (Alba-Ferrara, Fernyhough, Weis, Mitchell, & Hausmann, 2012; Shea et al., 2007) and less accurate in decoding

emotions in non-verbal vocalizations (Rossell & Boundy, 2005). Nonetheless, no significant differences were observed between patients with *vs.* without AVH in the recognition of emotions from speech prosody (Rossell, & Boundy, 2005). It is possible that semantic processing deficits (Rossell, & Boundy, 2005) have masked symptom-specific differences in vocal emotional processing. Together, these findings suggest that schizophrenia patients who are less able to recognize emotions from both speech prosody and non-verbal vocalizations are more likely to experience AVH. Deficits in vocal emotional processing could contribute to inner speech misattribution that is thought to occur in AVH (e.g., Alba-Ferrara, Fernyhough, Weis, Mitchell, & Hausmann, 2012). Note, however, that only a few studies examined whether and how the occurrence of positive-like symptoms (i.e., hallucinations and/or delusions) in non-clinical individuals affects the processing of vocal emotions (Addington et al., 2012; Amminger, Schäfer, Klier, et al., 2012; Amminger, Schäfer, Papageorgiou, et al., 2012; Pinheiro, Farinha-Fernandes, Roberto, & Kotz, 2019). These behavioral studies have been mixed, with some reporting altered (Addington et al., 2012; Amminger, Schäfer, Klier, et al., 2012; Amminger, Schäfer, Papageorgiou, et al., 2012) or preserved (Pinheiro, Farinha-Fernandes, Roberto, & Kotz, 2019) vocal emotional recognition.

5.2.2 Vocal emotional perception: Insights from event-related potentials (ERP)

ERP evidence supports the notion that the processing of vocal emotions involves three distinct, but interactive, stages (Paulmann & Kotz, 2008a; 2008b; Schirmer & Kotz, 2006). After the sensory processing of the voice signal (reflected in the N1), the detection of its emotional salience takes place (reflected in the P2). Higher-order processes, such as the cognitive evaluation of the emotional significance of the voice, are typically reflected in components such as the Late Positive Potential (LPP – Thierry & Roberts, 2007). An early differentiation between neutral and emotional vocal cues is reflected in N1 and P2 amplitude modulations (Liu et al., 2012; Paulmann, Bleichner, & Kotz, 2013; Sauter & Eimer, 2009). Decreased N1 (Liu et al., 2012) and enhanced P2 (Sauter & Eimer, 2009) amplitudes for emotional relative to neutral vocal sounds have been reported, suggesting that the emotional content of a stimulus facilitates acoustic sensory processing and salience detection, respectively. Further, emotional vocal cues tend to elicit larger LPP amplitudes than neutral voices (Pell et al., 2015; Pinheiro, Rezaii, Nestor, et al., 2016), reflecting enhanced sustained attention towards the processing of emotionally relevant information (e.g., Hajcak, MacNamara, Foti, Ferri, & Keil, 2013; Schupp et al., 2000).

Vocal emotions are expressed through the combination of different types of acoustic features, such as fundamental frequency (F0) or pitch, intensity, and duration (Schirmer & Kotz, 2006). Of note, acoustic changes may contribute to the enhanced salience of emotional voices. Using an oddball task, Schirmer and colleagues (2007) demonstrated an amplitude increase of the mismatch negativity (MMN – an index of automatic deviance detection – Näätänen, Pakarinena, Rinnea, & Takegataa, 2004) and P3a (an index of attention orienting – Duncan et al., 2009) in response to vocal emotions characterized by high relative to low intensity, indicating that loud emotional voices were acoustically more salient. Moreover, irrespective of their intensity, vocal emotional sounds were more easily detected and captured more attention than non-vocal sounds, which confirms the primacy of social sounds in the auditory system (Schirmer, Simpson, & Escoffier, 2007).

Stimulus duration was also found to modulate ERP signatures of vocal emotional processing. For instance, Chang and colleagues (2018) observed decreased N1 amplitude in response to vocal emotions of short and long (vs. medium) duration, as well as increased P2 amplitude in response to vocal emotions of short (vs. medium and long) duration (Chang, Zhang, Zhang, & Sun, 2018). Furthermore, the N1 was decreased in response to vocalizations expressing anger, sadness, and surprise relative to happiness in the short duration condition, whereas the P2 was increased in response to happy and angry relative to surprised voices, especially when their duration was shorter (Chang, Zhang, Zhang, & Sun, 2018). These findings indicate that sound duration may also affect the sensory processing and the automatically perceived salience of vocal emotions, which may be facilitated for vocal cues of short duration (Chang, Zhang, Zhang, & Sun, 2018).

Altered bottom-up and top-down processing of vocal emotions has been consistently reported in schizophrenia patients with AVH (Alba-Ferrara, Fernyhough, Weis, Mitchell, & Hausmann, 2012; Leitman et al., 2005; Pinheiro et al., 2013; 2014; Rossell & Boundy, 2005; Shea et al., 2007). Consistent with the hypothesized psychosis continuum, it is likely that high hallucination proneness (HP) is associated with changes in the processing of vocal emotions at both early sensory (N1 and P2) and higher-order cognitive (LPP) stages. To the best of our knowledge, no study has examined how HP affects the time course of vocal emotional processing reflected in distinct ERP indices. Nevertheless, some behavioral studies probing vocal emotional processing in individuals at genetic (Tucker, Farhall, Thomas, Groot, & Rossell, 2013) and clinical (Addington et al., 2012; Amminger, Schäfer, Klier, et al., 2012; Amminger, Schäfer, Papageorgiou, et al., 2012) high-risk of converting to psychosis and reporting positive-like symptoms (hallucinations and/or delusions) revealed similar alterations to those observed in schizophrenia patients with AVH. Specifically, Tucker and colleagues (2013) demonstrated that first-

degree relatives of schizophrenia patients with AVH made significantly more errors in the discrimination of intensity and duration of pure tones compared to healthy controls. Furthermore, the discrimination of pure tones in these participants was associated with vocal emotional recognition accuracy: the number of errors in intensity and pitch discrimination was negatively correlated with recognition accuracy of vocal emotions (Tucker, Farhall, Thomas, Groot, & Rossell, 2013). Auditory processing deficits in relatives of schizophrenia patients with AVH, which were associated with reduced processing speed of vocal emotional cues, were also found to predict AVH proneness: the more prominent the auditory processing deficits were, the more likely non-clinical AVH were to occur (Tucker, Farhall, Thomas, Groot, & Rossell, 2013). Reduced accuracy in vocal emotional recognition was also reported in non-clinical participants experiencing psychotic-like symptoms in three additional behavioral studies (Addington et al., 2012; Amminger, Schäfer, Klier, et al., 2012; Amminger, Schäfer, Papageorgiou, et al., 2012). Using words with emotional semantic content, van't Wout and colleagues (2004) showed that the frequency of hallucinations in non-clinical individuals with high HP was positively associated with the time needed to process neutral (target) words when preceded by positive or negative emotional (prime) words (van't Wout, Aleman, Kessels, Larøi, & Kahn, 2004). Hence, it is crucial to clarify whether AVH proneness is related to changes in the perception of vocal emotions, and whether these putative changes are similar to those observed in schizophrenia patients. As ERPs are examined before a behavioral response is made, they afford excellent temporal resolution of the sensory and cognitive processes under study.

5.2.3 The current study and hypotheses

Here, we probed whether the processing of emotional vocal cues is altered as a function of increased HP, and whether these potential changes are associated with specific acoustic cues of vocal emotions, namely intensity and duration. Manipulations of these cues may signal changes in the acoustic saliency of vocal emotions (e.g., Schirmer, Simpson, & Escoffier, 2007). Non-verbal vocalizations were selected to avoid potential biases related to the concurrent processing of semantic information, and as they represent more primitive expressions of emotions compared to speech prosody (Pell et al., 2015). ERP data were expected to provide insights into three processing stages of vocal emotional processing (N1, P2, and LPP).

Consistent with continuum models of psychosis (Baumeister, Sedgwick, Howes, & Peters, 2017; van Os, Hanssen, Bijl, & Ravelli, 2000; van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam,

2009), increased HP was expected to be associated with alterations in both early (N1, P2) and late (LPP) stages of vocal emotional processing. The hypothesized association between HP and altered perception of vocal emotions was further expected to be modulated by stimulus valence and acoustic parameters that were shown to increase emotional arousal (increased stimulus intensity – Schirmer, Simpson, & Escoffier, 2007) and facilitate emotion decoding (increased stimulus duration – Castiajo & Pinheiro, 2019).

Specifically, we hypothesized that increased HP would be associated with larger P2 amplitudes to positive vocalizations. This hypothesis was grounded in previous evidence showing selective changes in salience detection of positive vocal cues in psychotic patients (Pinheiro et al., 2013; 2014). We also hypothesized that high HP would be associated with increased LPP amplitude to negative vocalizations, irrespective of acoustic-specific changes. This hypothesis considered previous studies with schizophrenia patients revealing that AVH are associated with enhanced sustained attention to negative voices (Alba-Ferrara, Fernyhough, Weis, Mitchell, & Hausmann, 2012).

Finally, considering that altered vocal emotional processing in psychotic patients with AVH has been specifically related to changes in duration discrimination (Fisher, Labelle, & Knott, 2008; Fisher et al., 2011), we expected that an increased HP would be associated with more pronounced N1 and P2 alterations (i.e., increased and decreased amplitude, respectively) when stimulus duration is manipulated.

5.3 Method

5.3.1 Participants

In the first stage of the study, a large sample of college students from different Portuguese Universities (N = 354) were enrolled in a study aiming to adapt the Launay-Slade Hallucination Scale-Revised (LSHS – Larøi & van der Linden, 2005) for the Portuguese population (Castiajo & Pinheiro, 2017). The LSHS Portuguese version includes 16 items that tap into distinct forms of hallucinations (auditory, visual, olfactory, tactile, hypnagogic, and hypnopompic). The overall score ranges from 0 to 64, with higher scores indicating higher HP. This scale has been widely used to probe non-clinical hallucinatory experiences (e.g., Morrison, Wells, & Nothard, 2000; Morrison, Wells, & Nothard, 2002; Waters, Badcock, & Maybery, 2003; Larøi, Marczewski, & van der Linden, 2004; Larøi & van der Linden, 2005). The

Portuguese version of the LSHS has shown adequate psychometric properties (Castiajo & Pinheiro, 2017).

In the second stage, and after being screened via phone to ensure eligibility, 45 participants who initially took part in the LSHS validation study were recruited for an ERP experiment on the basis of their total LSHS scores. Additional inclusion criteria were: 1) right-handedness (Oldfield, 1971); 2) European Portuguese as first language; 3) no hearing and vision impairment; 4) no history of neurological illness; 5) no history of drug or alcohol abuse in the past year (APA, 2000); and 6) no presence of medication for medical disorders that would impact electroencephalogram (EEG) morphology. All participants were screened for psychopathological symptoms and for schizotypal traits with the Brief Symptom Inventory (BSI – Derogatis & Spencer, 1982; Portuguese version – Canavarro, 1999) and the Schizotypal Personality Questionnaire (SPQ – Raine, 1991; Portuguese version – Santos, 2011), respectively.

Of the 45[8] eligible participants, 10 subjects declined to participate due to scheduling reasons and 2 subjects (outliers) had to be excluded due to EEG artifacts. The final sample comprised 33 participants varying in their LSHS total scores (M = 22.15, SD = 11.70, range 4-47 points; **Table 10**) who met the inclusion criteria and completed the clinical and ERP assessments (mean age = 25.27, SD = 5.87 years, age range 18-42 years; mean education level = 15.21, SD = 2.39 years, education range 12-21 years; 25 females). **Table 11** shows the prevalence, frequency of occurrence, perceived degree of control, and emotional content of the hallucinatory experiences for each type of hallucination measured by the LSHS.

In this sample, the LSHS total score was positively correlated with the SPQ total score (r = .665, p < .001), and with the BSI positive symptom distress index (r = .453, p = .008), ensuring good convergent validity with other self-reported clinical measures. Participants who reported AVH were further screened with the Psychotic Symptom Rating Scale (PSYRATS – Haddock, McCarron, Tarrier, & Faragher, 1999; Portuguese version – Telles-Correia et al., 2017) to better understand the phenomenological characteristics of their experiences. Voice-hearing experiences were predominantly described as not unpleasant and not distressful. Participants provided written informed consent (see Appendix D) and received vouchers or course credit for their participation. The experiment was approved by a local Ethics Committee (University of Minho, Braga, Portugal).

[8]The hypotheses of the current study were tested with mixed-effects models. Since the best procedure to determine sample size when using mixed-effects modeling remains to be specified (Maas & Hox 2005; McNeish & Stapleton 2016), sample size was determined based on previous studies probing the effects of HP measured with the LSHS (e.g., N = 20 – Bentall & Slade, 1985; N = 32 – Pinheiro, Schwartze, & Kotz, 2018; N = 40 – van't Wout, Aleman, Kessels, Larøi, & Kahn, 2004; N = 42 – Vercammen & Aleman, 2010).

Table 10. Frequency distribution of the LSHS total scores.

LSHS total scores	Frequency	Percent
4	1	3%
7	1	3%
8	2	6.1%
9	1	3%
10	2	6.1%
11	1	3%
12	1	3%
14	1	3%
15	2	6.1%
17	3	9.1%
18	2	6.1%
19	1	3%
25	1	3%
27	2	6.1%
29	1	3%
30	1	3%
31	3	9.1%
33	1	3%
36	1	3%
37	1	3%
38	1	3%
39	1	3%
41	1	3%
47	1	3%
	(*N* = 33)	(100%)

Table 11. Proportion of different types of hallucinatory experiences (LSHS) according to prevalence, frequency of occurrence, perceived degree of control, and affective content.

Type of hallucination (LSHS)	Prevalence[a]	Frequency[b] (rare-often)	Control[c] (low-high)	Emotional content[d] (negative-positive)
Auditory verbal hallucinations	13 (39%)	4–9 (12–27%)	3–10 (9–30%)	2–5 (6–15%)
Visual hallucinations	6 (18%)	3–2 (9–6%)	2–4 (6–12%)	2–1 (6–3%)
Olfactory hallucinations	5 (15%)	2–3 (6–9%)	0–5 (0–15%)	0–3 (0–9%)
Tactile hallucinations	4 (12%)	1–2 (3–6%)	0–4 (0–12%)	1–2 (3–6%)
Vividness of daydreams	10 (30%)	0–7 (0–21%)	1–8 (3–24%)	0–6 (0–18%)
Intrusive or vivid thoughts	26 (79%)	1–6 (3–18%)	6–18 (18–54%	0–9 (0–27%)
Sleep-related hallucinations	19 (58%)	6–6 (18–18%)	6–13 (18–39%)	4–7 (12–21%)

[a]Percentage of participants who answered "possibly applies to me" or "definitely applies to me".
[b]Percentage of participants who answered "it occurs very rarely" (rare) and "it occurs very often" (often).
[c]Low control is represented by the percentage of participants who answered "it is very difficult to cease the experience" and "it is very difficult to avoid the experience," whereas high control is represented by the percentage of participants who answered "it is very easy to cease the experience" and "it is very easy to avoid the experience".
[d]Percentage of participants who answered "the experience is very negative" (negative) and "the experience is very positive" (positive).

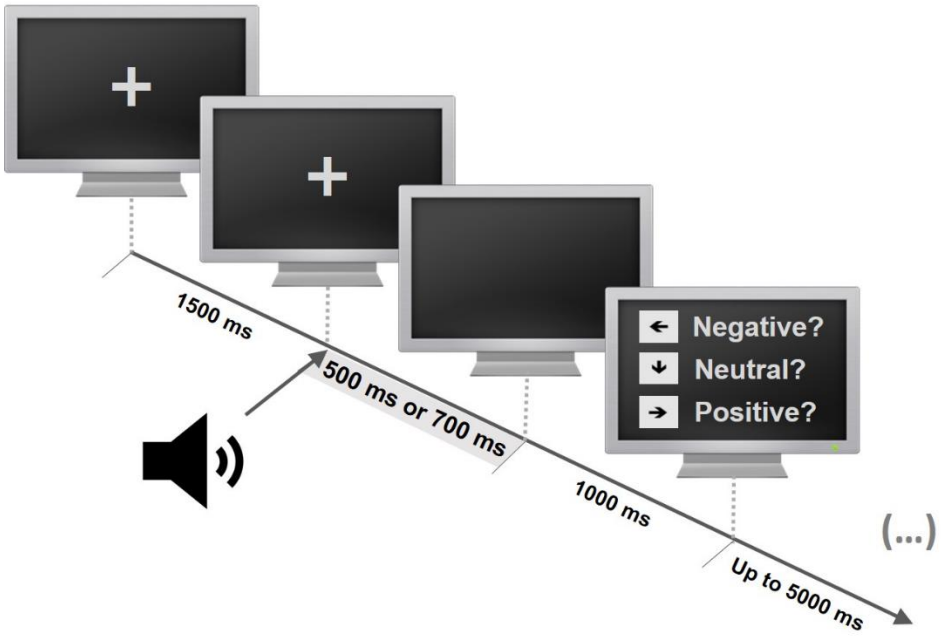
5.3.2 Stimuli

Thirty non-verbal vocalizations (15 from female and 15 from male speakers) expressing anger (growls; $n = 10$), amusement (laughter; $n = 10$), and neutrality ($n = 10$) were selected from the Montreal Affective Voices battery (MAV, Belin, Fillion-Bilodeau, & Gosselin, 2008). The selected MAV stimuli were acoustically manipulated. First, their duration was equalized to 700 milliseconds (ms) (Castiajo & Pinheiro, 2019). Then, a shorter (500 ms) version of each type of vocalization was created. To test whether the manipulated vocal samples still conveyed the intended emotions, they were first judged by a sample of participants who did not take part in the EEG experiment ($N = 52$; mean age = 23.42, $SD =$ 7.80 years, age range 18-49 years; 27 females – see Castiajo & Pinheiro, 2019). The overall mean recognition accuracy (proportion of correct responses) for the three types of vocalizations was 0.80 in the 500 ms condition (anger – 0.53; amusement – 0.97; neutral – 0.91), and 0.84 in the 700 ms condition (anger – 0.62; amusement – 0.98; neutral – 0.92). The MAV vocal samples were also manipulated in terms of intensity (55 dB *vs.* 75 dB). Therefore, 10 exemplars of each type of vocalization in all four acoustic conditions (short-soft, short-loud, long-soft, long-loud) were used as stimuli in the current experiment. The manipulation of stimulus duration and intensity was performed with Praat software (Boersma & Weenink, 2005, www.praat.org).

5.3.3 Procedure

Participants were seated comfortably at a distance of 100 cm from a computer screen in a sound and light-attenuating chamber, with a keyboard in front of them. The experimental session included three blocks, each comprising 10 random presentations of each type of vocalization in four acoustic conditions (3 types of vocalizations × 10 speakers × 4 acoustic conditions = 120 total trials per block). Stimuli were presented binaurally through Sennheiser CX 300-II headphones. Presentation software (Version 18.3, Neurobehavioral Systems, Inc., Berkeley, CA, www.neurobs.com) was used to control stimulus presentation and timing, as well as to record each participants' responses. **Figure 4** illustrates the design of an experimental trial. Participants were asked to categorize each vocalization according to its emotional quality by pressing one of three keys (negative, neutral, positive). During each block, a break was provided after 60 trials, and no feedback was provided. The experimental session lasted approximately 40 minutes.

