

Universidade de Lisboa
Faculdade de Medicina de Lisboa



The impact of hallucination predisposition on vocal perception mechanisms: An ERP study of attention, identity and emotion.

João Pereira Sarzedas

Orientador: Prof. Doutora Ana Patrícia Teixeira Pinheiro

Coorientadora: Prof. Doutora Maria Luísa Figueira

Dissertação especialmente elaborada para a obtenção do grau de Mestre em

Psicopatologia

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A impressão desta dissertação foi aprovada pelo Conselho Científico da Faculdade de Medicina de Lisboa em reunião de 17 de dezembro de 2019.

Agradecimentos

Uma frase de origem duvidosa, mas habitualmente atribuída a Antoine de Saint-Exupéry diz que “Aqueles que passam por nós, não vão sós, não nos deixam sós. Deixam um pouco de si, levam um pouco de nós”. Assim como na vida, uma tese não se faz sem a contribuição de várias pessoas que nos ajudam a superar os obstáculos que vão surgindo. Gostaria por isso de dedicar esta tese a todos aqueles que, deixando um pouco de si, me permitiram finalizar esta dissertação.

À minha orientadora, a professora Ana Pinheiro pelo apoio e motivação dados durante todas as etapas deste projeto. Sinto-me muito grato por ter tido a oportunidade de trabalhar com uma investigadora tão profissional e prestável, que me acolheu no seu laboratório e me permitiu colaborar neste estimulante projeto de investigação. Sinto que desenvolvi mais competências nestes últimos dois anos do que durante todo o meu restante percurso académico. À minha co-orientadora, a professora Maria Luísa Figueira, pelas inspiradoras aulas que lecionou na parte curricular do mestrado e pela disponibilidade de me co-orientar.

Ao Gonçalo Ferreira e à Inês Serafim, por terem servido de vozes modelo, e ao João Rodrigues por ter servido de Piloto. A todos os participantes que despenderam do seu tempo para participarem neste projeto.

Ao António Fernandes por me ter mostrado o processo de gravação. Ao Fran Gutierrez pela ajuda nas recolhas e na análise de EEG. À Maria Amorim pela ajuda em diversas etapas deste projeto, desde a programação da tarefa até à recolha de dados. À Tatiana Conde pela ajuda nas recolhas. Mais do que pelas ajudas técnicas, quero agradecer ao António, Fran, Maria, Tatiana e à Mónica Costa, por terem tido sempre uma palavra de encorajamento e de profunda empatia para me oferecer.

Às várias músicas que me ajudaram durante o processo de escrita. Músicas de Caetano Veloso, Idan Raichel, Maro, Manel Cruz, Miles Davis, Nat King Cole, Nick Cave, Samuel Úria e The National. Aos álbuns “*Built on glass*” de Chet Faker e “*The art of slowing down*” de Slow J.

À Beatriz Moreno, por todo o carinho e apoio incondicional nos momentos mais difíceis desta caminhada. À minha Família, em especial aos meus pais por sempre acreditarem em mim, mesmo quando eu próprio tinha dificuldade em fazê-lo.

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Abstract

In recent years, a more dimensional view of psychotic disorders has been supported by several epidemiological studies showing the existence of a continuum of psychotic like-experiences in the general population. Reported similarities between the cognitive and neural mechanisms underpinning hallucinatory experiences in psychotic and in individuals with high hallucination predisposition provide further support for this psychosis continuum model. In the auditory domain, schizophrenic patients show altered perception of vocal information with negative content, as well as of voice identity. Whether the same voice processing mechanisms are similarly altered in individuals with high hallucination predisposition remains to be clarified. In the current study, thirty nonclinical participants with different scores on the Launay-Slade Hallucination Scale (a measure of hallucination predisposition) listened to prerecorded words varying in identity (self vs. non-self-voice) and emotional quality (negative vs. neutral vs. positive), while electroencephalographic data were recorded. Two tasks with a different attentional focus (identity focus task vs. emotional focus task) were conducted. In the identity focus task, participants attended to the identity of the voice and decided whether the voice they heard was their own voice, the voice of another person or if they were unsure. In the emotional focus task, they evaluated the emotional quality of the words. The N1, P2 and late positive potential (LPP) components were analyzed. We found a larger N1 in response to self-voice in the identity focus task and a larger LPP for the self-voice, irrespective of the attention focus. Furthermore, in the emotional focus task, we observed an association between high hallucination predisposition and a trend for a reduced LPP amplitude in response to the self-voice. The LPP result suggests the existence of an altered perception of voice identity, dependent of the attention focus, in individuals with high hallucination predisposition. Overall, the current findings partially support the psychosis continuum model.