Figure 4. Schematic illustration of an experimental trial.



Note. Vocalizations were presented binaurally. Growls and laughs represented exemplars of negative and positive vocalizations, respectively. The order of the experimental blocks was counterbalanced across participants.

5.3.4 EEG data acquisition and analysis

The (electroencephalogram) EEG was recorded with a 64-channel BioSemi Active Two System (http://www.biosemi.com/products.htm) at a sampling rate of 512 Hz. Reference electrodes were placed on the left and right mastoids. In addition, eye blinks and movements were monitored through two electrodes placed on both left and right temples (horizontal electrooculogram, HEOG), and one below the left eye (vertical electrooculogram, VEOG). The offset of all electrodes was kept below 30 mV.

EEG data were analyzed using Brain Vision Analyzer 2.0.4 software (www.brainproducts.com). The signal was filtered offline with a 0.1 to 30 Hz 2nd order Butterworth bandpass filter, and then re-referenced to the average of the left and right mastoids. Individual ERP epochs were created for each vocalization type in each condition, with a -150 ms pre-stimulus baseline and 700 ms post-stimulus duration. After applying a baseline correction from -150 to 0 ms, eye blinks were corrected using the method of Gratton et al. (Gratton, Coles, & Donchin, 1983). Single trial epochs containing excessive motor artifacts (±100 μV criterion) were not included in the ERP averages. For each participant, ERP averages included at least 70% of the trials per condition. The number of discarded epochs did not differ between conditions ($p > .05$).

After a careful visual inspection of grand average waveforms, three ERP components were selected for statistical analyses: N1, P2, and LPP. The amplitude of each component was measured as the mean voltage in the following latency windows, following prior studies (Pell et al., 2015; Pinheiro et al., 2014; Pinheiro, Rezaii, Nestor, et al., 2016; Pinheiro et al., 2017): 100-200 ms (N1), 200-300 ms (P2), and 500-700 ms (LPP). Mean amplitudes for each component of interest were measured at four regions-of-interest (ROIs): ROI1 (left fronto-central): F1, F3, FC1, FC3; ROI2 (right fronto-central): F2, F4, FC2, FC4; ROI3 (left centro-parietal): C1, C3, CP1, CP3; ROI4 (right centro-parietal): C2, C4, CP2, CP4.

5.3.5 Statistical analyses

ERP and accuracy data were separately analyzed with linear mixed-effects models using the lmer4 (Bates, Maechler, Bolker, & Walker, 2014) and lmerTest (Kuznetsova, Brockhoff, & Christensen, 2017) packages in the R environment (R3.4.3. GUI 1.70). HP was calculated as the sum of the 16 LSHS items (i.e., LSHS total score). Rather than splitting participants into high and low HP subgroups, a continuous variable (LSHS total scores) was used in the statistical model to avoid issues associated with dichotomization, including loss of statistical power and biased estimates (Altman & Royston, 2006; Selvin, 1987). Mixed-effects models were chosen since they have benefits over traditional statistical methods (i.e., analysis of variance). Specifically, they consider both fixed and random effects (participants' intra-individual variability) and have the advantage of reducing the potential occurrence of spurious effects (Jaeger, 2008). Due to its robustness and efficient estimates, mixed-effects models have been proposed as alternatives to traditional methods for statistically analyzing ERP data using a repeated-measures design (Baayen, Davidson, & Bates, 2008; Bagiella, Sloan, Heitjan, 2000). Since the best procedure to correct for multiple testing in mixed-effects modeling remains to be determined (Joo, Hormozdiari, Han, & Eskin, 2016), and as the current study is driven by a priori hypotheses (Streiner & Norman, 2011), no adjustment for multiple comparisons was used. Notwithstanding, we provide confidence intervals, which have been proposed as an alternative to traditional methods to correct for multiple comparisons (e.g., Nakagawa, 2004; Thompson, 2002).Only statistically significant findings ($p < .05$) are reported.

ERP data: The hypothesis that HP would affect the processing of vocal emotions at early and later stages was tested for each ERP component with three distinct mixed-effects models including amplitude as outcome, participants as random effects, and HP (LSHS total score), intensity (loud [75 dB], soft [55

dB]), valence (neutral, positive, negative), duration (long [700 ms], short [500 ms]), and ROI (left fronto-central, right fronto-central, left centro-parietal, right centro-parietal) as fixed effects.

Behavioral data: To specify the effects of HP on the recognition accuracy of vocal emotions (proportion of correct responses), a linear mixed-effects model was tested. Specifically, recognition accuracy was included as outcome, participants as random effects and HP (LSHS total score), intensity (loud [75 dB], soft [55 dB]), valence (neutral, positive, negative), and duration (long [700 ms], short [500 ms]) as fixed effects.

5.4 Results

5.4.1 ERP data

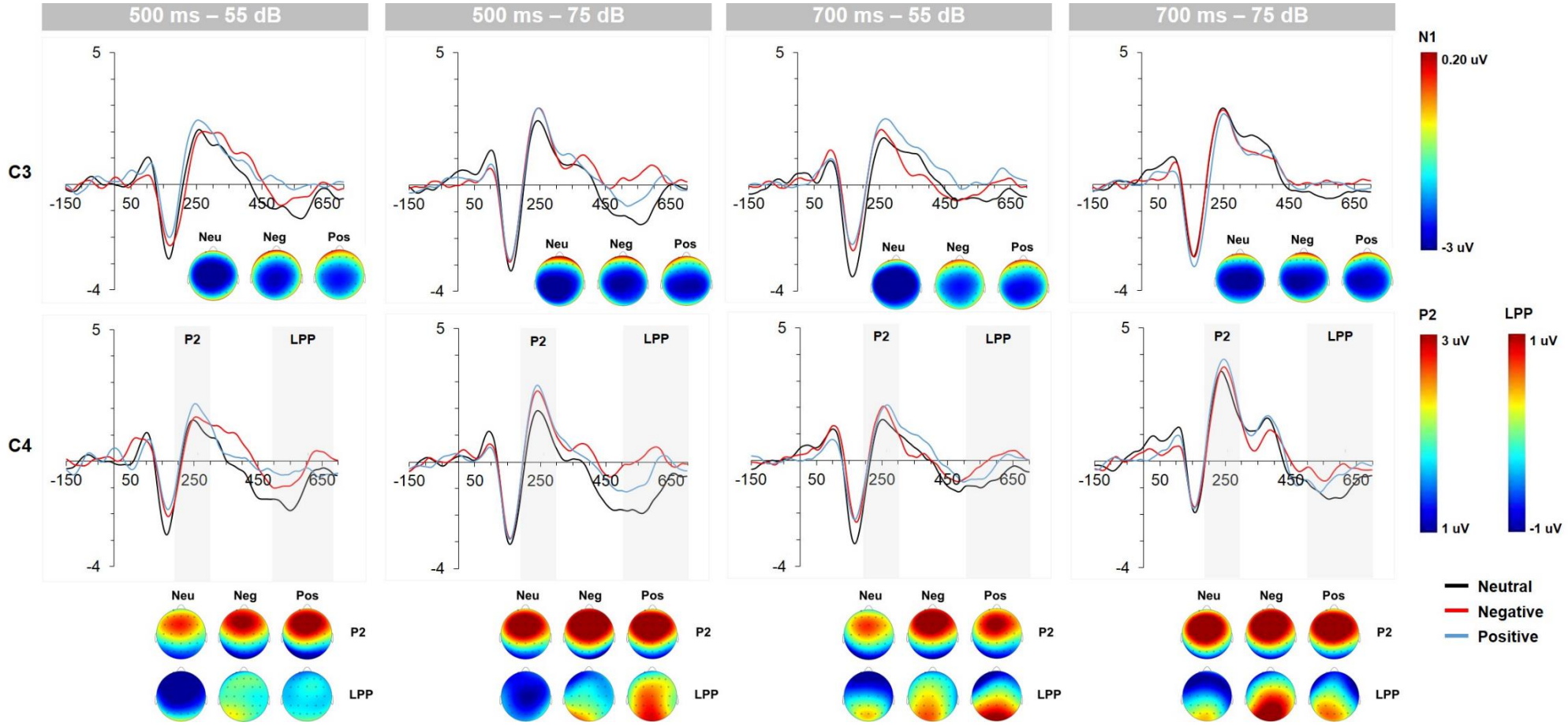
Figure 5 illustrates grand average waveforms as a function of emotion and manipulations of intensity and duration. Mean amplitudes for each emotion type and acoustic condition are presented in **Figure 6**. Scatterplots in **Figure 7** show the mean N1, P2, and LPP amplitudes for each participant as a function of HP.

5.4.1.1 N1

N1 amplitude was modulated by stimulus intensity and valence, but not by stimulus duration ($p > .05$). The N1 was decreased in response to loud compared to soft vocalizations ($\beta = 1.915$, SE = 0.398, $t(1551) = 4.801$, $p < .001$, 95% CI: [1.132, 2.697]), as well as in response to both negative ($\beta = 0.847$, SE = 0.398, $t(1551) = 2.126$, $p = .033$, 95% CI: [0.065, 1.630]) and positive ($\beta = 1.403$, SE = 0.398, $t(1551) = 3.519$, $p < .001$, 95% CI: [0.621, 2.185]) compared to neutral vocalizations. Intensity interacted with valence: loud vocalizations elicited a less negative N1 response when they had a neutral compared to positive quality ($\beta = -2.311$, SE = 0.564, $t(1551) = -4.098$, $p < .001$, 95% CI: [-3.418, -1.205]).

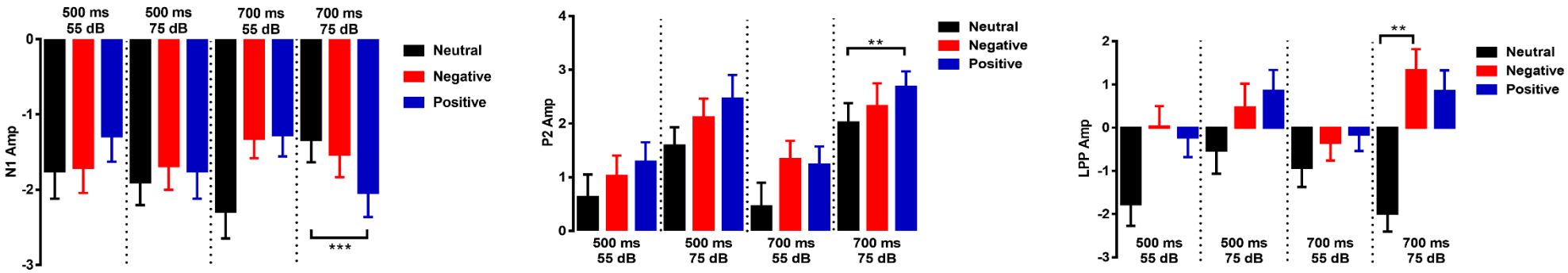
HP interacted with valence, intensity, and duration: an increase in HP was associated with a decreased N1 in response to neutral compared to positive vocalizations in the high intensity (loud) and long duration conditions ($\beta = -0.081$, SE = 0.031, $t(1551) = -2.556$, $p = .011$, 95% CI: [-0.143, -0.018]).

Figure 5. Grand average waveforms contrasting neutral, negative and positive vocalizations under intensity and duration manipulations at C3 and C4 electrodes.



Note. Topographic maps show the spatial distribution of the N1, P2 and LPP effects in the total sample (N = 33). Neu = neutral; Neg = negative; Pos = positive; LPP = Late Positive Potential.

Figure 6. Amplitude differences between neutral and emotional vocalizations in each acoustic condition based on duration and intensity manipulations.



Note. Bars represent mean amplitudes over left centro-parietal electrodes (ROI3) in the case of N1, and LPP and over right centro-parietal electrodes (ROI4) in the case of P2. Standard error (SE) of the means is represented in error bars. Amp = amplitude.

5.4.1.2 P2

P2 amplitude was modulated by valence and intensity: the P2 was increased (i.e., more positive) in response to positive compared to neutral vocalizations (β = 1.185, SE = 0.461, *t*(1551) = 2.569, *p* = .010, 95% CI: [0.280, 2.090]) and to loud compared to soft vocalizations (β = 2.132, SE = 0.461, *t*(1551) = 4.621, *p* < .001, 95% CI: [1.227, 3.037]). Valence interacted with intensity and duration: an increase in P2 amplitude was observed in response to positive compared to neutral vocalizations in the high intensity and long duration conditions (β = 2.202, SE = 0.922, *t*(1551) = 2.387, *p* = .017, 95% CI: [0.392, 4.012]).

HP interacted with valence, intensity, and duration: an increase in HP was associated with a less positive P2 for positive compared to neutral vocalizations when they were acoustically more salient, i.e. in the high intensity and long duration conditions (β = -0.117, SE = 0.036, *t*(1551) = -3.193, *p* = .001, 95% CI: [-0.189, -0.045]).

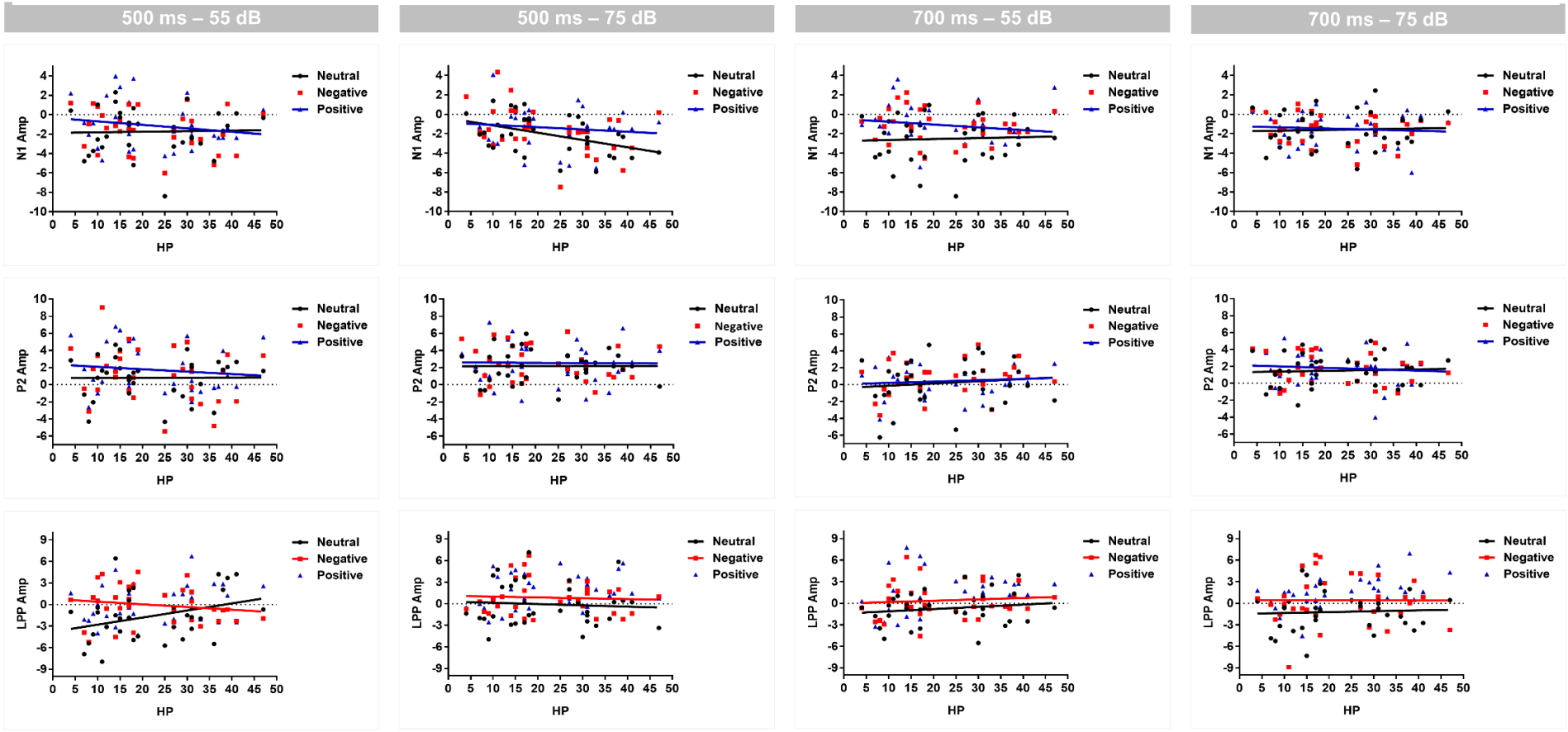
5.4.1.3 LPP

LPP amplitude was modulated by valence and intensity: the LPP was increased (i.e., more positive) in response to negative compared to neutral vocalizations (β = 2.778, SE = 0.645 *t*(1551) = 3.318, *p* < .001, 95% CI: [1.513, 4.044]), and in response to loud compared to soft vocalizations (β = 2.140, SE = 0.645, *t*(1551) = 3.318, *p* < .001, 95% CI: [0.875, 3.405]). Intensity interacted with valence and duration: the LPP was increased in response to loud negative vocalizations with a longer duration compared to neutral vocalizations (β = 3.980, SE = 1.290, *t*(1551) = 3.085, *p* = .002, 95% CI: [1.450, 6.511]).

HP modulated the interaction between duration and valence: higher HP was associated with an increased LPP for negative compared to neutral vocalizations with a long duration (β = 0.097, SE = 0.036, *t*(1551) = 2.675, *p* = .008, 95% CI: [0.025, 0.168]). HP also modulated the interaction between intensity and valence: higher HP was associated with an increased LPP for loud negative compared to neutral vocalizations (β = 0.074, SE = 0.036, *t*(1551) = 2.033, *p* =. 042, 95% CI [0.002, 0.145])[9].

[9]In an exploratory analysis, we probed whether the ERP responses were modulated by the emotional content of AVH assessed with the PSYRATS. These effects were tested in the nine participants who more frequently reported hearing voices based on the LSHS items specifically tapping into AVH (i.e., "I have been troubled by hearing voices in my head", "In the past, I have had the experience of hearing a person's voice and then found that no one was there", "I often hear a voice speaking my thoughts aloud") and follow-up questions ("It occurs to me very rarely – It occurs to me very often"). The N1, P2, and LPP responses to vocal emotions showed no effects of the emotional content of AVH (*p* > .05).

Figure 7. Mean amplitude at centro-parietal electrodes as a function of hallucination proneness across emotion types (neutral, negative, positive) and acoustic manipulations (shorter/softer: 500 ms – 55 dB; shorter/louder: 500 ms – 75 dB; longer/softer: 700 ms – 55 dB; longer/louder: 700 ms – 75 dB).



Note. HP = hallucination proneness; Amp = amplitude.

5.4.2 Behavioral data

Recognition accuracy was modulated by stimulus valence: negative vocalizations were less accurately recognized than neutral vocalizations (β = -0.087, SE = 0.033, $t(363) = -2.595$, $p = .010$, 95% CI: [-0.154, -0.021]; **Table 12**). Neither stimulus intensity and duration nor individual differences in HP affected recognition accuracy ($p > .05$).

Table 12. Proportion of correct responses for each type of vocalization and acoustic condition.

	Recognition Accuracy			
	Acoustic Condition			
Emotion Category	Shorter / Softer	Shorter / Louder	Longer / Softer	Longer / Louder
	500 ms – 55 dB	500 ms – 75 dB	700 ms – 55 dB	700 ms – 75 dB
Negative	0.84 (0.11)	0.85 (0.10)	0.82 (0.12)	0.84 (0.10)
Positive	0.99 (0.03)	0.98 (0.03)	0.98 (0.05)	0.99 (0.03)
Neutral	0.94 (0.07)	0.94 (0.11)	0.94 (0.08)	0.93 (0.10)

Note. Standard deviation is shown in parentheses.

5.5 Discussion

Alterations in vocal emotional perception were found to be associated with AVH in psychotic patients (e.g., Alba-Ferrara, Fernyhough, Weis, Mitchell, & Hausmann, 2012; Rossell & Boundy, 2005; Shea et al., 2007). However, whether similar changes are observed in non-clinical participants with high HP remained to be clarified. Using ERP, the current study demonstrates that both early and later stages of vocal emotional processing are affected by HP. Further, it provides preliminary evidence for a link between abnormal perception of vocal emotions and hallucination proneness, consistent with the hypothesis of a psychosis continuum (Baumeister, Sedgwick, Howes, & Peters, 2017; van Os, Hanssen, Bijl, & Ravelli, 2000; van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009).

5.5.1 The sensory processing of vocal emotions (N1) as a function of hallucination proneness

The auditory N1 indexes the sensory processing of the stimulus (Näätänen & Picton, 1987) and the allocation of resources to form and maintain a sensory memory trace of the eliciting stimulus (Obleser & Kotz, 2011). In good agreement with previous evidence (Liu et al., 2012), the current study revealed that positive (amusement) and negative (angry) vocalizations elicited a decreased N1 response compared to neutral vocalizations, suggesting that auditory sensory information is more easily processed when it has an emotional quality (Jessen & Kotz, 2011; Paulmann, Jessen, & Kotz, 2009). Studies using pure tones have shown that an increase in sound intensity (above 70 dB) results in decreased N1 amplitude. Here, we support this finding: higher sound intensity was associated with a less negative N1 amplitude, irrespective of valence. In contrast, we found a decreased N1 response to neutral relative to positive vocalizations in the high intensity condition, which indicates that valence modulates the effects of sound intensity on the N1, plausibly via arousal and its effects on attention (Lithari et al., 2010). Listeners tend to associate an increase in stimulus intensity with an increase in emotional arousal: for example, sound intensity correlates with distance and can inform on whether danger is approaching (Schirmer, Simpson, & Escoffier, 2007). Arousal and attention effects were found to be reflected in an increased N1 response (Coull, 1998). The current finding may indicate that the sensory processing of loud emotional (positive) vocalizations is facilitated relative to the sensory processing of loud neutral vocalizations, possibly due to increased automatic attention. No significant changes in N1 amplitude were observed in response to duration manipulations, revealing that the N1 was mainly modulated by intensity changes.

Consistent with our hypothesis, the N1 was also affected by HP. An increase in HP was associated with a decreased N1 amplitude in response to neutral relative to positive vocalizations, but only in the high intensity and long duration conditions, i.e. when sounds were physically more salient. In other words, more salient acoustic information was needed to normalize the N1 response to positive vocalizations as a function of increased HP. Similarly, alterations in the sensory processing of vocal emotions have been reported in psychotic patients with AVH (Fisher, Labelle, & Knott, 2008; Fisher et al., 2011).

5.5.2 The detection of the emotional salience of the voice (P2) as a function of hallucination proneness

In good agreement with previous evidence (Liu et al., 2012; Sauter & Eimer, 2009), we observed a more positive P2 response to emotional relative to neutral vocalizations. This effect occurred specifically for positive vocalizations, supporting its socially relevant role (Pell et al., 2015; Pinheiro, Barros, Dias, & Kotz, 2017; Pinheiro, Barros, Vasconcelos, Obermeier, & Kotz, 2017). The P2 amplitude increase to positive vocalizations was further enhanced when the voice was acoustically more salient, i.e. in the high intensity and long duration conditions. This may have contributed to facilitated emotional salience detection.

We also observed that an increased HP resulted in a reverse P2 effect: loud and long positive vocalizations led to a decreased P2 amplitude relative to loud and long neutral vocalizations. This finding suggests that HP is associated with altered emotional salience detection in voices, particularly of positive vocal cues. Positive vocalizations could elicit decreased attention, which might affect how emotional salience is automatically perceived. Previous studies with psychotic patients demonstrated selective changes in salience detection from positive vocal cues (i.e., increased P2 amplitude to happy prosody – Pinheiro et al., 2013; 2014). The current findings suggest that the early stages of vocal emotional processing might be more affected during the perception of positive vocalizations also in non-clinical persons with high HP.

5.5.3 The cognitive evaluation of the emotional significance of the voice (LPP) as a function of hallucination proneness

Consistent with previous studies (Pell et al, 2015), we found that the LPP amplitude was increased for negative (angry) compared to neutral vocalizations, irrespective of stimulus intensity and duration. In healthy participants, the increased sustained attention to angry voices, reflected in larger LPP amplitudes, has been shown to indicate the preferential processing of potentially threatening cues (Frühholz & Grandjean, 2012). The current finding reveals that negative vocalizations were associated with enhanced sustained attention and required increased elaborative processing relative to neutral vocalizations, corroborating its adaptive function (Pell et al., 2015).

HP also affected the cognitive evaluation of the emotional significance of the voice. Typically, emotional vocalizations elicit an increased LPP amplitude compared to neutral vocal cues (Pell et al., 2015; Pinheiro, Rezaii, Nestor, et al., 2016). In the current study, we observed that listeners with high HP benefited from cues that were acoustically more salient: LPP was enhanced for negative relative to neutral vocalizations in the high intensity and duration conditions. Studies with schizophrenia patients with AVH have shown enhanced sustained attention to negative vocal cues even when the acoustic properties of the voice were not manipulated (Alba-Ferrara, Fernyhough, Weis, Mitchell, & Hausmann, 2012). However, the current study reveals that a negativity bias in voice perception (reflected in an increased LPP for negative relative to neutral voices) in participants with high HP is only observed when voices are acoustically more salient. Given that HP did not modulate the recognition accuracy of negative vocalizations, which achieved high recognition accuracy in all four acoustic conditions (see **Table 12**), this pattern of findings suggests interactive effects of HP and salience rather than the effects of lower recognizability of negative cues.

Overall, our findings indicate that alterations in vocal emotional processing in high HP may be primarily driven by altered salience of acoustic representations of emotions. The aberrant salience hypothesis of psychosis (Kapur, 2003) postulates that psychotic symptoms are associated with altered dopaminergic transmission that leads to abnormal salience assignment to stimuli in the world. The current study indicates that high hallucination proneness in the general population may also be associated with changes in how salience is detected and assigned to emotional voices. Longitudinal investigations of non-clinical persons with high HP are necessary to examine whether and how changes in vocal emotional perception may predict transition to psychosis.

5.6 Limitations

The interpretation of the current findings should consider the relatively small sample size and convenience sampling approach. Evidence has shown little to no degree of bias in the estimation of fixed effects with mixed-effects modeling, even when the sample size is small (e.g., Clarke & Wheaton, 2007; Maas & Hox, 2005). Notwithstanding, the current findings (especially those concerning interactions between factors) should be considered as exploratory and replicated in future studies with larger samples.

5.7 Conclusions

Our findings suggest that the sensory processing (N1), salience detection (P2), and cognitive evaluation of the emotional significance of vocalizations (LPP), taking place before a behavioral response is made, are affected by high HP. However, individual differences in HP did not modulate recognition accuracy of emotional vocalizations. Hence, electrophysiological measures may represent a more sensitive measure of the effects of high HP on the perception of vocal emotions. Importantly, the effects of high HP were modulated by the acoustic properties of emotional vocalizations, specifically intensity and duration, which were found to change the acoustic saliency of sounds. Additionally, these effects were valence-specific: whereas changes in the processing of positive vocalizations were enhanced in early stages (N1 and P2), changes in the processing of negative vocalizations were more pronounced in later cognitive stages (LPP). Similarities in ERP changes underlying the processing of vocal emotions in non-clinical persons with high HP and psychotic patients (Pinheiro et al., 2013; 2014) support the hypothesis of a psychosis continuum (Baumeister, Sedgwick, Howes, & Peters, 2017; van Os, Hanssen, Bijl, & Ravelli, 2000; van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009). Changes in voice perception mechanisms may be a core feature of hallucination proneness (Pinheiro et al., 2018).

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Chapter 6

6. Attention to voices is increased in non-clinical voice hearers irrespective of salience[10]

6.1 Abstract

Alterations in the processing of vocal emotions have been associated with both clinical and non-clinical auditory verbal hallucinations (AVH), suggesting that changes in the mechanisms underpinning voice perception contribute to AVH. These alterations seem to be more pronounced in psychotic patients with AVH when attention demands increase. However, it remains to be clarified how attention modulates the processing of vocal emotions in non-clinical voice-hearers. Using an active auditory oddball task, the current study clarified how emotion and attention interact during voice processing as a function of AVH proneness, and examined the contributions of stimulus valence and intensity. Participants with *vs.* without non-clinical AVH were presented with target vocalizations differing in valence (neutral *vs.* positive *vs.* negative) and intensity (55 dB *vs.* 75 dB). The P3b amplitude was larger for louder (*vs.* softer) vocal targets irrespective of valence, and for negative (*vs.* neutral) vocal targets irrespective of intensity. Of note, the P3b amplitude was generally increased in response to vocal targets in participants reporting AVH, irrespective of valence and intensity of vocalizations. These findings indicate that difficulties in discriminating salient (emotional; louder) from non-salient (neutral, softer) social stimuli such as voices may be specifically related to the experience of AVH. Alterations in salience detection of voices may potentially increase cognitive control demands contributing to AVH onset.

Keywords: Attention; Auditory Verbal Hallucinations; Emotion; Event-related potentials; Non-clinical voice-hearers; Voice.

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[10]Publications derived from this study:

Peer reviewed publications in print or other media

Castiajo, P. & Pinheiro, A. P. (submitted). Attention to voices is increased in non-clinical voice hearers irrespective of salience. *Neuropsychologia*

6.2 Introduction

Listeners are continuously exposed to multiple concurrent sounds in the acoustic environment. Due to competition for limited resources (Marois & Ivanoff, 2005), sounds that are perceived as salient attract more attention. The emotional tone of the voice is one of the most salient cues in the social environment (Liu et al., 2012; Sauter & Eimer, 2009). Emotions are communicated by the voice through a combination of acoustic cues, including pitch, intensity, and duration (Schirmer & Kotz, 2006). The different combination of these acoustic cues gives rise to different discrete emotions (Banse & Scherer, 1996; Juslin & Laukka, 2003). The perception of vocal emotions seems to involve several interactive stages (Frühholz, Ceravolo, & Grandjean, 2012; Paulmann & Kotz, 2008a; 2008b; Pinheiro et al., 2013; Schirmer & Kotz, 2006), which include the sensory processing, emotional salience detection, and cognitive evaluation of the emotional significance of the voice (Schirmer & Kotz, 2006). Due to the high temporal resolution of the electroencephalogram (EEG), event-related potentials (ERP) may clarify how the processing of vocal emotions unfolds over time. In this context, specific ERP components have been proposed to index distinct stages of vocal emotional processing: the N1 reflects sensory operations, whereas P2 modulations reflect salience detection in vocal emotions (Paulmann & Kotz, 2008a; 2008b; Schirmer & Kotz, 2006). Later ERP components (e.g., N3; P3; Late Positive Potential – LPP) reflect higher-order cognitive operations, such as the evaluation of the emotional significance of the voice (Chang, Zhang, Zhang, & Sun, 2018; Pell et al., 2015; Pinheiro, Barros, & Pedrosa, 2015; Pinheiro, et al., 2016). Selective attention towards or away from specific features of voices, such as their emotional quality, may be reflected in amplitude modulations of the P3, a positive deflection occurring between 250 milliseconds (ms) and 500 ms post-stimulus onset (Duncan et al., 2009; Polich, 2007). Specifically, increased P3 amplitudes were reported for happy relative to both angry and neutral vocalizations (Pinheiro, Barros, Dias, & Kotz, 2017), or for angry compared to neutral prosodic cues (Wambacq, Shea-Miller, & Abubakr, 2004). Attention modulations in vocal emotional perception might be driven by changes in the acoustic properties of the voice that affect salience detection (Pinheiro, Barros, Dias, & Kotz, 2017). Together, these findings suggest that attention may change how vocal emotions are processed (Frühholz & Grandjean, 2013). This evidence may contribute to the understanding of clinical conditions in which voice perception is altered, such as psychotic disorders (Pinheiro et al., 2013; 2014; 2017; Rossell & Boundy, 2005).

6.2.1 Vocal emotional perception in auditory verbal hallucinations

Alterations in the processing of vocal emotions have been consistently reported in schizophrenia patients (Bozikas et al., 2006; Gold et al., 2012; Jahshan, Wynn, & Green, 2013; Leitman et al., 2005, 2010; Pinheiro et al., 2013; 2014; Rossell & Boundy, 2005). These deficits were found to be aggravated in patients with *vs.* without AVH (Alba-Ferrara, Fernyhough, Weis, Mitchell, & Hausmann, 2012; Rossell & Boundy, 2005; Shea et al., 2007). Compared to patients without AVH, hallucinating patients are also more likely to judge positive vocal expressions as negative (Rossell & Boundy, 2005), and neutral vocal expressions as emotional (Shea et al., 2007), which suggests altered emotional salience detection.

AVH are predominantly experienced in the context of schizophrenia (with an estimated prevalence of 70% – Johns et al., 2004), although they may also occur in approximately 5 to 28% of the general population without need for psychiatric care (de Leede-Smith & Barkus, 2013; Johns et al., 2004; van Os, Hanssen, Bijl, & Ravelli, 2000; Tien, 1991). Direct comparisons of clinical and non-clinical AVH revealed similarities, but also some differences in phenomenology. Specifically, similarities include the location (i.e., inside the head), loudness (i.e., less intense than one's own voice), and source (i.e., external) of the hallucinated voices (Daalman et al., 2011). Differences are mainly related to the emotional valence, experience of control, associated distress and frequency (Choong, Hunter, & Woodruff, 2007; Daalman et al., 2011; de Leede-Smith & Barkus, 2013; Honig et al., 1998; Larøi & van der Linden, 2005; Larøi, 2012). In particular, non-clinical AVH tend to be perceived as less unpleasant and more controllable (Choong, Hunter, & Woodruff, 2007; Daalman et al., 2011; de Leede-Smith & Barkus, 2013; Honig et al., 1998), as well as less distressful and frequent (Daalman et al., 2011; Larøi & van der Linden, 2005; Larøi, 2012) than psychotic AVH. Similarities in the cognitive (Allen, Freeman, Johns, & McGuire, 2006; Brébion et al., 2016; Larøi, van der Linden, & Marczewski, 2004) and neural (Barkus, Stirling, Hopkins, Mckie, & Lewis, 2007; Diederen et al., 2012; Linden et al., 2010) mechanisms underpinning clinical and non-clinical AVH support a psychosis continuum, i.e., the hypothesis that psychotic symptoms exist on a continuum in the general population (Baumeister, Sedgwick, Howes, & Peters, 2017; van Os, Hanssen, Bijl, & Ravelli, 2000; van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009). For example, both psychotic and non-clinical voice-hearers are less likely to distinguish between internal and external sources of information (Allen, Freeman, Johns, & McGuire, 2006; Brébion et al., 2016). Non-clinical voice-hearing experiences offer an unprecedented opportunity to examine the neural and cognitive mechanisms of AVH, avoiding confounding factors typically related to schizophrenia such as medication,

hospitalization, and concurrent presence of other symptoms such as negative symptoms (Badcock & Hugdahl, 2012).

Consistent with the hypothesis of a psychosis continuum (Baumeister et al., 2017; van Os et al., 2000; van Os et al., 2009), alterations in vocal emotional perception and recognition have been also reported in individuals presenting clinical (Addington et al., 2012; Amminger, Schäfer, Klier, et al., 2012; Amminger, Schäfer, Papageorgiou, et al., 2012) and genetic (Kee, Horan, Mintz, & Green, 2004; Tucker, Farhall, Thomas, Groot, & Rossell, 2013) vulnerability to psychosis. For example, Tucker and colleagues (2013) demonstrated that first-degree relatives of schizophrenia patients with AVH who were less able to discriminate intensity and pitch modulations of pure tones (i.e., neutral sounds) were also less accurate at recognizing vocal emotions, as well as more prone to AVH. Reduced accuracy in vocal emotional recognition was also observed in non-clinical individuals with psychotic-like symptoms (Addington et al., 2012; Amminger, Schäfer, Klier, et al., 2012; Amminger, Schäfer, Papageorgiou, et al., 2012). Moreover, the processing of neutral (target) words preceded by positive or negative emotional (prime) words was found to be associated with longer reaction times in non-clinical individuals with high hallucination proneness relative to those with low hallucination proneness (van't Wout, Aleman, Kessels, Larøi, & Kahn, 2004).

Altered perception of vocal emotions has been proposed to contribute to the formation of AVH, potentially via disruption of a common mechanism underpinning voice processing (Alba-Ferrara et al., 2012). Specifically, patients tend to describe their hallucinated voices as emotionally negative (Daalman et al., 2011; de Leede-Smith & Barkus, 2013; Nayani & David, 1996), and to experience more difficulty in recognizing negative vocal emotions (Pinheiro et al., 2013; 2014; Rossell & Boundy, 2005). Furthermore, negative AVH tend to be perceived as less controllable than AVH with positive content (Birchwood & Chadwick, 1997). Of note, attentional mechanisms have been suggested to modulate the interaction between impaired recognition of vocal emotions and AVH in schizophrenia patients (Alba-Ferrara et al., 2012): the tendency to display an attentional bias towards threat-related vocal cues was found to increase as a function of AVH proneness.

6.2.2 Contributions of attention to vocal emotional perception in AVH

Amplitude modulations of the P3 component may inform on how much attention is directed towards the processing of vocal emotions (Duncan et al., 2009; Polich, 2007). Two P3 subcomponents

are proposed to reflect distinct attention-related processes: the frontocentral P3a has been associated with stimulus-driven and automatic attention to novel and unexpected stimuli, whereas the centroparietal P3b has been related to voluntary attention allocation to task-relevant stimuli (Duncan et al., 2009; Polich, 2007). In the context of the current study, we focused exclusively on the P3b response to emotional vocalizations.