Key words: Hallucination predisposition; self-voice; emotion; attention focus; event-related potentials

Resumo

Nas últimas décadas, uma abordagem mais dimensional das perturbações psicóticas tem ganho força com base em vários estudos epidemiológicos que demonstram a existência de um continuum de experiências psicóticas na população em geral.

O modelo do continuum de psicose advoga a existência de vários fenótipos de psicose num continuum que engloba indivíduos com um diagnóstico psiquiátrico (e.g., esquizofrenia) mas também indivíduos sem diagnóstico clínico que manifestam experiências do tipo psicótico. O modelo do continuum de psicose é suportado por estudos que mostram semelhanças entre os mecanismos cognitivos e neuronais que estão na base das experiências alucinatórias de pacientes psicóticos e de indivíduos sem diagnóstico clínico.

As alucinações (i.e., experiências percetuais que ocorrem na ausência de estimulação externa correspondente) são um sintoma característicos das perturbações psicóticas. Contudo, também são reportadas experiências alucinatórias em pacientes com outras perturbações psiquiátricas e em indivíduos sem diagnóstico que não necessitam de apoio clínico.

Os indivíduos sem diagnóstico clínico que experienciam alucinações auditivas verbais breves ou outras experiências alucinatórias são descritos na literatura como indivíduos com alta predisposição alucinatória. Numa amostra de 84711 participantes foi encontrada uma taxa de prevalência de 9.6 % de experiências alucinatórias, o que demonstra que este não é um fenómeno incomum na população em geral. A maioria das experiências alucinatórias são transitórias, mas em alguns casos persistem e aumentam o risco de transição para psicose. O estudo de experiências alucinatórias em indivíduos com predisposição alucinatória pode contribuir para uma melhor compreensão e tratamento de perturbações clínicas.

Existe evidência que demonstra a existência de uma associação entre alucinações auditivas verbais e défices específicos de processamento vocal. Os modelos neurocognitivos de processamento de voz postulam que a identidade, a emoção e a fala são processados por regiões corticais funcionalmente distintas. Em indivíduos com esquizofrenia têm sido consistentemente reportadas alterações no processamento vocal da identidade, da fala e da emoção. Contudo, ainda não é claro qual o impacto destas alterações de processamento vocal no desencadear de sintomas psicóticos específicos. Examinar a existência destas alterações em indivíduos com alta predisposição

alucinatória pode ser um passo útil para uma melhor compreensão da influência que estes processos têm no desencadear de experiências alucinatórias.

Os escassos estudos que testaram simultaneamente o processamento de identidade, discurso e emoção parecem demonstrar diferenças de processamento vocal entre indivíduos com esquizofrenia e indivíduos com alta predisposição alucinatória. Em comparação com grupos de controlo e pacientes sem alucinações auditivas verbais, os pacientes com alucinações auditivas verbais demonstraram uma maior dificuldade no reconhecimento da sua própria voz quando esta apresentava um conteúdo negativo. Por outro lado, em indivíduos com alta predisposição alucinatória, as dificuldades no reconhecimento da própria voz não parecem estar relacionadas com o conteúdo emocional da fala.

Uma das técnicas que tem vindo a demonstrar a sua utilidade para a investigação de mecanismos de perceção vocal é a técnica de potenciais evocados por eventos (*event related potentials* – ERP), caracterizada por elevada resolução temporal.

Um dos estudos que investigou o processamento vocal da identidade, discurso e emoção com ERP encontrou efeitos de interação entre identidade (voz própria vs. voz de um desconhecido) e emoção (palavras negativas vs. neutras vs. positivas) em três componentes: N1, P2 e *late positive potential* (LPP). O N1 é um componente associado ao processamento sensorial da voz. O P2 é um componente associado a uma deteção precoce de saliência emocional de um estímulo. O LPP está associado a processos de atenção sustentada e de avaliação do conteúdo emocional da voz. Um estudo subsequente, utilizando um paradigma idêntico, encontrou alterações de processamento vocal, nos componentes P2 e LPP, em indivíduos com esquizofrenia. Nestes dois estudos, o conteúdo emocional foi processado implicitamente, uma vez que os participantes foram instruídos a focarem a sua atenção na identidade da voz e avaliarem se as gravações que ouviam pertenciam a eles próprios ou a outra pessoa.

Alguns estudos demonstram que alterar o foco atencional de uma tarefa influencia o modo como os estímulos são processados neurofisiologicamente. Deste modo, é possível que sejam encontrados resultados diferentes numa condição onde os participantes são instruídos a focarem a sua atenção no conteúdo emocional do estímulo (i.e., avaliarem se o estímulo é negativo, neutro ou positivo). Tanto em indivíduos com esquizofrenia como em indivíduos com alta predisposição alucinatória, têm vindo a ser reportadas alterações de processos atencionais. Por conseguinte, é possível que o foco

atencional module o presumível impacto da predisposição alucinatoria em mecanismos de percepção de voz.

No presente estudo foi explorado, através de ERPs: 1) o impacto do foco atencional na interação entre o processamento vocal da identidade e da emoção; 2) o impacto da predisposição alucinatoria nestes mecanismos (foco atencional, identidade e emoção). Para esse propósito, foram realizadas duas tarefas. Em ambas as tarefas, os participantes ouviram gravações de uma voz (própria voz vs. voz de um desconhecido) a proferir palavras com conteúdo negativo, neutro ou positivo. Enquanto que na primeira tarefa (tarefa do foco na identidade) os participantes tinham de identificar a identidade da voz, na segunda tarefa (tarefa do foco na emoção) eram instruídos a avaliar o conteúdo emocional das palavras proferidas. Na tarefa de foco na identidade, procurámos replicar resultados de estudos anteriores que observaram efeitos de interação entre identidade e emoção e efeitos principais de identidade, bem como uma associação entre altos níveis de predisposição alucinatoria e uma maior dificuldade no reconhecimento da própria voz. Ainda para esta tarefa, foi explorada a hipótese de que altos níveis de predisposição alucinatoria predizem um padrão neurofisiológico semelhante ao dos pacientes com esquizofrenia, uma observação que serviria de suporte para a hipótese do continuum de psicose. Na tarefa de foco na emoção era esperada uma maior amplitude de LPP em resposta a palavras negativas e positivas, em comparação com palavras neutras e, em termos exploratórios, era esperado uma influência do foco atencional no presumível impacto da predisposição alucinatoria em mecanismos de percepção de voz. Foram recrutados 30 participantes “saudáveis”, sendo que o grau de predisposição alucinatoria de cada individuo foi avaliado através da *Launay-Slade Hallucination Scale* (LSHS).

No presente estudo não foram observadas interações entre identidade e emoção, nem efeitos principais de emoção. É possível que este resultado se deva a diferenças linguísticas existentes entre os estímulos usados neste estudo e os estímulos usados em estudos anteriores. Contudo, em comparação com uma voz desconhecida, a voz dos participantes elicitou uma maior amplitude de N1 na tarefa de foco na identidade e uma maior amplitude de LPP em ambas as tarefas. Estes resultados parecem sugerir que, em termos neurofisiológicos, a própria voz de uma pessoa é mais saliente do que a voz de um desconhecido. Na tarefa do foco na emoção foi também encontrada uma associação entre altos níveis de predisposição alucinatoria e uma tendência para uma menor amplitude de LPP em resposta a gravações da própria voz. Este resultado sugere que o foco atencional modela o presumível impacto da predisposição alucinatoria em mecanismos de percepção

de voz. Ao contrário do observado em pacientes com esquizofrenia (menor amplitude de LPP em resposta a gravações da própria voz e de vozes desconhecidas com conteúdo negativo), o presumível déficit de processamento vocal em indivíduos com predisposição alucinatória parece não depender do conteúdo emocional e parece ser menos marcado, uma vez que é observado apenas em resposta a gravações da própria voz e numa condição onde a identidade não está a ser explicitamente processada. Em suma, os resultados encontrados parecem servir de suporte parcial para o modelo de continuum de psicose.

Palavras chaves: Predisposição alucinatória; própria voz; emoção; foco atencional; potenciais evocados por eventos.

1. Introduction

1.1. The psychosis continuum hypothesis

The term ‘psychosis’ is often used to describe a set of symptoms, such as hallucinations and delusions, which ultimately lead to a loss of contact with reality (Bürgy, 2008; Tandon et al., 2013; van Os & Reininghaus, 2016). For several years, psychosis research and clinical practice have been heavily influenced by a categorical approach to diagnosis, conceptualizing psychotic disorders as a number of unique dissociated mental disorders (Keshavan, Nasrallah, Tandon, & Israel, 2011). Influenced by the dichotomy proposed by Kraepelin (i.e., classic distinction between schizophrenia-related illness and manic-depressive illness; Bürgy, 2008), this approach guided psychiatric classification systems until recently (Cuthbert & Insel, 2010).

In the last decade, however, a more dimensional view of psychotic disorders has been supported by several epidemiological studies showing the existence of a continuum of psychotic like-experiences in the general population (Johns et al., 2014; Majjer, Begemann, Palmen, Leucht, & Sommer, 2018; Siddi et al., 2019). Opposing the traditional kraepelinian approach (i.e., considering a discontinuity between schizophrenia and other psychotic disorders, Cuthbert & Insel, 2010), the psychosis continuum model advocates an extended psychosis phenotype blending gradually into clinical manifestations (van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009).