Reduced amplitude of the auditory P3b is one of the most robust electrophysiological findings in schizophrenia (e.g., Bramon, Rabe-Hesketh, Sham, Murray, & Frangou, 2004; Ford, 1999; Hamilton et al., 2019; Jeon & Polich, 2003; Perlman et al., 2015). Decreased attention to vocal information has been proposed to contribute not only to an inability to recognize targets in oddball tasks (Ford, 1999), but also to the experience of AVH (Behrendt, 1998; Ilankovic et al., 2011; Liemburg et al., 2012; Papageorgiou et al., 2004). In particular, Liemburg and collaborators (2012) demonstrated that AVH proneness may result from increased attention to internally generated speech. Moreover, alterations in the attentional processing of salient vocal information were found to account for the external misattributions of self-generated speech typically observed in patients with AVH (Ensum & Morrison, 2003; Ilankovic et al., 2011). Despite the well-documented association between greater P3b amplitude reductions and increased severity of psychotic symptoms (Egan et al., 1994; Ford, 1999; McCarley et al., 1989; Perlman et al., 2015), some evidence suggests decreased P3b amplitude before psychosis onset (i.e., in individuals at clinical and genetic risk for psychosis – Bramon et al. 2008; Frangou et al., 1997; Kidogami, Yoneda, Asaba, & Sakai, 1991). Accordingly, amplitude reduction of the auditory P3b has been considered as a potential vulnerability marker for psychosis (Hamilton et al., 2019; Jahshan et al., 2012; Turetsky et al., 2007). Much less is known about how attention to emotional voices modulates the P3b as a function of AVH proneness. Using ERPs, Pinheiro and Niznikiewicz (2019) reported a reduced P3b amplitude in response to positive relative to negative vocal targets in schizophrenia patients relative to controls. These differences were not modulated by AVH severity (Pinheiro & Niznikiewicz, 2019). To the best of our knowledge, no study has directly investigated how AVH proneness in non-clinical participants affects the P3b response to changes in vocal emotions.

6.2.3 The current study and hypotheses

Evidence from psychotic patients suggests that the ability to selectively orient attention to vocal emotions is altered (Pinheiro & Niznikiewicz, 2019). However, it remains to be clarified whether similar

changes are observed in non-clinical individuals prone to AVH. Attentional impairments may contribute to the observed vocal emotional recognition impairments in both psychotic voice-hearers (Rossell & Boundy, 2005; Shea et al., 2007) and individuals with psychotic-like symptoms (Addington et al., 2012; Amminger, Schäfer, Klier, et al., 2012; Amminger, Schäfer, Papageorgiou, et al., 2012). Here, we probed for the first time whether attention allocation to vocal emotions is affected by AVH proneness, and whether these potential changes are modulated by two sources of salience: the valence (positive, negative, neutral) and intensity (loud, soft) of vocalizations. Intensity manipulations, which were found to change the acoustic saliency of sounds (e.g., Schirmer, Simpson, & Escoffier, 2007), may clarify whether attention allocation to vocal emotions is increased as a function of enhanced acoustic saliency: this would indicate an additive effect of valence and intensity. Non-verbal vocalizations were used to avoid potential confounds related to the concurrent processing of semantic information in emotional prosody, and as they represent a more primitive form of vocal emotional expression than speech prosody (Pell et al., 2015).

Given that the P3b amplitude reduction to high-pitched pure tones is a robust finding in individuals with psychotic-like symptoms (Bramon et al., 2008; del Re et al., 2015; Fusar-Poli et al., 2011; Hamilton et al., 2019; van Tricht et al., 2010), we also expected a reduced P3b amplitude to more complex vocal sounds (i.e. vocal emotions) as a function of increased AVH proneness in non-clinical participants. This amplitude reduction would reflect alterations in attention allocation to vocal emotions, supporting a psychosis continuum in the general population (Baumeister et al., 2017; van Os et al., 2000; van Os et al., 2009).

In addition, we hypothesized that the P3b amplitude in AVH proneness would be modulated by valence. Specifically, we expected a larger P3 amplitude to negative compared to neutral vocalizations. This hypothesis was grounded in prior studies revealing that AVH are associated with enhanced attention to threat-related voices in psychotic patients (Alba-Ferrara et al., 2012).

Finally, considering previous observations of preserved detection of intensity-based emotion in schizophrenia patients (Gold et al, 2012; Leitman et al., 2010), intensity manipulations were expected to change attention to vocal emotions irrespective of individual differences in AVH proneness.

6.3 Method

6.3.1 Participants

This study involved two stages. In the first one, a group of college students (N = 354) from several Portuguese Universities were invited to participate in a study aiming to adapt and validate the Launay-Slade Hallucination Scale-Revised (LSHS – Larøi & van der Linden, 2005) for the Portuguese population (Castiajo & Pinheiro, 2017). The LSHS includes 16 items that assess distinct forms (auditory, visual, olfactory, tactile, hypnagogic, and hypnopompic) and critical dimensions (frequency, degree of control, and emotional content) of hallucinations.

In the second stage, 36 participants from the initial sample (Castiajo & Pinheiro, 2017) were further invited to participate in an ERP experiment. Participation was based on the LSHS total scores (mean score = 22.85, SD = 11.74 points, ranging from 4 to 47 points, with higher scores indicating higher hallucination proneness). Data from two participants (outliers) had to be excluded due to EEG artifacts, yielding a final total sample of 34 participants (mean age = 25.18, SD = 5.85 years, range 18-42 years; mean education level = 15.21, SD = 2.36 years, range 12-21 years; 25 female). Of those, 14 participants (mean age = 27.21, SD = 7.28 years, range 18-42 years; mean education level = 15.57, SD = 3.13 years, range 12-21 years; 12 female) reported the experience of AVH. Demographic and clinical differences between participants with *vs.* AVH are presented in **Table 13**. **Table 14** shows the prevalence, frequency of occurrence, perceived degree of control, and emotional content of the hallucinatory experiences for each type of hallucination measured by the LSHS considering the full sample.

Additional selection criteria included: 1) right-handedness (Oldfield, 1971); 2) European Portuguese as first language; 3) no hearing and vision impairment; 4) no history of neurological illness; 5) no history of drug or alcohol abuse in the past year (APA, 2000); and 6) no presence of medication for medical disorders that would impact EEG morphology. Psychopathological symptoms and schizotypal traits were assessed using the Brief Symptom Inventory (BSI – Derogatis & Spencer, 1982; Portuguese version – Canavarro, 1999) and the Schizotypal Personality Questionnaire (SPQ – Raine, 1991; Portuguese version – Santos, 2011), respectively. Those who reported AVH were also screened with the Psychotic Symptom Rating Scale (PSYRATS – Haddock, McCarron, Tarrier, & Faragher, 1999; Portuguese version – Telles-Correia et al., 2017). The convergent validity among the self-reported clinical measures was good: the LSHS total score was positively correlated with the SPQ total score (r = .627, p < .001), and with the BSI positive symptom distress index (r = .463, p = .006); the experience of non-clinical AVH

was positively correlated with the SPQ total score (r = .429, p = .011). Participants provided written informed consent (see Appendix D) and received vouchers or course credit for their participation. The experiment was approved by a local Ethics Committee (University of Minho, Braga, Portugal).

Table 13. Demographic and clinical characteristics of participants with *vs.* without AVH.

Variable	With AVH (n = 14)	Without AVH (n = 20)	t, p value[a]
Age (years)	27.21 (7.28)	23.75 (4.24)	-1.752, 0.089^{+}
Sex (n)	12 Female	13 Female	
Education (years)	15.57 (3.13)	14.95 (1.67)	
LSHS Total score	34.71 (6.04)	14.55 (6.19)	-9.435, < 0.001***
SPQ Total score	24.36 (11.17)	13.45 (11.99)	-2.683, < 0.011*
BSI Positive symptoms distress index	1.47 (0.26)	1.31 (0.29)	-1.653, 0.108

Note. All values represent mean ± *SD*. AVH = auditory verbal hallucinations.
[a]Independent sample t-tests tested for group differences in age, LSHS, SPQ and BSI.
$^{***}p < 0.001$; $^{*}p < 0.050$; $^{+}p < 0.100$.

Table 14. Proportion of different types of hallucinatory experiences (LSHS) according to prevalence, frequency of occurrence, perceived degree of control, and affective content.

Type of hallucination (LSHS)	Prevalence[a]	Frequency[b] (rare-often)	Control[c] (low-high)	Emotional content[d] (negative-positive)
Auditory verbal hallucinations	14 (41%)	3–11 (9–32%)	3–11 (9–32%)	3–5 (9–15%)
Visual hallucinations	6 (18%)	3–2 (9–6%)	2–4 (6–12%)	2–1 (6–3%)
Olfactory hallucinations	6 (18%)	2–3 (6–9%)	6–0 (18–0%)	0–3 (0–9%)
Tactile hallucinations	4 (12%)	1–2 (3–6%)	4–0 (12–0%)	1–2 (3–6%)
Vividness of daydreams	11 (32%)	0–8 (0–34%)	1–9 (3–27%)	0–6 (0–18%)
Intrusive or vivid thoughts	27 (79%)	1–7 (3–21%)	7–19 (21–56%	1–9 (3–27%)
Sleep-related hallucinations	20 (59%)	6–6 (18–18%)	6–14 (18–41%)	5–7 (15–21%)

[a]Percentage of participants who answered "possibly applies to me" or "definitely applies to me".
[b]Percentage of participants who answered "it occurs very rarely" (rare) and "it occurs very often" (often).
[c]Low control is represented by the percentage of participants who answered "it is very difficult to cease the experience" and "it is very difficult to avoid the experience," whereas high control is represented by the percentage of participants who answered "it is very easy to cease the experience" and "it is very easy to avoid the experience".
[d]Percentage of participants who answered "the experience is very negative" (negative) and "the experience is very positive" (positive).

6.3.2 Stimuli

Three male vocalizations with positive (laughs), negative (growls), and neutral (the vowel ah - /ɑ/ with neutral intonation) quality were selected from the Montreal Affective Voices (MAV) battery (Belin,

Fillion-Bilodeau, & Gosselin, 2008) based on valence and arousal ratings for the Portuguese population (Vasconcelos, Dias, Soares, & Pinheiro, 2017).

The selected MAV vocalizations were acoustically manipulated to an equalized duration of 700 milliseconds (ms). Given the original duration of each vocalization, the vocalization of neutrality had to be increased to 700 ms by gradually adding less variable segments of the sound to its waveform, while the two emotional vocalizations had to be shortened to 700 ms by cutting the endpoint of their waveforms. To test whether the manipulated vocal samples still conveyed the intended emotions, they were first judged by a sample of participants who did not take part in this experiment (N = 52; mean age = 23.42, SD = 7.80 years, age range 18-49 years; 27 females – see Castiajo & Pinheiro, 2019). The overall mean recognition accuracy (proportion of correct responses) for the three types of vocalizations with 700 ms was high (0.91 (negative – 0.81; positive – 1.00; neutral – 0.92) – Castiajo & Pinheiro, 2019). Each vocalization was also manipulated into two different levels of intensity (55 dB *vs.* 75 dB). The manipulation of stimulus duration and intensity was performed with Praat software (Boersma & Weenink, 2005, www.praat.org).

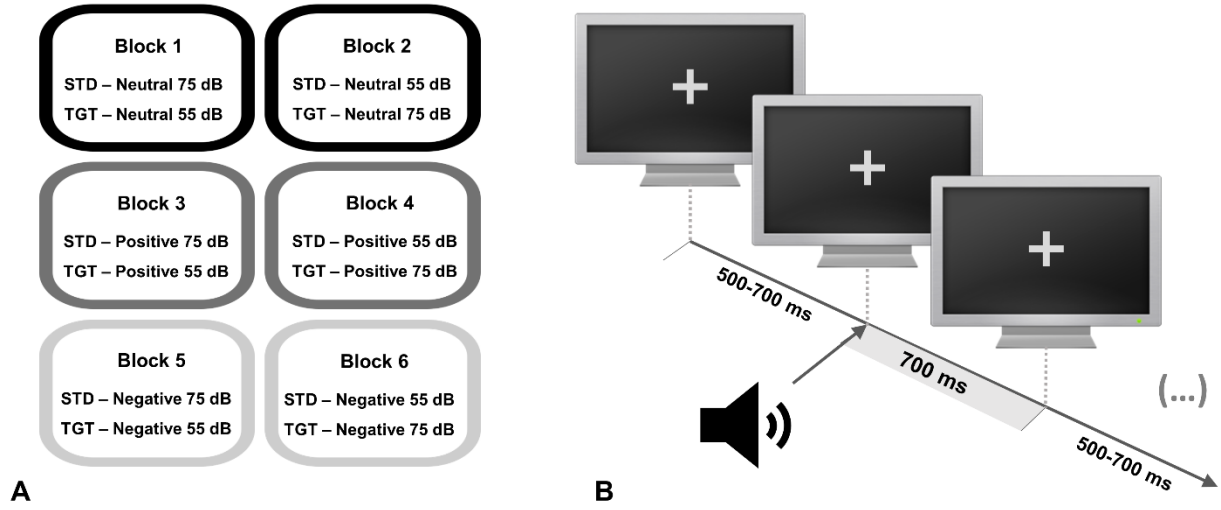
6.3.3 Procedure

Participants were seated comfortably at a distance of 100 cm from a computer screen in a sound and light-attenuating chamber. The experimental session included six oddball task blocks, each of them comprising frequent (standard) emotional vocalizations differing in valence intermixed with infrequent (target) emotional vocalizations with the same valence but differing in intensity (see **Figure 8**). In each block, participants were presented with 295 standard (P = 85%) and 40 target (P = 15%) vocalizations. Fifteen standards were presented sequentially at the beginning of each block (Polich, 2007). Stimuli were delivered by headphones and presented in a random sequence within each block, but with a minimum of five standards between targets. The presentation order of the six blocks was counterbalanced across participants. Presentation software (Neurobehavioral Systems, Albany, CA, USA) was used to control stimulus presentation and timing.

Before stimulus onset, a fixation cross was presented centrally on the screen and was kept during sound presentation to minimize eye movements. The time interval between two successive stimuli (inter-stimulus interval – ISI) varied between 500 and 700 ms. **Figure 8** illustrates the design of an experimental trial. Participants were instructed to focus their attention on the sounds and to silently count the number

of targets. The total number of counted targets was asked at the end of each block. A short pause was provided after each block, and no feedback was given during the experiment. The experimental session lasted approximately 50 minutes. The EEG signal was recorded while participants performed the task.

Figure 8. Schematic illustration of the structure of the experimental blocks **(A)** and of an experimental trial **(B)**.



Note. Vocalizations were presented binaurally. Growls and laughs represented exemplars of negative and positive vocalizations, respectively. The order of the experimental blocks was counterbalanced across participants. STD = standard; TGT = target.

6.3.4 EEG data acquisition and analysis

The electroencephalogram (EEG) was recorded at 512 Hz using a 64-channel BioSemi Active Two System (http://www.biosemi.com/products.htm). External reference electrodes were placed on both mastoids (left and right). In addition, eye blinks and movements were monitored with two external electrodes placed on both left and right temples (horizontal electrooculogram, HEOG), and one below the left eye (vertical electrooculogram, VEOG). The offset of all electrodes was kept below 30 mV.

EEG data were analyzed using Brain Vision Analyzer 2.0.4 software (www.brainproducts.com). Data were filtered offline with a 0.1 to 30 Hz 2nd order Butterworth bandpass filter and referenced to the average of the left and right mastoids. Individual ERP epochs for each vocalization type in each acoustic condition were created using a -150 ms pre-stimulus baseline and 700 ms post-stimulus duration. Ocular artifacts were corrected using the method of Gratton et al. (Gratton, Coles, & Donchin, 1983) after

applying a baseline correction from -150 to 0 ms. Single trial epochs containing excessive eye blinks or motor artifacts (±100 μV criterion) were rejected. ERP epochs were averaged separately for standards (STD) and targets (TGT) per participant (STD-Positive 55 dB; TGT-Positive 55 dB; STD-Positive 75 dB; TGT-Positive 75 dB; STD-Negative 55 dB; TGT-Negative 55 dB; STD-Negative 75 dB; TGT-Negative 75 dB; STD-Neutral 55 dB; TGT-Neutral 55 dB; STD-Neutral 75 dB; TGT-Neutral 75 dB). For each participant, ERP averages were based on at least 70% of the trials per condition. The number of epochs discarded did not differ significantly between conditions ($p > .05$). The waveforms (STD and TGT) from each participant were averaged to create grand averaged waveforms for the full sample.

After visual inspection of the ERP waveforms, a time window from 300 to 500 ms (corresponding to the typical latency window of the component of interest – Duncan et al., 2009; Polich, 2007) was used to extract P3b amplitudes. Given that P3b amplitudes were largest at midline sites from where this ERP component is usually derived (Duncan et al., 2009; Polich, 2007), mean amplitudes were extracted from midline electrodes: Fz (frontal); Cz (central); and Pz (parietal). We opted to include the Fz electrode site to assess differences in the midline scalp distribution of the P3, particularly the frontal-smaller-than-centroparietal P3b voltage asymmetry typically observed (Duncan et al., 2009; Polich, 2007). Moreover, the selection of midline electrodes for the statistical analyses offer us the possibility to compare our experimental data with other ERP experiments with non-clinical individuals experiencing psychotic-like experiences that have used the same electrode sites to measure auditory P3b amplitudes (e.g., Bramon et al., 2008; van der Stelt, Lieberman, & Belger, 2005). P3b mean amplitudes were analyzed separately for standards and targets.

6.3.5 Statistical analyses

Linear mixed-effects models were used to describe the relationship between the number of targets counted (behavioral data) and AVH proneness (with *vs.* without), as well as the relationship between P3b amplitude to vocalizations differing in valence and intensity (ERP data) and AHV proneness (with *vs.* without). Participants were assigned to the AVH subgroup if the LSHS score on at least one of the three items[11] related to AVH was ≥ 3 (3 = possibly applies to me, 4 = definitely applies to me). Both models were fitted with the lmer4 (Bates, Maechler, Bolker, & Walker, 2014) and lmerTest (Kuznetsova,

[11] "I have been troubled by hearing voices in my head"; "In the past, I have had the experience of hearing a person's voice and then found that no one was there"; "I often hear a voice speaking my thoughts aloud".

Brockhoff, & Christensen, 2017) packages in the R environment (R3.4.3. GUI 1.70). By accounting for individual variance (random effects), the linear mixed-effects models overcome some of the limitations of conventional inferential statistics, yielding more generalizable results (Jaeger, 2008).

Behavioral data: To specify the effects of AVH proneness on the number of counted targets, a linear mixed-effects model was conducted. Specifically, the number of counted targets was included as outcome, participants as random effects and AVH proneness, intensity and valence as fixed effects.

ERP data: The hypothesis that the P3b response to vocalizations differing in valence and intensity would decrease as a function of AVH proneness was tested with a mixed-effects model including amplitude as outcome, participants as random effects, and AVH proneness (with *vs.* without), intensity (soft [55 dB] *vs.* loud [75 dB]), valence (neutral *vs.* negative *vs.* positive), task-relevance (STD, TGT), and electrode location (frontal [Fz], central [Cz], parietal [Pz]) as fixed effects.