Studies that show similarities between the cognitive and neural mechanisms underpinning hallucinatory experiences in psychotic and nonclinical individuals provide further support for the psychosis continuum model (Brookwell, Bentall, & Varese, 2013; Waters et al., 2012). Hallucinations (i.e., perceptual experiences occurring in the absence of corresponding external stimulation; Nayani & David, 1996) are one of the main psychotic symptoms that have been studied in order to probe the latter hypothesis (Majjer et al., 2018).

1.2. Hallucinations in nonclinical individuals

Hallucinations are a core characteristic of psychotic disorders (e.g., schizophrenia; schizoaffective disorder; Heckers et al., 2013; Tandon et al., 2013). Nevertheless, they may also be present in other psychiatric (e.g., major depression and bipolar disorder; Toh, Thomas, & Rossell, 2015) and neurological disorders (e.g., Parkinson’s disease; Holroyd,

Currie, & Wooten, 2001) as well as in nonclinical individuals without a need for care or not seeking help (Johns et al., 2014; Majjer et al., 2018; Siddi et al., 2019). Hallucinations may occur in any sensory modality, but auditory verbal hallucinations are the type more often reported by patients with schizophrenia (Mueser, Bellack, & Brady, 1990).

Auditory verbal hallucinations bear some phenomenological similarities in psychotic and nonclinical individuals, such as the perceived voice localization, number of voices, loudness, and personification (Daalman et al., 2011). Nonetheless, there are also some important differences. Auditory verbal hallucinations in psychotic patients are associated with an increased frequency, lower degree of control, older age of onset and a more negative content (Baumeister, Sedgwick, Howes, & Peters, 2017; Daalman et al., 2011), whereas in nonclinical individuals they are not sufficiently severe to affect daily functioning (Johns et al., 2014; van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009). Furthermore, linguistic differences between auditory verbal hallucinations experienced by patients and nonclinical individuals were found, with patients showing lower syntactic complexity, higher number of repetitions and higher frequency of verbal abuse and negative content (de Boer, Heringa, van Dellen, Wijnen, & Sommer, 2016). Despite that, the phenomenology of auditory verbal hallucinations is largely similar between the two groups, with the evidence gathered in a recent systematic review ultimately suggesting a continuity of experiences (Baumeister et al., 2017).

There are conceptual differences to note when referring to nonclinical individuals who experience auditory verbal hallucinations. Individuals who experience persistent auditory verbal hallucinations but do not need clinical care are called ‘healthy voice-hearers’ (Baumeister et al., 2017), while individuals who occasionally experience brief auditory verbal hallucinations or other hallucination-like experiences (i.e., a broader set of experiential anomalies reported in different sensory modalities; Siddi et al., 2019) are described in the literature as individuals with high hallucination predisposition (e.g., Pinheiro, Schwartz, & Kotz, 2018) or hallucination proneness (e.g., van Os et al., 2009).

The occurrence of hallucination-like experiences in nonclinical individuals is not uncommon, as the most recent meta-analysis on the topic found a 9.6% lifetime prevalence of auditory hallucinations in the general population (Majjer et al., 2018). Most of these hallucinatory-like experiences are transitory, although in some cases they persist and increase the risk of transition to clinical psychosis (van Os et al., 2009). Overall, the study of hallucinatory-like experiences in nonclinical individuals is specifically advantageous, as it can contribute to the understanding and treatment of more severe

clinical manifestations, while avoiding confounding effects of medication and hospitalization that are often present in psychotic patients (Allen et al., 2005; Castiajo & Pinheiro, 2017).

1.3. Identity, speech and emotion in auditory verbal hallucinations

Auditory verbal hallucinations are essentially perceived as “voices” talking to each other (Nayani & David, 1996), with evidence supporting an association between this phenomenon and altered voice processing mechanisms (Conde, Gonçalves, & Pinheiro, 2016).

The current neurocognitive models of voice processing postulate that identity, emotion and speech are processed by functionally separable cortical regions (Belin, Fecteau, & Bédard, 2004; Latinus & Belin, 2011). Altogether, disturbed processing of identity (e.g., Chhabra, Badcock, Maybery, & Leung, 2012) speech (e.g. Henry & Crawford, 2005) and emotion (e.g., Lin, Ding, & Zhang, 2018) voice dimensions have been consistently reported in patients with schizophrenia. However, the extension of these impairments and how they are related to specific symptoms such as auditory verbal hallucinations is not yet clear (for a review see Conde, Gonçalves, & Pinheiro, 2016).