6.4 Results

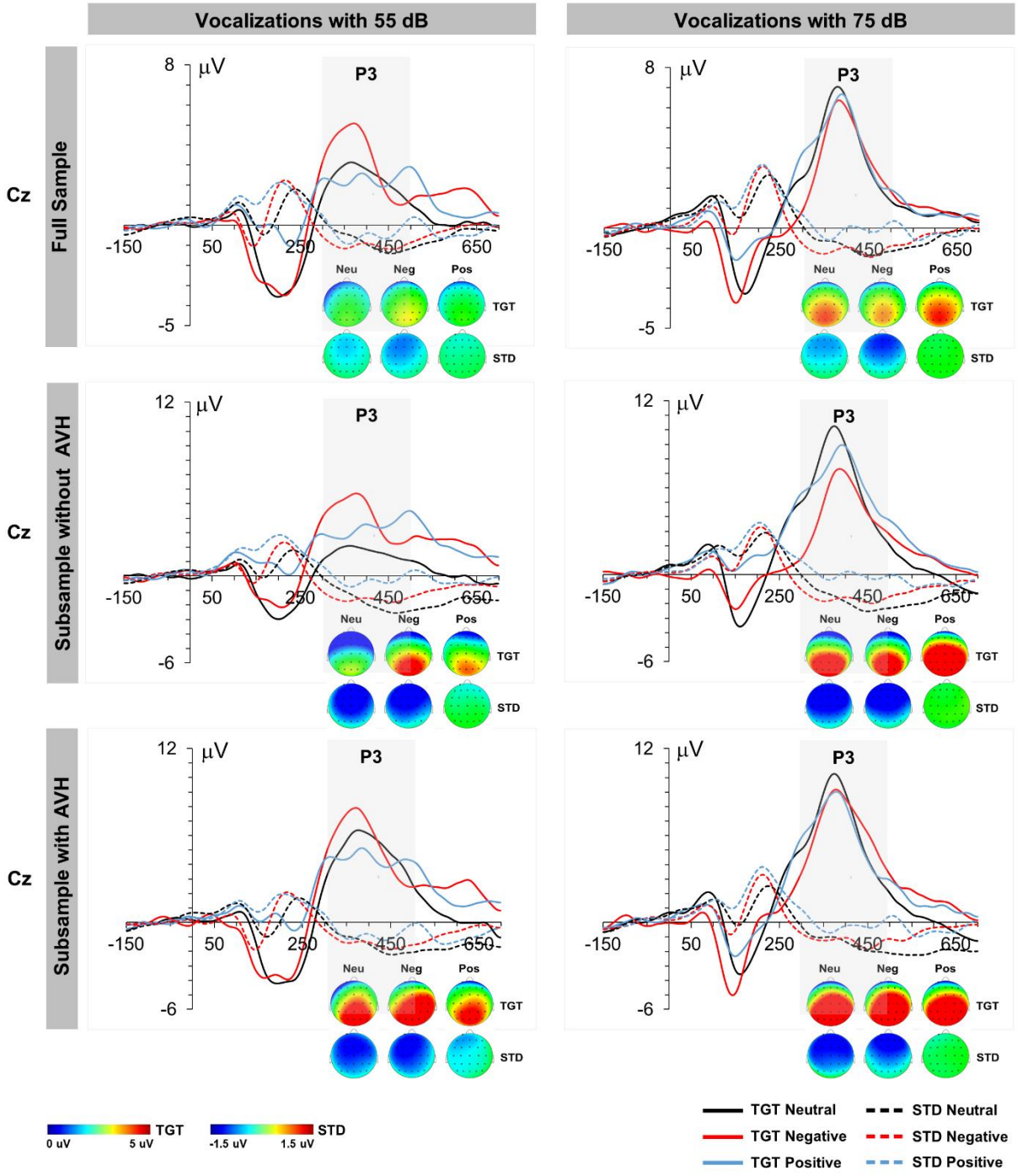
6.4.1 Behavioral data

Neither stimulus valence and intensity nor AVH proneness affected the number of times each type of target was counted ($p > .05$; Negative-softer = 39.66 ± 1.64; Negative-louder = 40.06 ± 2.22; Positive-softer = 39.71 ± 2.61; Positive-louder = 40.06 ± 1.88; Neutral-softer = 39.40 ± 1.50; Neutral-louder = 40.46 ± 1.60).

6.4.2 ERP data

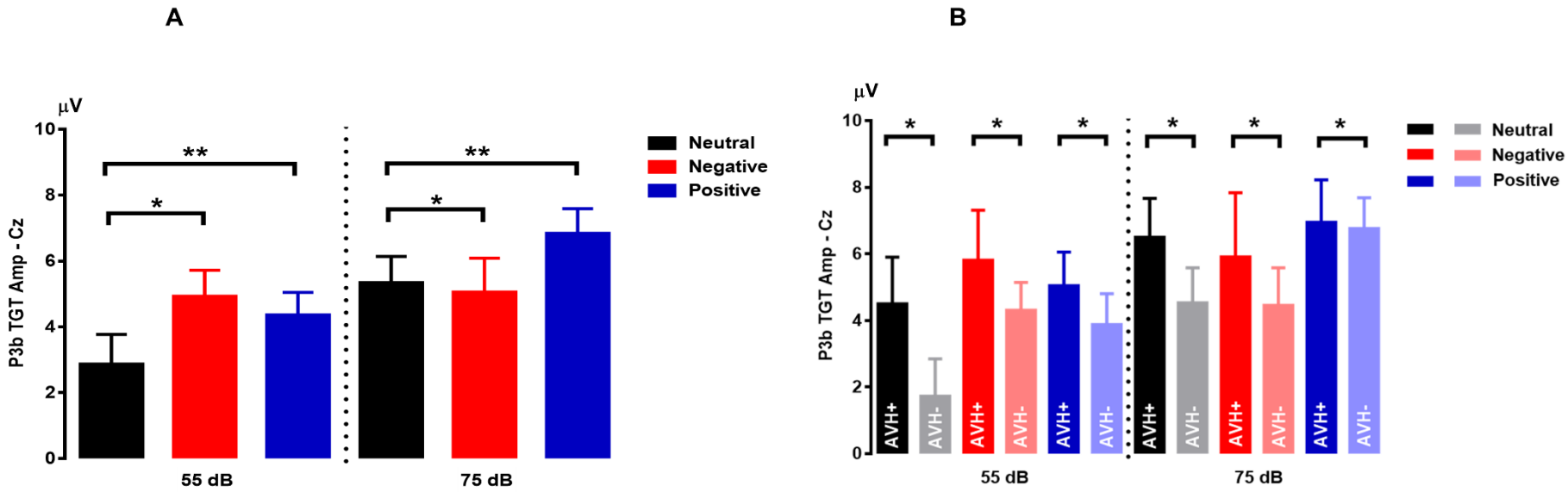
Figure 9 illustrates grand average waveforms for standards and targets as a function of valence and intensity manipulations considering the global sample and contrasting participants with and without AVH. Mean amplitudes for neutral and emotional targets in each acoustic condition in the full sample and in participants with and without AVH are presented in **Figure 10**.

Figure 9. Grand average waveforms contrasting neutral, negative, and positive vocalizations as a function of intensity manipulations at Cz electrode.



Note. Topographic maps show the spatial distribution of the P3b effects in the full sample (N = 34) and in the subsamples without (n = 20) and with (n = 14) AVH. Neu = neutral; Neg = negative; Pos = positive; TGT = target; STD = standard; AVH = auditory verbal hallucinations.

Figure 10. P3b amplitude differences as a function of valence and intensity manipulations in the full sample **(A)** and in the subsamples with *vs.* without AVH **(B)**.



Note. Bars represent mean amplitudes over Cz. Standard error (SE) of the means is represented in error bars. Amp = amplitude; TGT = target; AVH = auditory verbal hallucinations; AVH+ = with AVH; AVH– = without AVH.

6.4.2.1 P3b amplitude

The P3b amplitude was modulated by task-relevance and valence. Specifically, its amplitude was increased for targets compared to standards (β = 3.386, SE = 0.585, *t*(1190) = 5.784, *p* < .001, 95% CI: [2.238, 4.534]), and in response to positive compared to neutral vocalizations (β = 1.584, SE = 0.585, *t*(1190) = 2.707, *p* = .007, 95% CI: [0.436, 2.733]). As expected, P3b amplitude was more positive over Cz compared to Fz (β = 2.110, SE = 0.224, *t*(1190) = 9.401, *p* < .001, 95% CI: [1.670, 2.550]) and over Pz compared to Fz (β = 3.478, SE = 0.224, *t*(1190) = 15.493, *p* < .001, 95% CI: [3.037, 3.920]). Task-relevance interacted with intensity: P3b was increased for loud relative to soft targets (β = 2.470, SE = 0.828, *t*(1190) = 2.984, *p* = .003, 95% CI: [0.846, 4.094]). Moreover, a significant interaction between task-relevance and valence factors revealed valence-related differences in the processing of targets: P3b amplitude was increased for negative relative to neutral targets (β = 1.842, SE = 0.828, *t*(1190) = 2.226, *p* = .026, 95% CI: [0.218, 3.466]).

AVH proneness affected the ERP response to targets. The P3b was more positive for targets, irrespective of valence and intensity, in participants with *vs.* without AVH (β = 2.225, SE = 0.912, *t*(1190) = 2.439, *p* = .015, 95% CI: [0.436, 4.015]).

6.5 Discussion

The current study aimed to clarify whether attention allocation to vocal emotions is altered as a function of AVH proneness, and whether these potential changes are modulated by stimulus valence and intensity. The P3b showed significant main effects of task-relevance, intensity, valence, and AVH proneness. Specifically, its amplitude was larger for loud *vs.* soft vocal targets irrespective of valence, and for negative *vs.* neutral vocal targets irrespective of intensity. Of note, the P3b amplitude was generally increased in response to vocal targets in participants reporting AVH, irrespective of valence and intensity of vocalizations. These findings suggest that AVH proneness in non-clinical participants is related to changes in the detection of salience from the vocal stimuli.

6.5.1 Attention to vocal emotions irrespective of AVH proneness

Studies probing effects of emotion on the auditory P3b amplitude are still scarce. The existing studies revealed attention modulations by valence, with the P3b amplitude being increased in response to positive (Pinheiro, Barros, Dias, & Kotz, 2017) and negative (Wambacq, Shea-Miller, & Abubakr, 2004) compared to neutral vocal cues. Adding to previous evidence (Wambacq, Shea-Miller, & Abubakr, 2004), our study demonstrated increased P3b amplitude for negative *vs.* neutral vocal targets, irrespective of intensity. This finding suggests that vocalizations signaling a negative change attract more attention than those signaling a neutral change. From an evolutionary perspective, negative information is associated with a specific adaptive function: threat-related stimuli may indicate an imminent threat or danger (Frühholz & Grandjean, 2012; Pell & Kotz, 2011; Pell et al., 2015). The current P3b findings corroborate the high adaptive relevance of negative vocal emotions and suggest that emotional valence per se intensifies the perceived salience of sounds. It further supports an attentional bias towards negative information (Carretié, Mercado, Tapia, & Hinojosa, 2001; Ito, Larsen, Smith, & Cacioppo, 1998), even though we note this is not a consistent effect in auditory perception (for example, see Pinheiro, Barros, Dias, & Kotz, 2017).

In good agreement with previous studies supporting the contribution of sound intensity to selective attention (Huang & Elhilali, 2017; Kaya & Elhilali, 2014; Kim, Lin, Walther, Hasegawa-Johnson, & Huang, 2014), loud vocal targets elicited a larger P3b amplitude than soft vocalizations irrespective of valence. Attention modulations driven by arousal (Coull, 1998) may account for this effect. Specifically, sound intensity tends to increase the perceived arousal of vocal emotions (Schirmer, Simpson, & Escoffier, 2007), which in turn affects attention: the higher the perceived arousal, the more attention is devoted to the sound (Coull, 1998).

6.5.2 Attention to vocal emotions as a function of AVH proneness

As expected, voluntary attention to vocal emotions was modulated by AVH proneness. Notwithstanding, contrary to our hypothesis, we found that the P3b was generally increased rather than reduced in participants reporting AVH irrespective of sound valence and intensity. This finding

stands in contrast with previous observations of reduced P3b to pure (neutral) tones in both non-clinical individuals with psychotic-like symptoms (Bramon et al., 2008; del Re et al., 2015; Fusar-Poli et al., 2011; Hamilton et al., 2019; van Tricht et al., 2010) and psychotic patients (e.g., Bramon, Rabe-Hesketh, Sham, Murray, & Frangou, 2004; Ford, 1999; Hamilton et al., 2019; Jeon & Polich, 2003; Perlman et al., 2015). However, we note that the current study is not the first to observe an increased auditory P3b in AVH-prone individuals. Using and active auditory oddball task, van Lutterveld and collaborators (2010) documented an increased P3b amplitude in response to rare high-pitched tones in non-psychotic individuals with AVH relative to healthy controls. Given the absence of delusions and negative symptoms in those participants, the P3b reduction in schizophrenia patients with AVH was interpreted as reflecting the effects of concurrent positive, negative, and cognitive symptoms (van Lutterveld et al., 2010). In the current study, the relationship between AVH and attention is also less likely to be biased by the presence of other symptoms as AVH proneness was only associated with schizotypal traits (see **Table 13**). The similarly increased P3b response to neutral and emotional, as well as to soft and loud vocal targets indicates alterations in the discrimination between salient and non-salient voices. More recently, voice-selective alterations were related to increased hallucination proneness in a sensory prediction task contrasting tones and vocalizations (Pinheiro, Schwartze, & Kotz, 2018; Pinheiro et al., 2020): specifically, self-generated voices elicited larger N1 amplitudes compared to tones in non-clinical voice-hearers (Pinheiro, Schwartze, & Kotz, 2018; Pinheiro et al., 2020). This pattern of findings suggested that specific alterations in the processing of vocalizations may establish a core feature of the psychosis continuum, and may explain why hallucinated voices represent the most common abnormal perceptual experience (Pinheiro, Schwartze, & Kotz, 2018; Pinheiro et al., 2020). If voices become more salient compared to other types of sounds, they should attract more attention. Accordingly, in the current study we observed that the P3b was generally increased in response to vocal changes in AVH-prone individuals and was not modulated by two common sources of salience: sound valence (emotional > neutral) and intensity (loud > soft). The less discriminative P3b response agrees with the aberrant salience hypothesis of psychosis (Kapur, 2003). As voices become similarly salient and attract similar attentional resources, cognitive control demands may increase. As a result, the environment may be perceived as less controllable, setting the stage for an AVH (Alderson-Day et al., 2019; Hugdahl et al., 2013; Weber et al., 2020).

6.6 Limitations

Some limitations should be considered. First, the results should be interpreted with some caution due to the small sample size. Second, the severity of non-clinical AVH of this sample is not representative of the full spectrum of severity in the general population. Future studies should address these limitations.

6.7 Conclusions

The current study demonstrated that difficulties in distinguishing salient (emotional; loud) from non-salient (neutral; soft) vocal information, reflected in enhanced P3b responses to vocal targets, may be specifically related to the experience of AVH. If vocal stimuli are treated similarly irrespective of their salience (valence, intensity), cognitive control demands may increase. Consequently, events in the environment may be perceived as less controllable, setting the stage for an AVH. Longitudinal investigations of non-clinical individuals with AVH are necessary to specify how an increase in AVH severity affects selective attention to social stimuli such as voices, clarifying the role of altered salience detection in AVH proneness along the psychosis continuum.

6.8 References

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PART III CONCLUDING REMARKS

Chapter 7

7. Discussion

7.1 Main research findings

The current Dissertation started by giving the readers an overview on research focused on vocal emotional processing in individuals of the general population with *vs.* without positive-like symptoms and psychotic voice-hearers. The literature reviewed shows that altered processing of vocal emotions in schizophrenia patients seems to play a core role in the development of AVH (e.g., Alba-Ferrara, Fernyhough, Weis, Mitchell, & Hausmann, 2012). However, whether a similar association occurs between alterations in vocal emotional processing and non-clinical hallucinations remains unclear. Furthermore, the contribution of attention and acoustic salience to vocal emotional processing is still to be clarified. Together, these questions were the motto for the current Dissertation. Specifically, Study 3 (Chapter 5) examined the impact of hallucination proneness on the sensory and cognitive processing of vocal emotions and specified whether manipulations of sound acoustic salience (intensity and duration) affect the time course of voice processing; Study 4 (Chapter 6) clarified whether hallucination proneness affects attention allocation to vocal emotions and specified the role of stimulus valence and intensity in this process. Since we wanted to provide a rigorous assessment of the time course of vocal emotional processing with ERPs, two additional studies preceded the main ERP experiments, which aimed to validate the LSHS, a self-report instrument to measure hallucination proneness (Study 1, Chapter 3), and a set of non-verbal emotional vocalizations varying in duration (Study 2, Chapter 4).

The findings of each study have been discussed in detail in the previous four Chapters of this Dissertation (see **Table 15** for a brief summary). Three main topics emerged from these studies: 1) the lower degree of severity and unpleasantness of non-clinical *vs.* clinical hallucinations and the comparable

degree of uncontrollability across them; 2) the accurate recognition of emotions from short non-verbal vocalizations: evidence for faster categorization of amusement; and 3) the role of acoustic salience in explaining alterations in the time course of vocal emotional processing as a function of hallucination proneness. Each of these topics will be outlined in the sections to follow.

Table 15. Summary of findings per Chapter.

Chapter	Research question	Brief answer
3	What are the phenomenological characteristics underlying hallucinatory experiences in the non-clinical Portuguese population?	Portuguese non-clinical individuals were not only more likely to experience intrusive or vivid thoughts and hypnagogic and hypnopompic hallucinations relative to the other types of hallucinations (auditory, visual, olfactory, tactile, and vividness of daydreams), but also to perceive their hallucinatory experiences as less unpleasant than what is commonly reported in individuals with a psychotic disorder. Contrary to previous evidence, all types of hallucinations were described as uncontrollable and dominating. However, the more pleasant they were perceived, the more controllable they were assessed.
4	How much voice signal is enough for a listener to successfully recognize emotions from non-verbal vocalizations? Does the amount of acoustic information for recognition vary by emotion type?	Gate 3 (300 ms after stimulus onset) was the most critical time window for recognition. Subsequent time windows facilitated emotional recognition in general, but not as much as the early 200-300 ms time window. The gate at which each vocalization was accurately recognized (without categorization changes at longer gate durations) varied by emotion type: amusement (266 ms), disgust (296 ms), and sadness (305 ms) were identified at shorter gate intervals than anger (342 ms) and fear (367 ms). Thus, whereas the recognition of amusement (laughter) required the shortest acoustic signal, anger and fear required the longest acoustic signal for successful recognition.
5	Is the sensory and cognitive processing of vocal emotions affected by hallucination proneness? Are these potential changes associated with stimulus intensity and duration?	ERP results revealed interactive effects of hallucination proneness, valence, and stimuli acoustic cues (intensity and duration) on both early sensory (N1, P2) and higher-order cognitive (LPP) stages of vocal emotional processing. Specifically, higher HP was associated with decreased N1 and increased P2 amplitudes in response to louder and longer neutral (*vs.* positive) vocalizations, as well as with a larger LPP to louder and longer negative (*vs.* neutral) vocalizations. Alterations in the sensory and cognitive processing of vocal emotions in high hallucination proneness were primarily driven by altered salience of acoustic representations of emotions.
6	Is the ability to selectively orient attention towards vocal emotions affected by hallucination proneness? Are these potential changes associated with stimulus intensity?	The P3b amplitude was generally increased in response to vocal targets in participants specifically reporting AVH, irrespective of valence and intensity of vocalizations, suggesting difficulties in distinguishing salient (emotional; loud) from non-salient (neutral; soft) vocal information.