In schizophrenia patients, auditory verbal hallucinations are often experienced as having a specific identity (Stephane, Thuras, Nasrallah, & Georgopoulos, 2003), a negative emotional tone (Copolov, Mackinnon, & Trauer, 2004) and a derogatory and self-referential semantic content (Beck & Rector, 2003; Nayani & David, 1996). Therefore, it is plausible that identity, emotion and speech deficits are enhanced in patients with auditory verbal hallucinations compared to patients without them (Conde et al., 2016). Examining whether nonclinical individuals with high hallucination predisposition (HP) present alterations in voice processing might contribute to a better understanding of the presumed relationship between those alterations and the experience of auditory verbal hallucinations, in the absence of confounds typically found in psychotic patients (e.g., medication, hospitalization).

1.4. The processing of voice identity, emotion and speech in AVH

Behavioral studies show that healthy adults can discriminate between self and non-self-voice recordings with a high accuracy recognition rate (above 89% - Hughes &

Nicholson, 2010; Rosa, Lassonde, Pinard, Keenan, & Belin, 2008). On the other hand, schizophrenia patients with auditory verbal hallucinations are more prone than healthy controls to misidentify self-voice recordings as being from someone else (Allen et al., 2005; Johns et al., 2001; Pinheiro, Rezaii, Rauber, & Niznikiewicz, 2016) and to incorrectly differentiate between familiar and unfamiliar voices (Alba-Ferrara, Weis, Damjanovic, Rowett, & Hausmann, 2012; Zhang et al., 2008).

Likewise, when discriminating pairs of unfamiliar voices, patients seem to rely less on specific acoustic characteristics (e.g., formant dispersion) than healthy controls (Chhabra et al., 2012) and individuals with high HP (Badcock & Chhabra, 2013; Chhabra, Badcock, Maybery, & Leung, 2014). Such voice discrimination differences between patients and nonclinical individuals, suggest that nonclinical individuals with high HP do not show altered voice identity perception (Badcock & Chhabra, 2013). Notwithstanding, a more recent finding challenges this idea by showing an association between high HP and reduced accuracy in the recognition and discrimination of self-voice speech (Pinheiro, Farinha-Fernandes, Roberto, & Kotz, 2019). Furthermore, altered sensory feedback to the self-voice was reported in nonclinical individuals with high HP (Pinheiro et al., 2018).

Altered perception of vocal emotions and speech has also been associated with auditory verbal hallucinations. Emotional prosody processing deficits have been consistently reported in schizophrenia (e.g., Pinheiro et al., 2013; Pinheiro et al., 2014, for a review see Lin, Ding, & Zhang, 2018) and seem to be increased in patients with auditory verbal hallucinations compared to patients without them and with healthy controls (Alba-Ferrara, Fernyhough, Weis, Mitchell, & Hausmann, 2012; Rossell & Boundy, 2005). Likewise, schizophrenia patients often present a worse performance, compared to healthy controls, in tasks that assess semantic processing, such as semantic priming and semantic fluency tasks (Henry & Crawford, 2005; Pomarol-Clotet, Oh, Laws, & McKenna, 2008). Specifically, a link between hallucination severity and worse performance in specific aspects of semantic fluency tasks (e.g., lexical overactivation) has been reported (DeFreitas, Dunaway, & Torres, 2009; Kerns, Berenbaum, Barch, Banich, & Stolar, 1999; Thoma et al., 2018). Accordingly, excessive semantic top-down processing (e.g., expectation effects) has been associated with a cognitive predisposition towards auditory hallucinations in schizophrenia patients (Aleman, Böcker, Hijman, de Haan, & Kahn, 2003; Haddock, Slade, & Bentall, 1995). An increased top-down processing was also reported in nonclinical voice-hearers (Alderson-Day et al., 2017;

Daalman, Verkooijen, Derks, Aleman, & Sommer, 2012) and in nonclinical individuals with high HP (de Boer et al., 2019; Vercammen & Aleman, 2010).

Lastly, studies testing the three voice dimensions simultaneously found that identity processing deficits in patients with auditory verbal hallucinations were modulated by alterations in emotional semantic processing. More specifically, patients with auditory verbal hallucinations showed more difficulties recognizing self-voice speech with negative semantic content when compared to patients without auditory verbal hallucinations and healthy controls (Costafreda, Brébion, Allen, McGuire, & Fu, 2008; Johns et al., 2001; Johns, Gregg, Allen, & McGuire, 2006; Pinheiro, Rezaii, Rauber, et al., 2016). On the other hand, nonclinical individuals showed more difficulties recognizing the self-voice, irrespective of its emotional content (Pinheiro et al., 2019).

1.5. Event related potential (ERP) studies probing identity, speech and emotion

Electroencephalography (EEG) is a noninvasive method used to record brain electrical activity (Luck, 2005). The ERP technique measures voltage fluctuations, in an ongoing electroencephalogram, that are time-locked to a specific event (Luck, 2005). This technique has a high temporal resolution and previous studies have shown the usefulness of the tool for probing the multi-stage processing of voice information (e.g., Conde, Gonçalves, & Pinheiro, 2015, 2018).

One study that used ERP to examine voice identity, emotion and speech processing mechanisms found interactive effects of speaker's identity (self vs. non-self - voice) and speech emotion (i.e., negative, neutral and positive words) on both early and late processing stages (Pinheiro, Rezaii, Nestor, et al., 2016). These differences were observed in the N1, P2 and late positive potential (LPP) components.

The auditory N1 peaks approximately 100 ms after sound onset and it is maximally recorded at frontocentral electrode sites (Näätänen & Picton, 1987). An early discrimination between self and non-self-voice was reported in this latency window and reflected in a larger negativity for the self-voice compared to other voices (Graux et al., 2013). Furthermore, N1 amplitude was found to be suppressed in response to the self-voice while speaking when compared to the passive listening to tape-recorded self-voice (e.g., Heinks-Maldonado et al., 2005). The sensory suppression to self-generated feedback is significantly reduced in schizophrenia patients (e.g., Ford et al., 2001) and in

nonclinical participants with high HP (Pinheiro et al., 2018). Regarding emotion processing, some studies show larger N1 amplitudes for highly frequent emotional words, compared with low-frequency emotional words (e.g., Scott, O'Donnell, Leuthold, & Sereno, 2009) suggesting that emotion affects early lexical access (Citron, 2012).

The P2 peaks approximately at 200 ms post-stimulus onset and is thought to reflect stimulus categorization processes (Crowley & Colrain, 2004). Several studies reported larger P2 amplitude for emotional words compared with neutral words (e.g., Herbert, Kissler, Junghöfer, Peyk, & Rockstroh, 2006; Kanske & Kotz, 2007; Kanske, Plitschka, & Kotz, 2011), suggesting that P2 modulations reflect increased intrinsic allocation of attentional resources to emotional stimuli (Pinheiro, Rezaii, Nestor, et al., 2016).

The LPP has been consistently associated with emotional processing, with larger amplitudes reported for stimuli with both negative and positive content relative to neutral content (Herbert, Junghofer, & Kissler, 2008; Hettich et al., 2016; Masuda et al., 2018; Schirmer & Gunter, 2017), reflecting sustained elaborative processing of emotional information. Furthermore, a larger LPP amplitude was reported in response to self-voice recordings when compared with unfamiliar non-self-voice recordings (Pinheiro, Rezaii, Nestor, et al., 2016).

Overall, these three ERP components are proposed to index dissociable stages of voice processing. The N1 has been related to the early sensory processing of the voice signal (Ford et al., 2001; Pinheiro et al., 2017); the P2 has been related to an early detection of emotional salience (Herbert et al., 2006; Pinheiro et al., 2017), whereas the LPP has been related to the sustained attentional processing and cognitive emotional appraisal of the voice (Ferrari, Codispoti, Cardinale, & Bradley, 2008; Pinheiro et al., 2017).

As already mentioned, the study of Pinheiro and collaborators (2016) found interactive effects of speaker's identity and speech emotion on both early (N1, P2) and late (LPP) processing stages. In an early sensory processing stage, a more negative N1 amplitude was observed for the self-voice than for non-self-voice recordings with neutral content. This effect suggests that, when listening to self-voice recordings, neutral words automatically attract more attention. In a subsequent voice processing stage, self-voice with positive content elicited a more positive P2 amplitude than non-self-voice positive words, which suggests an increased salience of the self-voice when it has a positive quality. Lastly, a larger LPP was found for self-voice relative to non-self-voice with

positive and negative content. The LPP enhancement is associated with sustained attentional processing of emotionally relevant cues. Thus, it reflects an additive effect of self-relevance (i.e., self-voice) and emotion (i.e. positive and negative speech).

A subsequent study, using a similar task, found voice processing differences between a sample of schizophrenia patients and healthy controls (Pinheiro et al., 2017). In the healthy control group, self-generated positive speech elicited a more positive P2 amplitude than non-self positive speech. In the patients group, non-self neutral speech prompted a larger P2 amplitude than self-generated neutral speech. These findings suggest altered identity categorization and detection of emotional salience in schizophrenia. In other words, at an early processing stage, the patients' attention seems to be more driven by non-emotional and non-self vocal stimuli. Additional differences were found in LPP component. Compared with the healthy control group, the patients revealed a reduced LPP in response to self-generated and non-self-voices with negative content. This finding might reflect the existence of altered higher-order cognitive evaluation of voice stimuli.