7.1.1 The lower degree of severity and unpleasantness of non-clinical *vs.* clinical hallucinations and the comparable degree of uncontrollability across them

Hallucinatory experiences are not restricted to psychiatric disorders (Johns et al., 2004), but are also common in the general (non-clinical) population (Barrett & Etheridge, 1992; de Leede-Smith & Barkus, 2013; Paulik, Badcock, & Maybery, 2006; Badcock, Chhabra, Maybery, & Paulik, 2008; Sommer et al., 2010). However, and despite some phenomenological similarities, there are important differences between clinical and non-clinical hallucinations (Daalman et al., 2011; de Leede-Smith & Barkus, 2013). For example, non-clinical voice-hearers tend to perceive their hallucinated voices as more controllable and less unpleasant than clinical voice-hearers (Choong, Hunter, & Woodruff, 2007; Daalman et al., 2011; Larøi et al., 2012; de Leede-Smith & Barkus, 2013; Nayani et al., 1996). Differences in the predominant type of hallucinations in patients and non-clinical individuals have also been reported: whereas AVH are the most common type in schizophrenia patients (Andreasen & Flaum, 1991; de Leede-Smith & Barkus, 2013), the hallucinations of non-clinical individuals are typically hypnagogic [experiences occurring while falling asleep] and hypnopompic [experiences occurring while waking up] (Choong, Hunter, & Woodruff, 2007; de Leede-Smith & Barkus, 2013; Ohayon, 2000). Combined with several other clinical conditions (i.e., anxiety, depressed mood, suspiciousness, disorganization, irritability, social withdrawal, poor functioning) and cognitive and behavioral changes (Yung & McGorry, 1996; Yung et al., 2003), the phenomenological characteristics of hallucinatory experiences provide important clues that can facilitate an accurate clinical diagnosis of psychotic disorders.

Study 1 (Chapter 3) corroborates the tendency of non-clinical individuals to experience less severe and unpleasant hallucinations compared to psychotic patients (Choong, Hunter, & Woodruff, 2007; Daalman et al., 2011; Larøi et al., 2012; de Leede-Smith & Barkus, 2013; Nayani et al., 1996), and suggests that the degree of perceived control over non-clinical hallucinations may be not as high as most evidence claims (Andrew, Gray, & Snowden, 2008; Baumeister, Sedgwick, Howes, & Peters, 2017; Daalman et al., 2011; Honig et al., 1998; Larøi, 2012; Powers, Kelley, & Corlett, 2017; Romme & Escher, 1989; Roxburgh & Roe, 2014; Taylor & Murray, 2012). Specifically, all types of hallucinatory experiences (auditory, visual, olfactory, tactile, intrusive or vivid thoughts, vividness of daydreams, hypnagogic and hypnopompic) were perceived as highly uncontrollable and dominating. Furthermore, AVH were more difficult to control than olfactory, tactile and visual hallucinations. Given that non-clinical voice-hearers who perceive their AVH as highly controllable are also more likely to consider their experiences as less disruptive and distressful (Garety, Kuipers, Fowler, Freeman, & Bebbington, 2001), we can speculate that

participants who perceived their AVH as uncontrollable may also experience associated distress. This study was not the first to demonstrate that non-clinical AVH may be as uncontrollable as clinical AVH. Using the original French version of the LSHS that was used to assess the Portuguese sample, Larøi and van der Linden (2005) reported a similar tendency for the three auditory hallucination-items. Furthermore, recent evidence suggests that the experience of AVH in both non-clinical individuals and psychotic patients may vary in terms of degree of controllability (Swyer & Powers, 2020).

The observed tendency of non-clinical individuals to perceive their hallucinatory experiences as highly uncontrollable and dominating suggests a general incapacity to apply strategies (i.e., direct or indirect strategies such as problem-solving, attention – Larøi, 2012) to control the onset and offset of these experiences (Swyer & Powers, 2020). It is worth noting, however, that the perceived degree of control over the hallucinatory experiences may be affected by the emotional content of the experiences. Specifically, and as shown in Chapter 3, the more pleasant the hallucinatory experiences were perceived, the more controllable they were judged. Though in the opposite direction (i.e., unpleasant experiences were associated with a lower degree of control), an association between the emotional content of the hallucinatory experiences and the degree of control over the experiences was also observed in the study of Larøi and van der Linden (2005). Importantly, together with its associated distress, the absence of perceived control over unpleasant hallucinatory experiences is thought to be critical in determining the transition from non-clinical to clinical hallucinations (Larøi et al., 2012).

The results of Study 1 (Chapter 3) suggest that, at least in some cases, non-clinical hallucinations may be as uncontrollable as clinical hallucinations. If indeed a lower degree of control over unpleasant hallucinations aggravates its severity (Larøi et al., 2012), then the assessment of non-clinical hallucinations should include a detailed evaluation of the perceived degree of control over the experiences (especially those with negative emotional content). A more detailed understanding of the phenomenology of hallucinations will contribute to better differentiate between experiences that do not need treatment from those that do.

7.1.2 The accurate recognition of emotions from short non-verbal vocalizations: Evidence for faster categorization of amusement

Duration plays a key role in vocal emotional processing (Cornew, Carver, & Love, 2010; Pell & Kotz, 2011; Rigoulot, Wassiliwizky, & Pell, 2013). In speech prosody, evidence has shown emotion-

specific differences in the time course for explicit recognition of emotions: anger, fear, sadness, and neutral expressions seem to be accurately identified from short prosodic pseudo-utterances (500-700 ms), while listeners might need more time to recognize happiness (1000 ms) and disgust (1500 ms) prosodic cues (Pell & Kotz, 2011). Aiming to clarify the time course for explicit recognition of emotions from non-verbal vocalizations, and to validate a set of vocalizations varying in duration to use in the ERP experiments, Study 2 (Chapter 4) demonstrates that the recognition of emotions from non-verbal vocalizations *vs.* speech prosody (Cornew, Carver, & Love, 2010; Pell & Kotz, 2011; Rigoulot, Wassiliwizky, & Pell, 2013) requires much less acoustic information. This may occur because non-verbal emotional vocalizations have played a crucial role in communication long before the emergence of language (Belin, Fecteau, & Bédard, 2004). Moreover, whereas the processing of emotional prosody requires listeners to perform emotional judgments based on both segmental and suprasegmental cues (which involves more processing resources), recognition of emotional vocalizations relies only on non-verbal information (Pell et al., 2015).

Study 2 also revealed emotion-specific differences in the gate at which each vocalization was accurately recognized: disgust (296 ms), and sadness (305 ms) were identified at shorter gate intervals than anger (342 ms) and fear (367 ms). These findings suggest that ERP effects occurring within 300 ms post-stimulus onset reflect processes involved in the rapid emotional categorization of vocal information. Previous ERP evidence demonstrated that the decoding of non-verbal acoustic expressions of amusement occurs earlier than anger and sadness (Pell et al., 2015). Our findings add to this evidence by suggesting that the recognition of vocalizations of amusement also requires less amount of acoustic information than vocalizations of anger and fear. The social function played by vocal emotions (Belin, 2006; Latinus & Belin, 2011; Meneses & Díaz, 2017) may explain why amused *vs.* angry and fearful voices needed for less acoustic information to be correctly identified. Particularly, spontaneous laughter (e.g., amused laughter, joyful laughter) facilitates cooperative behavior among individuals (Gervais & Wilson, 2005; Greatbatch & Clark, 2003). Further, laughter may elicit emotional contagion (Mehu & Dunbar, 2008), which is critical for building strong bonds between social partners (Gervais & Wilson, 2005; Vettin & Todt, 2004). Together, the social benefits associated with laughing voices may contribute to their high recognizability even when listeners are briefly exposed to them.

By defining the minimum amount of acoustic information necessary to recognize emotions from non-verbal vocalizations, the study presented in the Chapter 4 can be extremely useful for subsequent research aiming to unveil temporal effects in vocal emotional perception. The finding that different amounts of voice information are required to recognize different emotional states (i.e., anger, disgust,

fear, amusement and sadness states) expressed through non-verbal vocalizations should be accounted for in studies of vocal emotional processing.

7.1.3 The role of acoustic salience in explaining alterations in the time course of vocal emotional processing as a function of hallucination proneness

Salience refers to the quality of a stimulus to stand out from the rest (Guido, 1998). Stimulus qualities that contribute to the distinctiveness of a salient cue can be either physical or emotional and motivational (Kapur, 2003). Being able to efficiently detect salience in the environment is critical to ensure the selective allocation of limited-capacity processing resources to the most relevant sensory stimuli (Phan et al., 2004). The ability to discriminate between salient and irrelevant information is also mandatory for successful interpretation of social cues (e.g., other's feelings and emotions) and attentional priorities (Santuzzi & Ruscher, 2002). The emotional tone of the voice is one of the most salient cues in the social environment (Vuilleumier, 2005). Support for this idea comes from studies showing that vocal emotions tend to be perceived as more salient (reflected in P2 amplitude modulations – Liu et al., 2012; Sauter, & Eimer, 2009) and to attract more attention (reflected in P3b amplitude modulations – Wambacq, Shea-Miller, & Abubakr, 2004) than neutral vocal cues.

Aberrant salience, referred to as the inappropriate attribution of salience to internal and external stimuli (Kapur, 2003), is often reported in schizophrenia patients (Gray, 1995; Heinz & Schlagenhauf, 2010; Kapur, 2003). Specifically, schizophrenia patients are more likely to attribute emotional pleasantness or unpleasantness to neutral stimuli than healthy controls (Kring, Kerr, Smith, & Neale, 1993). Furthermore, patients are particularly likely to misidentify neutral prosodic cues as negatively valenced (Hoekert, Vercammen, Kahn, Knegtering, & Aleman, 2009). ERP data provides further evidence for salience-related alterations in vocal emotional processing in schizophrenia patients. In particular, patients *vs.* healthy controls have been shown to display a specific difficulty in extracting emotional salience from happy prosody (reflected in increased P2 amplitude – Pinheiro et al., 2013; 2014), and in paying attention to salient targets of happy prosody (reflected in decreased P3b amplitude – Pinheiro & Niznikiewicz, 2019). According to the aberrant salience hypothesis of psychosis (Heinz, 2002; Howes & Murray, 2014; Kapur, 2003), the inappropriate attribution of salience to internal and external stimuli is closely related to brain dopamine dysfunction and the development of psychotic symptoms. Aberrant salience attribution has been associated with the occurrence of psychotic symptoms not only in

schizophrenia patients (e.g., hallucinations and delusions – Kapur, 2003; disorganization – Hoekert, Vercammen, Kahn, Knegtering, & Aleman, 2009), but also in individuals at ultra-high risk for psychosis (e.g., positive-like symptoms – Modinos et al., 2015; delusion-like symptoms – Roiser, Howes, Chaddock, Joyce, & McGuire, 2013). This hypothesis is further supported by evidence showing that alterations in salience attribution tend to disappear with the remission of both psychotic symptoms (Roiser et al., 2009) and psychotic-like symptoms (Schmidt et al., 2017). It has also been suggested that dopamine abnormalities in psychosis may reflect increased attribution of salience to irrelevant stimuli, as well as decreased attribution of salience to relevant stimuli (Heinz, 2002; Kapur, 2003). Indeed, recent studies with schizophrenia patients and ultra-high risk individuals provide evidence for impairments in both forms of salience processing (Modinos et al., 2015; Pankow et al., 2016; Roiser et al., 2009; Roiser, Howes, Chaddock, Joyce, & McGuire, 2013; Schmidt et al., 2017). Note, however, that the studies that examined salience in individuals with psychotic-like symptoms have used visual-reward stimuli (Roiser, Howes, Chaddock, Joyce, & McGuire, 2013; Schmidt et al., 2017), emotional pictures (Modinos et al., 2015) and emotional faces (van't Wout, Aleman, Kessels, Larøi, & Kahn, 2004) and, therefore, it remains to clarify whether alterations in salience detection extend to vocal emotional cues.

The studies presented in Chapters 5 and 6 were the first to investigate ERP correlates of vocal emotional processing in non-clinical individuals reporting hallucinations. Specifically, Study 3 (Chapter 5) examines the effects of individual differences in hallucination proneness on vocal emotion processing, and Study 4 (Chapter 6) addresses the specific relationship between AVH proneness and altered attention allocation to vocal emotions. Results from Study 3 demonstrate that vocal emotions tend to be perceived as less salient as a function of increased hallucination proneness. Specifically, more salient acoustic information was needed to normalize the N1 and LPP responses to positive and negative vocalizations, respectively. Furthermore, participants with high hallucination proneness perceived positive vocalizations as less salient than neutral vocalizations (reflected in P2 amplitudes) even when the voice was acoustically more salient, i.e., in the high intensity and long duration conditions. Consistent with these findings, previous evidence shown that ultra-high risk individuals with psychotic-like symptoms (positive and negative) are particularly likely to attribute less salience to (relevant) rewarding visual stimulus (Schmidt et al., 2017). As for Study 4, the results indicate that changes in attention allocation to vocal emotions (reflected in P3b amplitudes) were specifically related to AVH proneness [LSHS AVH-related items] (no significant association was observed between hallucination proneness [LSHS total score] and P3b responses to vocal emotions). Specifically, participants with AVH proneness devoted identical attention to salient (emotional; louder) and non-salient (neutral, softer) vocal targets. This finding is consistent with

previous evidence of increased attribution of salience to (irrelevant) no-rewarding visual stimuli in ultra-high risk individuals with positive and negative-like symptoms (Roiser, Howes, Chaddock, Joyce, & McGuire, 2013). It is worth noting, however, that while in the study of Roiser et al. (2013) aberrant salience was directly linked to the severity of delusion-like symptoms, our study suggests that the inappropriate attribution of salience to non-salient (neutral, softer) vocal targets may be related to non-clinical AVH. Furthermore, the observed attribution of emotional salience to neutral vocal cues agrees with previous data from schizophrenia patients (Hoekert, Vercammen, Kahn, Knegtering, & Aleman, 2009).

The combined results of the third and fourth studies of this Dissertation suggest that abnormal assignment of salience to emotional voices may be specifically related to the occurrence of hallucinations also in non-clinical samples. They further indicate that changes in the representation of vocal emotionally salient information associated with increased hallucination proneness (Chapter 5) may potentially contribute to attention discrimination difficulties in non-clinical individuals specifically prone to AVH (Chapter 6). The specific relationship between AVH proneness (rather than hallucination proneness) and the P3b less discriminable response to emotional and neutral vocal targets seems to confirm the particular relevance of these processes for eliciting voice-hearing experiences (e.g., Alba-Ferrara, Fernyhough, Weis, Mitchell, & Hausmann, 2012). Alterations in the attentional processing of salient vocal information have been found to account for external misattributions of self-generated speech in patients with AVH (Ensum & Morrison, 2003; Ilankovic et al., 2011). Impaired self-monitoring of inner speech is also thought to contribute to the emergence of AVH (Frith, 1987; 1996; Johns et al., 2001; Johns, Gregg, Allen, & McGuire, 2006), occurring not only in psychotic patients with AVH (Brébion et al., 2016; Johns et al., 2001, Johns, Gregg, Allen, & McGuire, 2006; Woodward, Menon, & Whitman, 2007), but also in non-clinical individuals prone to hallucinations (Brébion et al., 2016; Larøi, van der Linden, & Marczewski, 2004. AVH in schizophrenia patients have also been related to impaired emotional prosody processing that leads to self-speech misattribution via an incapacity to use these cues to determine the origin of the speech [internal *vs.* external] (Alba-Ferrara, Fernyhough, Weis, Mitchell, & Hausmann, 2012). Our findings suggest that AVH in non-clinical individuals may also occur due to self-voice misattribution via altered detection of acoustic (salient) changes in vocal emotional expressions. The current Dissertation provides the first pieces of evidence for salience-related alterations in both sensory and cognitive ERP responses to vocal emotions in non-clinical individuals reporting hallucinations that might be specifically related to the experience of hearing-voices. Further research is needed to probe the observed alterations, and to unveil whether these physiological changes reflect increased vulnerability to psychotic disorders.

7.2 Implications

In this section, we consider the main practical and theoretical implications of this Dissertation findings. **Table 16** summarizes the contributions of each individual Chapter.

Table 16. Summary of main contributions per Chapter.

Chapter	Title	Main contributions
3	On "hearing" voices and "seeing" things: Probing hallucination predisposition in a Portuguese non-clinical sample with the Launay-Slade Hallucination Scale-Revised	Chapter 3 provides evidence to support the construct validity and reliability of the Portuguese version of the LSHS, and sheds first light on the phenomenological characteristics of hallucinations in a Portuguese non-clinical sample. It therefore contributes to research on related topic by a) filling the gap in non-clinical hallucinations assessment instruments for Portuguese individuals; b) advancing the scientific knowledge about the phenomenology of non-clinical hallucinations; and c) calling into question the idea of perceived control over non-clinical hallucinations.
4	Decoding emotions from non-verbal vocalizations: How much voice signal is enough?	Chapter 4 contributes to a better understanding of the role of duration in vocal emotional processing. It has implications for research by a) probing the minimum amount of information necessary to decode emotions from non-verbal vocalizations; and b) making available a set of short non-verbal emotional vocalizations that can help users to reduce the duration of their tasks.
5	Acoustic salience in emotional voice perception and its relationship with hallucination proneness	Chapter 5 provides first evidence for alterations in early sensory (N1, P2) and higher-order cognitive (LPP) processing of vocal emotions as a function of hallucination proneness. It has implications for a) subsequent research on the relation between vocal emotional processing and hallucination proneness; b) research devoted to identifying biological markers to predict psychotic disorder; c) the aberrant salience hypothesis of psychosis; and d) the continuum hypothesis of psychosis.
6	Attention to voices is increased in non-clinical voice hearers irrespective of salience	Chapter 6 provides first evidence for alterations in attention allocation (P3b) to vocal emotions as a function of AVH proneness. It has implications for a) subsequent research on the relation between attention allocation to vocal emotions and AVH proneness; b) research devoted to identifying biological markers to predict psychotic disorder; c) the aberrant salience hypothesis of psychosis; and d) the continuum hypothesis of psychosis.

7.2.1 Practical implications

As mentioned in the begin of this Chapter, the main aim of the current Dissertation was to investigate early and late ERP correlates of vocal emotional processing in individuals varying in hallucination proneness, and to specify the contributions of stimulus valence and acoustic cues [duration and/or intensity] in these processes (Chapters 5 and 6). Achieving this goal required a prior study (Chapter 4) in which we specified the amount of acoustic information necessary for recognition of emotions from non-verbal vocalizations. Using vocal samples that were selected from the Montreal Affective Voices (MAV, Belin Fillion-Bilodeau, & Gosselin, 2008) for manipulation into seven gate intervals (100-700 ms), this study allowed us to validate a set of short and long vocalizations to use in the ERP experiments. Accordingly, the first major practical contribution of this Dissertation is that it provides much needed empirical data on both fields of research. Specifically, Chapter 4 shows that the accurate recognition of emotions from non-verbal vocalizations relies on short acoustic signals and emotion-specific amounts of acoustic information. These findings provide important guidance for subsequent research aiming to unveil temporal effects in vocal emotional perception. Chapters 5 and 6 provide first evidence for alterations in the sensory and cognitive processing of vocal emotions as a function of hallucination proneness (reflected in the N1, P2, and LPP amplitudes) and changes in attention allocation to vocal emotions as a function of AVH proneness (reflected in P3b amplitudes), respectively. They further highlight the role of acoustic salience in explaining the observed ERP pattern of findings. From a practical point of view, these findings may be particularly useful and the starting point for subsequent research on related topic.

A second important practical implication is that we provide evidence for alterations in the N1 (Chapter 5) and P3b (Chapter 6) responses to vocal emotions in hallucination-prone and AVH-prone individuals, respectively. Alterations in the N1 and P3b responses to neutral (pure) tones have been proposed as biomarkers for psychotic disorders (Foxe et al., 2011; Hamilton et al., 2019; Özgürdal et al., 2008; Rosburg, Boutros, & Ford, 2008; Turetsky et al., 2007). Therefore, the potential for altered N1 and P3b responses to vocal emotions to be also biomarkers of increased risk for psychotic disorders may have a significant impact on clinical practice. Specifically, ERP-based biomarkers, combined with increased severity of psychotic-like symptoms, may help to identify and refer high-risk individuals to early intervention programs (Luck et al., 2011).

A third important practical implication of the current Dissertation derives from the study presented in Chapter 3. This Chapter provides evidence to support the construct validity and reliability of

the Portuguese version of the 16-item LSHS. The adaption of the LSHS fills the gap in non-clinical hallucinations assessment instruments for the Portuguese population. Consequently, from the use of this scale, it will be possible to conduct further research that may contribute to a deeper understanding of the phenomenology of non-clinical hallucinations and effects of hallucination proneness on a wide range of cognitive and emotional skills. Combined with other screening measures, the Portuguese version of the LSHS can also be used to identify high-risk individuals.

A fourth practical implication derives also from Chapter 3. This Chapter sheds first light into the phenomenological characteristics of non-clinical hallucinations in a Portuguese sample and calls into question the idea of perceived control over non-clinical hallucinations. Specifically, we found that all types of hallucinations (auditory, visual, olfactory, tactile, intrusive or vivid thoughts, vividness of daydreams, hypnagogic and hypnopompic) assessed by the LSHS were perceived as uncontrollable and dominating experiences. This finding contradicts an extensive body of evidence (Andrew, Gray, & Snowden, 2008; Baumeister, Sedgwick, Howes, & Peters, 2017; Daalman et al., 2011; Honig et al., 1998; Larøi, 2012; Powers, Kelley, & Corlett, 2017; Romme & Escher, 1989; Roxburgh & Roe, 2014; Taylor & Murray, 2012), and highlights the importance of evaluating the hallucinatory experiences in detail (frequency, emotional content, degree of control) also in non-clinical samples.

Finally, Chapter 4 further contributes by adapting into short durations a set of emotional and neutral vocalizations selected from the Montreal Affective Voices (MAV, Belin Fillion-Bilodeau, & Gosselin, 2008). This set of short vocalizations can help users to reduce the duration of their tasks. This would be particularly advantageous for ERP studies, in which a large number of trials are required to get a significant effect (Luck, 2005), and research on vocal emotional processing with clinical samples.

7.2.2 Theoretical implications

This section discusses the theoretical implications of the findings under three headings: implications for the identification of biological markers for psychosis, implications for the aberrant salience hypothesis of psychosis, and implications for the continuum hypothesis of psychosis.

7.2.2.1 Implications for the identification of potential biological markers for psychosis

Early and late ERPs have shown strong potential as biomarkers for subsequent conversion to psychotic disorders (e.g., N1 – Foxe et al., 2011; Rosburg, 2018; Rosburg, Boutros, & Ford, 2008; Mismatch negativity [MMN] – Näätänen, Shiga, Asano, & Yabe, 2015; Näätänen, Todd, & Schall, 2016; P3 – Bestelmeyer, Phillips, Crombie, Benson, & Clair, 2009; Bramon et al., 2005; Earls, Curran, & Mittal, 2016; Lho, Kim, Lee, Kwak, & Kwon, 2019; Luck et al., 2011; Mathalon, Ford, Rosenbloom, & Pfefferbaum, 2000; Özgürdal et al., 2008; Seidman et al., 2015). For example, auditory N1 and P3b amplitudes have been shown to be reduced not only in schizophrenia patients (Foxe et al., 2011; Rosburg, 2018; Rosburg, Boutros, & Ford, 2008; van der Stelt, Lieberman, & Belger, 2005), but also in individuals at high risk for schizophrenia (Bramon et al., 2008; Foxe et al., 2011; Frommann et al., 2008; Özgürdal et al., 2008; van der Stelt, Lieberman, & Belger, 2005), i.e., before schizophrenia onset. Evidence-based biomarkers for psychotic disorders suggest that ERP markers can be especially useful in identifying endophenotypes, treatment targets and risk individuals who may benefit from early interventions (Luck et al., 2011).

Consistent with previous evidence with schizophrenia patients (Pinheiro et al., 2013; 2014; Pinheiro & Niznikiewicz, 2019), Chapter 5 revealed alterations in the sensory processing of vocal emotions in high hallucination proneness (reflected in N1 amplitudes), and Chapter 6 revealed alterations in attention allocation to vocal emotions in AVH proneness (reflected in P3b amplitudes). These findings add to previous ERP evidence proposing the auditory N1 and P3b amplitudes as potential biomarkers for psychotic disorders (Foxe et al., 2011; Hamilton et al., 2019; Özgürdal et al., 2008; Rosburg, Boutros, & Ford, 2008; Turetsky et al., 2007). The challenge now is to conduct longitudinal research to probe whether alterations in the N1 and P3b responses to vocal emotions in individuals reporting non-clinical hallucinations may also predict the transition to psychotic disorders.

7.2.2.2 Implications for the aberrant salience hypothesis of psychosis

As mentioned before, both psychotic patients (Pankow et al., 2016; Roiser et al., 2009) and individuals with psychotic-like symptoms (Modinos et al., 2015; Roiser, Howes, Chaddock, Joyce, & McGuire, 2013; Schmidt et al., 2017) tend to exhibit alterations in salience processing. While abnormal salience processing has been found to correlate with hallucinations and delusions in schizophrenia patients (Kapur, 2003), it appears to be directly linked to delusions in individuals with psychotic-like

experiences (Roiser, Howes, Chaddock, Joyce, & McGuire, 2013), but few studies were conducted (Modinos et al., 2015; Roiser, Howes, Chaddock, Joyce, & McGuire, 2013; Schmidt et al., 2017). There is also evidence to suggest alterations in salience detection of vocal emotions in schizophrenia patients (Pinheiro et al., 2013: 2014; Pinheiro & Niznikiewicz, 2019). Whether or not similar changes exist in non-clinical individuals reporting hallucinations remains unclear.

The ERP studies presented in this Dissertation provide first evidence for alterations in the representation of emotionally salient vocal information as a function of hallucination proneness (Chapter 5), which in turn may lead to attention discrimination difficulties in non-clinical individuals prone to AVH (Chapter 6). Taken together, these findings have important theoretical implications for the aberrant salience hypothesis of psychosis (Heinz, 2002; Howes & Murray, 2014; Kapur, 2003). An additional implication of these findings is that they provide further evidence to support similar cognitive mechanisms underlying the experience of hallucinations in psychotic patients and non-clinical individuals (Allen, Freeman, Johns, & McGuire, 2006; Barkus, Stirling, Hopkins, Mckie, & Lewis, 2007; Brébion et al., 2016; Larøi, van der Linden, & Marczewski, 2004), which supports the continuum of psychosis (Baumeister, Sedgwick, Howes, & Peters, 2017; van Os, Hanssen, Bijl, & Ravelli, 2000; van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009).

7.2.2.3 Implications for the continuum hypothesis of psychosis

Accumulating evidence has shown that psychotic symptoms (e.g., hallucinations, delusions) do not inevitably result in a psychotic disorder (e.g., Badcock, Chhabra, Maybery, & Paulik, 2008; Barrett & Etheridge, 1992; Maijer, Begemann, Palmen, Leucht, & Sommer, 2018; Paulik, Badcock, & Maybery, 2006; Sommer et al., 2010). Due to this evidence, a dimensional approach to psychosis has been in discussion: the continuum hypothesis of psychosis (Baumeister, Sedgwick, Howes, & Peters, 2017; van Os, Hanssen, Bijl, & Ravelli, 2000; van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009). From a fully-dimensional perspective, the continuum of psychosis ranges from psychotic-like experiences in non-clinical populations to clinically significant psychotic symptoms in diagnosed patients (Baumeister, Sedgwick, Howes, & Peters, 2017; van Os, Hanssen, Bijl, & Ravelli, 2000; van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009).

Evidence for similar neural and cognitive mechanisms underlying psychotic-like experiences and psychotic symptoms provides further support for the continuum hypothesis of psychosis (Allen, Freeman, Johns, & McGuire, 2006; Barkus, Stirling, Hopkins, Mckie, & Lewis, 2007; Brébion et al., 2016; Diederen

et al., 2012; Larøi, van der Linden, & Marczewski, 2004; Linden et al., 2010). For example, psychotic and non-clinical voice-hearers are equally likely to misattribute self-generated inner speech to external sources of information (Allen, Freeman, Johns, & McGuire, 2006; Brébion et al., 2016). Also, a common set of brain regions (bilateral inferior frontal gyri, insula, superior temporal gyri, supramarginal gyri, and postcentral gyri, left precentral gyrus, inferior parietal lobule, superior temporal pole, and right cerebellum) was found to be activated during AVH in clinical and non-clinical participants (Diederen et al., 2012).

The combined results of the fifth and sixth Chapters of this Dissertation suggest that the detected ERP pattern of changes to vocal emotions in psychotic patients (Pinheiro et al., 2013; 2014; Pinheiro & Niznikiewicz, 2019) may also be common in non-clinical individuals experiencing hallucinations. In this sense, our findings represent an important first step toward understanding how vocal emotional processing may be affected by hallucination proneness. Furthermore, they provide additional and important support for the continuum of psychosis (Baumeister, Sedgwick, Howes, & Peters, 2017; van Os, Hanssen, Bijl, & Ravelli, 2000; van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009). Although the great majority of individuals experiencing psychotic-like symptoms do not have a need for care, some will go on to develop a psychotic disorder (35% – Cannon et al., 2008; 29% – Fusar-Poli et al., 2012; 20% – Nelson et al., 2013). The idea that psychotic experiences may exist on a continuum contributes to the identification of risk and protective factors that can increase and decrease the vulnerability to develop a psychotic disorder, respectively (DeRosse & Karlsgodt, 2015). Those who are especially vulnerable to psychosis may benefit from early interventions (Soneson et al, 2019). Early interventions might either prevent (by reducing the frequency of psychotic-like experiences and associated distress – Soneson et al, 2019) or delay the onset of psychosis (Harris et al., 2005; McGorry et al., 2002; McGorry, Yung, & Phillips, 2003).

7.3 Research limitations

Although the current Dissertation yields promising results, some limitations need to be considered. Since the limitations of each study were separately reported in the previous four Chapters, this section only addresses the main limitations, and some not yet mentioned, that may have impacted the findings.

The most obvious limitation of this Dissertation is that of the generalizability of the findings (Rosnow & Rosenthal, 1991). Specifically, all studies were based on convenience samples of college students. College students constitute a core target group (e.g., Morrison, Wells, & Nothard, 2000; Paulik, Badcock, & Maybery, 2006) for the screening of non-clinical hallucinations (Chapter 3) and the study of hallucination proneness (Chapters 5 and 6), yet they represent only a part of the non-clinical population with hallucinations. Furthermore, the time course of vocal emotion recognition may have been affected by the high educational level of the sample (Chapter 4). The relatively small sample sizes used in the ERP experiments (Chapters 5 and 6) adds further caution regarding the generalizability of the findings. Both experiments were further limited by the lack of participants with more severe and frequent hallucinations, which precludes the opportunity to probe whether increased severity of non-clinical hallucinations correlates with more pronounced changes in vocal emotional processing.

Two additional methodological limitations derive from the study presented in Chapter 4. First, recognition accuracy was measured using a forced-choice format. This may have inflated decoding accuracy as listeners' judgments were restricted to the number of available options. Second, only one type of positive vocalization (laughter) was used. Consequently, it remains to be clarified whether the recognition of different types of positive vocalizations (e.g., achievement, sensual pleasure, relief) relies on different amounts of acoustic information.

In addition, the ERP findings (Chapters 5 and 6) were limited by the use of a cross-sectional design. Cross-sectional studies are particularly useful to compare multiple variables at the same time and to identify potential associations between them. However, cause and effect relationships cannot be inferred from cross-sectional studies (Setia, 2016). Furthermore, cross-sectional studies cannot address the potential effects of any change in vulnerability (hallucination proneness) over time (Setia, 2016).

Finally, and as with the majority of ERP studies, the studies presented in Chapters 5 and 6 were also subject to EEG-specific limitations: ERP tasks had to be long as a large number of trials is necessary to improve signal-to-noise ratios when averaging the waveforms (Luck, 2005). Long-duration measurements may lead to participants' fatigue and/or sleepiness and, consequently, may cause artifacts (i.e., unwanted activity) in the EEG signal.

7.4 Future research directions

The empirical findings from this Dissertation, combined with the limitations expressed above, reveal a number of interesting future research directions.

First, and due to constraints on the generalizability of the findings, it would be important to repeat the ERP experiments reported here in a larger and more heterogeneous and representative sample of individuals with non-clinical hallucinations. This would necessarily improve the generalizability of the findings and may lead to a deeper understanding of the relationship between the experience of non-clinical hallucinations and ERP correlates of vocal emotional processing.

Second, further work needs to be done to establish whether there is a causal relationship between the experience of non-clinical hallucinations and alterations in the ERP response to vocal emotions. A longitudinal approach to this issue can potentially enhance the value of the findings. Specifically, longitudinal studies allow researchers to establish cause-effect relationships and detect long-term changes in the characteristics of the target population (Setia, 2016).

Third, it would be interesting to directly compare non-clinical and clinical voice-hearers using the same ERP experiments. Future research could usefully explore whether any between-group differences in the phenomenology of AVH contributes to differences on the outcomes of interest (N1, P2, LPP and P3b responses to vocal emotions). Another possible area of future research would be to investigate whether the perceived salience of vocal emotions differs across the continuum of AVH.

Fourth, the ERP experiments reported in this Dissertation have open several new questions that have yet to be answered. Future research might account for the following examples: 1) does the increasing severity of non-clinical hallucinations aggravate salience attribution abnormalities during vocal emotional processing? 2) Is the perception of pitch-related vocal-emotional information also affected by hallucination proneness? 3) How well can the conversion to psychosis be predicted by alterations in the sensory processing (N1) of vocal emotions in high hallucination proneness? 4) How well can the transition to psychosis be predicted by alterations in attention allocation (P3b) to vocal emotions in AVH proneness? 5) Is the implicit attention (P3a) to vocal emotions also affected by AVH proneness?

Finally, the question raised in the study presented in Chapter 3 is that non-clinical hallucinations may be as uncontrollable as clinical hallucinations. Therefore, future research should include a continuous measurement of the perceived degree of control over non-clinical hallucinations. This would help to better understand the extent to which the lack of control happens, as well as to clarify how the

uncontrollability over non-clinical hallucinations interacts with other phenomenological characteristics of the experiences (i.e., emotional content, frequency).

7.5 Conclusion

The current Dissertation aimed to investigate early and late ERP correlates of vocal emotional processing in non-clinical individuals varying in hallucination proneness, and to specify the contributions of stimulus valence and acoustic cues (duration and/or intensity) in these processes (Chapters 5 and 6). To ensure a rigorous assessment of vocal emotional processing with ERPs, two additional studies, which aimed to validate a self-report instrument to measure hallucination proneness (Chapter 3) and a set of non-verbal emotional vocalizations varying in duration (Chapter 4), were conducted prior to the ERP experiments.

The findings from this Dissertation make significant contributions to the understanding of the phenomenology of non-clinical hallucinatory experiences (Chapter 3) and demonstrate, for the first time, how much acoustic information is necessary for an accurate recognition of emotions from non-verbal vocalizations (Chapter 4). Furthermore, they provide first evidence for alterations in the time course of vocal emotional processing in non-clinical individuals reporting hallucinations (Chapters 5 and 6). Most importantly, the combined results from Chapters 5 and 6 indicate that changes in the representation of vocal emotionally salient information associated with increased hallucination proneness (Chapter 5) may lead to difficulties in attention discrimination between relevant (emotional) and non-relevant (neutral) vocal cues (i.e., less discriminable P3b responses) in participants specifically prone to AVH (Chapter 6). Taken together, these studies support not only the aberrant salience hypothesis of psychosis (Howes & Nour, 2016; Kapur, 2003; Winton-Brown, Fusar-Poli, Ungless, & Howes, 2014), but also the continuum hypothesis of psychosis (Baumeister, Sedgwick, Howes, & Peters, 2017; van Os, Hanssen, Bijl, & Ravelli, 2000; van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009). Further, they open up promising new avenues for future ERP research on vocal emotional processing in non-clinical individuals with hallucinations.

7.6 References

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Appendix A

Portuguese version of the Launay Slade Hallucinations Scale

1. Por vezes, um pensamento passageiro parece-me tão real que me assusta.
2. Por vezes, os meus pensamentos parecem tão reais como as coisas que acontecem de verdade.
3. Por muito que tente concentrar-me, acabam sempre por me vir à mente pensamentos que não estão relacionados com aquilo que estou a fazer.
4. No passado, tive a experiência de ouvir a voz de uma pessoa, tendo-me apercebido, de seguida, que afinal não havia ali ninguém.
5. Os sons que ouço quando sonho acordado(a) são, geralmente, claros e nítidos.
6. As pessoas que aparecem nos meus sonhos, quando sonho acordado(a), parecem tão reais que, por vezes, penso mesmo que existem.
7. Quando sonho acordado(a), consigo ouvir o som de uma melodia quase tão nitidamente como se estivesse realmente a ouvi-la.
8. Ouço frequentemente uma voz que diz os meus pensamentos em voz alta.
9. Já me senti incomodado(a) por ouvir vozes na minha cabeça.
10. Em certas ocasiões, vi o rosto de uma pessoa em frente a mim quando, na realidade, não estava ali ninguém.
11. Por vezes, imediatamente antes de adormecer ou ao acordar, tive a experiência de ver, sentir ou ouvir algo ou alguém que não estava presente, ou a sensação de ser tocado apesar de ninguém estar presente.
12. Por vezes, imediatamente antes de adormecer ou ao acordar, tive a sensação de flutuar, ou de cair, ou de abandonar o meu corpo temporariamente.
13. Em certas ocasiões, tive a sensação de presença de alguém próximo que já faleceu.
14. No passado, experienciei um odor particular apesar de este não existir.
15. Já tive o sentimento de tocar algo ou de ser tocado(a), apesar de não haver nada ou ninguém por perto.
16. Por vezes, vi coisas ou animais quando na realidade não havia nada ali.