In these previous studies (Pinheiro, Rezaii, Nestor, et al., 2016; Pinheiro et al., 2017), the emotional content was implicitly processed, as participants were instructed to pay attention to the identity of the voice and to judge if the auditory input was a recording of their own voice (self-voice recording), of another person (non-self-voice recording), or if they were unsure. Some studies show that shifting the attentional focus of a task influences the cognitive mechanisms that underpin stimulus processing (e.g., Ferrari, 2008). Therefore, shifting the attentional focus from implicit to explicit emotional processing (i.e., judging the emotional quality of the voice) might influence voice processing mechanisms.

1.6. The impact of attention on voice perception

Attention can be conceptualized as a set of processes that control the flow of information through the nervous system and influence perceptual, memory and response mechanisms. Almost all cognitive systems are influenced by attention and, consequently, attention influences almost all ERP components (Luck & Kappenman, 2012). There are two main ways in which attention can be processed: in a top-down way as a function of instruction or task, and in a bottom-up manner prompted by intrinsic properties of a stimulus (Ferrari et al., 2008).

In the auditory domain, the N1 enhancement is thought to reflect a sensory filter mechanism of attention (Lange, 2013). In studies with emotional stimuli, a larger P2 amplitude has been related to increased intrinsic allocation of attentional resources to emotional (vs. neutral) stimuli (Pinheiro, Rezaii, Nestor, et al., 2016). An increased LPP has been associated with better perceptual judgments (Alain, Arnott, & Picton, 2001) and additional sustained attentional allocation invested in the processing of task-relevant events (Ferrari et al., 2008). Additive effects of sustained attention and emotion were observed at later processing stages indexed by the LPP component, but not at earlier perceptual stages (Chen, Zhang, & Jiang, 2018; Ferrari et al., 2008; Schindler & Kissler, 2016; Schupp, Flaisch, Stockburger, & Junghöfer, 2006). More specifically, a recent visual word processing study found an additive effect of emotion and attention, reflected in larger LPP amplitudes for explicit attention to emotional words relative to explicit attention to neutral words (Schindler & Kissler, 2016). Accordingly, a more positive LPP was found for emotional pictures that were targets of directed attention (Ferrari et al., 2008).

Furthermore, a previous functional magnetic resonance imaging (fMRI) study has shown the influence of attentional focus on the processing of speaker's voice and speech semantic content (von Kriegstein, Eger, Kleinschmidt, & Giraud, 2003). The right anterior superior temporal sulci were only activated in a task in which the speaker's voice was being explicitly processed. On the other hand, the left middle temporal regions were found to be more activated when speech semantic content was being explicitly processed (von Kriegstein et al., 2003). The ERP technique is characterized by higher temporal resolution than fMRI, therefore it can be a useful tool to further explore the impact of attention on the perception of speaker's voice and speech semantic content. To our knowledge, no other study used the ERP technique to explore the effect of attention focus on the interactions of identity and emotion during voice perception.

The existence of altered attentional processes in schizophrenia patients (Braff, 1993; Luck, Leonard, Hahn, & Gold, 2019; Ward, Catts, Fox, Michie, & McConaghy, 1991; Wood, Potts, Hall, Ulanday, & Netsiri, 2006) and in nonclinical individuals (Lewis-Hanna, Hunter, Farrow, Wilkinson, & Woodruff, 2011; Rayner, Lee, & Woodruff, 2015) is widely reported. In the auditory domain, patients often exhibit an attentional filtering impairment, where the ability to focus on relevant information and filter irrelevant data is compromised (Luck et al., 2019). In the current study, we wanted to explore the way

in which HP influences the impact of the attentional focus (identity focus task vs. emotional focus task) on voice processing mechanisms (identity and emotion).

1.7. The current study and hypotheses

In the current study, we used a high temporal resolution technique (ERP) to specify: 1) the impact of attention focus on the interaction between speaker's identity and emotion processing; 2) the impact of hallucination predisposition on those mechanisms.

For that purpose, two tasks were conducted. In the first task (identity focus task), individuals heard pre-recorded speech (self vs. non-self-voice words) differing in emotional content (negative vs. neutral vs. positive). Participants had to indicate whether the voice they heard was their own, of another person or if they were unsure. In the second task (emotional focus task), participants heard the same stimuli but were instructed to judge the emotional quality of the words. The degree of hallucination predisposition was accessed using the Portuguese adaptation of the Launay-Slade Hallucination Scale (LSHS, Castiajo & Pinheiro, 2017).