Appendix B

DECLARAÇÃO DE CONSENTIMENTO

Considerando a "Declaração de Helsínquia" da Associação Médica Mundial
(Helsínquia 1964; Tóquio 1975; Veneza 1983; Hong Kong 1989; Somerset West 1996 e Edimburgo 2000)

Exmo Senhor(a),
Convidámo-lo(a) a participar no estudo **"Efeitos da duração no reconhecimento emocional em vocalizações"** a decorrer na Escola de Psicologia, Laboratório de Neuropsicofisiologia, Universidade do Minho.

No decorrer do estudo, será realizada uma tarefa no computador que visa estudar os efeitos da duração no reconhecimento de vocalizações de conteúdo emocional ou neutro. Nesta tarefa ser-lhe-á apresentado um conjunto de vocalizações de durações variadas que poderão transmitir uma determinada emoção ou a ausência de emoção. Com base num conjunto de 6 opções de resposta, deverá optar por aquela que, na sua perspetiva, melhor representa a vocalização ouvida. Cada vocalização é ainda acompanhada de 4 escalas: grau de confiança (1 a 7), grau de autenticidade (1 a 7), grau de intensidade (1 a 7) e grau de aproximação (1 a 7). Outros procedimentos incluem a recolha de um conjunto de dados sociodemográficos e a resposta a um questionário. Estes procedimentos durarão aproximadamente 50 minutos, no total.

Uso dos resultados de investigação e confidencialidade: A informação recolhida para os objetivos deste estudo será mantida confidencial e anónima. Os resultados deste estudo poderão ser publicados para objetivos científicos, mas a sua identidade ou dados pessoais não serão revelados.
Toda a informação escrita será guardada num armário fechado à chave, e os dados eletrónicos serão encriptados. Apenas um número limitado de pessoas (membros da equipa de investigação) terão acesso

aos dados. Esta informação não será usada para nenhum outro fim que não os objetivos descritos na proposta de estudo.

Direitos do(a) participante da investigação: Em qualquer momento durante ou depois do estudo, se tiver questões acerca da investigação ou acerca dos seus direitos enquanto participante da investigação, poderá contactar o investigador principal, Doutora Ana Patrícia Teixeira Pinheiro, Investigadora na Escola de Psicologia da Universidade do Minho; através do número de telefone 253 601398.
A participação no projeto é totalmente voluntária, com liberdade para decidir querer participar ou não, podendo desistir de participar em qualquer momento.

Eu, abaixo-assinado, (nome completo do(a) participante voluntário(a)) _____

_____compreendi a explicação que me foi fornecida acerca do estudo em que eu serei incluído(a). Foi-me dada oportunidade de fazer as perguntas que julguei necessárias, e de todas obtive resposta satisfatória.
Tomei conhecimento de que, de acordo com as recomendações da Declaração de Helsínquia, a informação ou explicação que me foi prestada versou os objetivos, e os métodos do estudo. Além disso, foi-me afirmado que tenho o direito de recusar a qualquer momento a minha participação no estudo.
Por isso, consinto que me sejam aplicados os instrumentos propostos pela investigadora e autorizo que os dados sejam apresentados de forma completamente anónima e confidencial em apresentações públicas, congressos científicos e publicações.

Data: _____ / _____ / 201__

*Assinatura do(a) participante voluntário(a):*_____

A Investigadora:

Nome: **Ana P. Pinheiro**

*Assinatura:*_____

Appendix C

Dimensional ratings of neutral and emotional vocalizations at each gate duration (Study 2, Chapter 4)

Mean values of approachability considering the global sample, and male and female participants separately.

		Gate duration (ms)						
		G1	G2	G3	G4	G5	G6	G7
Emotion	Sample	100	200	300	400	500	600	700
Anger	Overall	3.28	3.10	2.87	2.73	2.77	2.75	2.74
		(1.09)	(1.02)	(1.06)	(1.04)	(1.13)	(1.13)	(1.07)
	Male	3.31	3.16	2.74	2.68	2.89	2.86	2.80
		(1.08)	(0.90)	(1.13)	(1.00)	(1.22)	(1.24)	(1.10)
	Female	3.24	3.05	2.98	2.78	2.65	2.66	2.69
		(1.13)	(1.13)	(1.01)	(1.08)	(1.05)	(1.03)	(1.06)
Disgust	Overall	3.27	3.01	2.78	2.73	2.72	2.58	2.62
		(1.05)	(1.12)	(1.05)	(1.16)	(1.15)	(1.18)	(1.13)
	Male	3.30	3.19	2.80	2.86	2.69	2.58	2.56
		(1.11)	(1.11)	(1.06)	(1.11)	(1.09)	(1.21)	(1.19)
	Female	3.24	2.84	2.76	2.60	2.76	2.59	2.67
		(1.01)	(1.12)	(1.06)	(1.22)	(1.23)	(1.17)	(1.09)
Fear	Overall	3.52	3.39	3.10	2.84	2.93	2.77	2.81
		(0.98)	(1.11)	(1.20)	(1.32)	(1.16)	(1.25)	(1.26)
	Male	3.55	3.36	3.24	3.01	2.99	2.77	2.73
		(0.82)	(1.02)	(1.12)	(1.31)	(1.22)	(1.30)	(1.26)
	Female	3.50	3.42	2.96	2.68	2.88	2.78	2.88
		(1.11)	(1.21)	(1.27)	(1.33)	(1.13)	(1.23)	(1.28)
Amusement	Overall	3.74	3.93	5.05	5.13	5.23	4.90	4.80
		(1.08)	(1.11)	(1.21)	(1.14)	(1.11)	(1.33)	(1.51)
	Male	3.60	3.94	5.08	5.19	5.22	4.99	4.94
		(1.00)	(0.94)	(1.08)	(1.19)	(1.12)	(1.33)	(1.69)
	Female	3.87	3.91	5.02	5.07	5.23	4.81	4.67
		(1.15)	(1.26)	(1.34)	(1.12)	(1.13)	(1.35)	(1.33)
Sadness	Overall	3.45	3.50	3.77	3.51	3.45	3.55	3.30
		(1.10)	(1.00)	(1.46)	(1.43)	(1.39)	(1.48)	(1.41)
	Male	3.53	3.57	3.78	3.44	3.49	3.62	3.33
		(1.02)	(0.92)	(1.35)	(1.41)	(1.28)	(1.32)	(1.35)
	Female	3.37	3.44	3.76	3.57	3.42	3.48	3.27
		(1.17)	(1.08)	(1.59)	(1.48)	(1.51)	(1.63)	(1.49)
Neutral	Overall	3.61	3.40	3.47	3.38	3.44	3.45	3.38
		(1.18)	(1.21)	(1.34)	(1.52)	(1.44)	(1.33)	(1.38)
	Male	3.41	3.34	3.42	3.58	3.54	3.58	3.56
		(1.11)	(1.10)	(1.20)	(1.52)	(1.39)	(1.39)	(1.52)
	Female	3.79	3.46	3.51	3.19	3.35	3.33	3.21
		(1.24)	(1.33)	(1.48)	(1.51)	(1.50)	(1.29)	(1.25)

Note. Standard deviation values are shown in parentheses.

Mean values of intensity considering the global sample, and male and female participants separately

		Gate duration (ms)						
		G1	G2	G3	G4	G5	G6	G7
Emotion	Sample	100	200	300	400	500	600	700
Anger	Overall	3.56	3.59	4.77	4.62	4.55	4.68	4.61
		(0.98)	(1.06)	(1.14)	(1.13)	(1.11)	(1.16)	(1.18)
	Male	3.71	3.82	5.05	4.76	4.69	4.85	4.82
		(1.04)	(0.93)	(0.90)	(1.16)	(1.14)	(1.11)	(1.23)
	Female	3.41	3.37	4.50	4.50	4.42	4.52	4.41
		(0.92)	(1.13)	(1.29)	(1.10)	(1.09)	(1.21)	(1.12)
Disgust	Overall	2.85	2.87	4.07	4.48	4.67	4.71	4.68
		(1.00)	(0.97)	(0.99)	(0.91)	(0.99)	(0.99)	(0.99)
	Male	3.10	3.07	4.20	4.53	4.66	4.59	4.67
		(0.95)	(0.92)	(0.76)	(0.76)	(0.72)	(0.87)	(0.89)
	Female	2.61	2.67	3.96	4.44	4.69	4.82	4.68
		(1.00)	(1.00)	(1.18)	(1.04)	(1.20)	(1.10)	(1.08)
Fear	Overall	4.02	4.17	5.15	5.18	5.14	5.28	5.11
		(1.07)	(1.04)	(0.98)	(1.00)	(0.99)	(0.94)	(1.06)
	Male	4.01	4.33	5.30	5.35	5.32	5.37	5.28
		(1.19)	(0.95)	(0.87)	(0.90)	(0.87)	(0.98)	(1.16)
	Female	4.04	4.03	5.02	5.02	4.98	5.20	4.95
		(0.98)	(1.12)	(1.07)	(1.07)	(1.09)	(0.91)	(0.94)
Amusement	Overall	3.48	3.72	5.04	5.01	5.09	5.07	5.07
		(1.00)	(0.97)	(1.03)	(1.01)	(0.96)	(1.06)	(1.02)
	Male	3.54	3.80	5.10	5.01	4.99	5.05	5.09
		(1.02)	(0.98)	(0.74)	(0.76)	(0.87)	(0.80)	(0.87)
	Female	3.41	3.64	4.99	5.01	5.19	5.09	5.05
		(0.98)	(0.97)	(1.26)	(1.20)	(1.05)	(1.26)	(1.17)
Sadness	Overall	3.37	3.83	4.83	4.92	4.82	4.93	4.96
		(1.08)	(0.98)	(1.05)	(1.14)	(1.11)	(1.20)	(1.16)
	Male	3.63	4.19	5.02	5.08	4.93	4.99	5.11
		(1.12)	(0.93)	(0.85)	(0.91)	(0.79)	(1.07)	(1.02)
	Female	3.13	3.49	4.65	4.76	4.71	4.87	4.82
		(1.00)	(0.92)	(1.20)	(1.32)	(1.35)	(1.33)	(1.28)
Neutral	Overall	2.82	2.97	3.06	3.20	3.13	3.26	3.28
		(0.91)	(1.18)	(1.36)	(1.43)	(1.38)	(1.37)	(1.36)
	Male	3.02	3.42	3.45	3.69	3.54	3.69	3.70
		(0.73)	(1.13)	(1.07)	(1.19)	(1.10)	(1.20)	(1.24)
	Female	2.64	2.56	2.70	2.76	2.76	2.87	2.90
		(1.03)	(1.09)	(1.51)	(1.51)	(1.52)	(1.42)	(1.38)

Note. Standard deviation values are shown in parentheses.

Mean values of authenticity considering the global sample, and male and female participants separately.

		Gate duration (ms)						
		G1	G2	G3	G4	G5	G6	G7
Emotion	Sample	100	200	300	400	500	600	700
Anger	Overall	3.52	3.60	4.41	4.36	4.28	4.41	4.30
		(0.88)	(1.02)	(1.18)	(1.13)	(1.14)	(1.15)	(1.16)
	Male	3.63	3.60	4.26	4.30	4.14	4.46	4.36
		(0.84)	(0.72)	(1.08)	(1.16)	(1.18)	(1.19)	(1.17)
	Female	3.41	3.59	4.56	4.41	4.41	4.36	4.25
		(0.91)	(1.25)	(1.26)	(1.13)	(1.11)	(1.14)	(1.18)
Disgust	Overall	3.18	3.21	4.36	4.72	4.88	4.97	4.97
		(1.06)	(1.07)	(1.13)	(0.92)	(0.96)	(1.02)	(1.03)
	Male	3.36	3.10	4.27	4.65	4.75	5.05	5.10
		(1.00)	(0.91)	(0.96)	(0.83)	(0.90)	(0.87)	(0.94)
	Female	3.01	3.32	4.44	4.78	5.01	4.90	4.85
		(1.10)	(1.20)	(1.28)	(1.01)	(1.01)	(1.15)	(1.12)
Fear	Overall	3.95	4.04	4.90	4.88	4.91	4.91	4.82
		(1.16)	(1.04)	(1.10)	(1.05)	(1.05)	(0.94)	(1.12)
	Male	3.87	3.93	4.96	4.83	4.95	4.88	4.82
		(1.21)	(0.93)	(0.93)	(0.95)	(0.89)	(0.95)	(1.12)
	Female	4.02	4.15	4.84	4.92	4.87	4.94	4.82
		(1.12)	(1.14)	(1.26)	(1.15)	(1.20)	(0.95)	(1.15)
Amusement	Overall	3.59	3.98	5.23	5.23	5.30	5.27	5.16
		(1.08)	(1.11)	(1.09)	(1.11)	(1.09)	(1.13)	(1.40)
	Male	3.39	3.85	5.34	5.36	5.38	5.37	5.28
		(1.16)	(1.02)	(0.95)	(0.87)	(1.02)	(0.92)	(1.39)
	Female	3.78	4.10	5.13	5.12	5.23	5.18	5.04
		(0.98)	(1.19)	(1.21)	(1.30)	(1.16)	(1.31)	(1.44)
Sadness	Overall	3.25	3.74	4.84	4.88	4.78	5.05	5.04
		(0.96)	(1.01)	(1.00)	(1.11)	(1.17)	(1.23)	(1.25)
	Male	3.25	3.62	4.92	4.87	4.86	5.13	5.26
		(0.96)	(0.81)	(0.88)	(1.01)	(0.95)	(1.01)	(1.04)
	Female	3.25	3.85	4.77	4.88	4.70	4.98	4.84
		(0.98)	(1.16)	(1.10)	(1.22)	(1.36)	(1.42)	(1.41)
Neutral	Overall	3.19	3.15	3.45	3.68	3.53	3.72	3.63
		(1.04)	(1.36)	(1.63)	(1.81)	(1.71)	(1.77)	(1.72)
	Male	3.18	3.25	3.57	3.99	3.54	3.86	3.83
		(0.90)	(1.10)	(1.21)	(1.54)	(1.39)	(1.65)	(1.66)
	Female	3.21	3.07	3.34	3.39	3.53	3.59	3.44
		(1.18)	(1.58)	(1.95)	(2.01)	(1.99)	(1.89)	(1.78)

Note. Standard deviation values are shown in parentheses.

Appendix D

DECLARAÇÃO DE CONSENTIMENTO

Considerando a "Declaração de Helsínquia" da Associação Médica Mundial
(Helsínquia 1964; Tóquio 1975; Veneza 1983; Hong Kong 1989; Somerset West 1996 e Edimburgo 2000)

Designação do Estudo:
As bases neuronais do processamento de voz

Exmo(a) Senhor(a),

Convidámo-lo(a) a participar num estudo sobre a forma como o cérebro processa diferentes tipos de sons, coordenado pela Doutora Ana Pinheiro, investigadora na Escola de Psicologia da Universidade do Minho.

Com este estudo pretendemos compreender melhor de que forma o cérebro processa e compreende sons ditos com diferentes tipos de entoação.

1. Objetivo do estudo: Este consentimento informado fornece informação que deverá ler antes de aceitar, voluntariamente, participar na investigação referida. O objetivo geral deste estudo é compreender melhor de que forma o nosso cérebro processa sons humanos e, em particular, os processos neuronais subjacentes à experiência de alucinações auditivas.

2. Descrição do estudo, procedimentos e duração: Uma parte do estudo envolverá a realização de um eletroencefalograma. Por conseguinte, elétrodos serão colocados no couro cabeludo para o registo da atividade elétrica cerebral. Este é um procedimento completamente não-invasivo e indolor, semelhante ao que acontece quando o seu médico coloca um estetoscópio para auscultar batimentos cardíacos. Enquanto a atividade cerebral estiver a ser registada, irá realizar tarefas como ouvir palavras ou frases, ou escutar outros tipos de sons. Também lhe poderá ser pedido que responda a questões simples sobre

o que estiver a ouvir, e as suas respostas serão registadas. Esta sessão durará aproximadamente 1 hora. Durante este período de tempo, ocorrerão pequenos intervalos quando assim o determinar.

Outros procedimentos incluem uma entrevista detalhada em que lhe faremos questões sobre a sua vida, a sua história pessoal e familiar, bem como o seu bem-estar emocional. Adicionalmente, testes cognitivos serão incluídos. Para alguns dos testes, ser-lhe-á pedida a gravação das suas respostas em formato áudio.

Estes procedimentos durarão aproximadamente 2 horas, no total.

3. Riscos associados à participação na investigação: Não há quaisquer riscos associados à participação nesta investigação. O único risco potencial poderá ser alguma irritação da pele provocada pela aplicação de gel para conectar os elétrodos ao couro cabeludo e a 5 pontos na face. Esta irritação é rara e, caso aconteça, é temporária e desaparecerá por si só.

4. Uso dos resultados de investigação e confidencialidade: A informação recolhida para os objetivos desta investigação será mantida confidencial e anónima. Os resultados desta investigação poderão ser publicados para objetivos científicos, mas a sua identidade ou dados pessoais não serão revelados.

Toda a informação escrita será guardada num armário fechado à chave, e os dados eletrónicos serão encriptados. Apenas um número limitado de pessoas (membros da equipa de investigação) terão acesso aos dados. Esta informação não será usada para nenhum outro fim que não os objetivos descritos na proposta de investigação.

Nas linhas seguintes, pedimos-lhe que dê especificamente o seu consentimento ou não consentimento para a condução de registos áudio de algumas das suas respostas/discurso, assinalando com uma cruz a linha correspondente à sua opção e fornecendo a sua assinatura de seguida:

Eu consinto que partes do meu discurso sejam gravadas em formato áudio. ☐

OU

Eu não consinto que partes do meu discurso sejam gravadas em formato áudio. ☐

Nome do(a) Participante: _____

Data: _____

5. Direitos do(a) participante da investigação: Em qualquer momento durante ou depois do estudo, se tiver questões acerca da investigação ou acerca dos seus direitos enquanto participante da investigação, poderá contactar o investigador principal, Doutora Ana Patrícia Teixeira Pinheiro, Investigadora na Escola de Psicologia da Universidade do Minho; através do número de telefone 253 601398.

A participação no projeto é totalmente voluntária, com liberdade para decidir querer participar ou não, podendo desistir de participar em qualquer momento do projeto.

Eu, abaixo-assinado, (nome completo do(a) participante voluntário(a)) _____

_____, compreendi a explicação que me foi fornecida acerca da investigação que se tenciona realizar, bem como do estudo em que eu serei incluído(a). Foi-me dada oportunidade de fazer as perguntas que julguei necessárias, e de todas obtive resposta satisfatória.

Tomei conhecimento de que, de acordo com as recomendações da Declaração de Helsínquia, a informação ou explicação que me foi prestada versou os objetivos, os métodos, os benefícios previstos, os riscos potenciais e o eventual desconforto. Além disso, foi-me afirmado que tenho o direito de recusar a todo o tempo a minha participação no estudo.

Por isso, consinto que me sejam aplicados os instrumentos propostos pela investigadora e autorizo que os dados sejam apresentados de forma completamente anónima e confidencial em apresentações públicas, congressos científicos e publicações.

Data: _____ / _____ / 201__

*Assinatura do(a) participante voluntário(a):*_____

A Investigadora:

Nome: **Ana P. Pinheiro**

*Assinatura:*_____