For the identity focus task, an interaction between identity and emotion was expected, replicating previous findings (Pinheiro, Rezaii, Nestor, et al., 2016). Specifically, when compared with an unfamiliar voice, we expected to observe a larger N1 amplitude for self-voice with neutral content, a more positive P2 amplitude for self-voice with positive content and a larger LPP for self-voice with both positive and negative content (Pinheiro, Rezaii, Nestor, et al., 2016). Likewise, a main effect of identity was also expected, reflected in a larger LPP amplitude for the self-voice compared to the non-self-voice (Pinheiro, Rezaii, Nestor, et al., 2016).

As for the influence of HP, we expected an association between high HP and reduced self-voice accuracy. This hypothesis is grounded on a recent behavioral study which reported an association between HP and voice identity recognition, irrespective of the emotional quality of the speech (Pinheiro et al., 2019). At a neurophysiologic level, we expected an influence of HP on the interaction of identity and emotion. Grounded on the results observed in a sample of schizophrenic patients (Pinheiro et al., 2017), we expected a similar influence of HP on early and higher-order cognitive mechanisms underpinning voice processing. At an early processing stage, we expected an association between high HP and a more positive P2 amplitude for non-self-neutral words. At a more cognitive processing stage, we expected an association between high HP and a reduced

LPP amplitude for both self-voice and non-self-voice with negative content (Pineiro et al. 2017). Observing a similar voice processing pattern between patients and nonclinical individuals would further support the psychosis continuum hypothesis (van Os, et al., 2009).

In the emotional focus task, following the results reported by Pineiro and collaborators (2019), we did not expect to observe an effect of HP on the evaluation of the emotional quality of the words. At a neurophysiologic level, considering previous works such as Schindler & Kissler (2016), we expected a larger LPP amplitude for both positive and negative words, in comparison with neutral words. Additive effects of attentional focus and emotion were previously observed at later processing stages indexed by the LPP component, but not at earlier perceptual stages (Chen et al., 2018; Ferrari et al., 2008; Schindler & Kissler, 2016; Schupp et al., 2006). Therefore, while sustained attention allocation should affect the LPP amplitude, it should not affect the amplitude of the N1 and P2 components.

At last, since attentional impairments have been reported in nonclinical individuals (Lewis-Hanna et al., 2011; Rayner et al., 2015), as an exploratory hypothesis, we expected an influence of HP on attentional focus mechanisms. The LPP is modulated by sustained attentional processing of the voice, therefore the presumed effect of HP on the attentional focus should be reflected in this component.

2. Method

2.1. Participants

Thirty-seven participants were recruited by word of mouth and internet advertising, but seven were excluded. Five of them did not meet the inclusion criteria and two were excluded due to excessive artifacts. The final sample included 30 participants (15 females), aged between 18 and 33 years (Mean age = 24.30, SD = 2.51). All participants met the following inclusion criteria: 1) European Portuguese as native language; 2) right handedness (Edinburgh inventory; Oldfield, 1971); 3) no history of neurological or major medical illness; 4) no history of electroconvulsive treatment; 5) no history of drug or alcohol abuse in the last 6 months; 6) no history of psychiatric disorder; 7) no present medication for medical disorders that would have effects on EEG morphology or consequences on the cognitive performance.

All participants had the procedures explained to them and read and signed an informed consent form to confirm their willingness to attend the study. This study is part of a project that was approved by the ethics committee of Faculty of Medicine and Faculty of Psychology of the University of Lisbon. All the experimental sessions were conducted in the Faculty of Psychology of the University of Lisbon.

2.2. Evaluation protocol

A semi-structured interview was administered to assess whether participants met all the inclusion criteria. In the interview it was asked if: the participant spoke European Portuguese as first language, took medication or had a psychiatric diagnosis, had a history of neurological or major medical illness, electroconvulsive treatment, drug or alcohol abuse in the last 6 months or first-degree relatives with a psychiatric diagnosis.

In order to verify other inclusion criteria and to control some variables, we applied the following questionnaires. A Portuguese translation of the Edinburg inventory (Oldfield, 1971) to guarantee the right handedness of all the participants, the Brief Symptoms Inventory (BSI; Portuguese adaptation by Canavarro, 1999; Derogatis & Spencer, 1982) and the Schizotypal Personality Questionnaire (SPQ; Portuguese adaptation by Santos, 2011; Raine, 1991) to further screen the existence of psychiatric symptoms and the LSHS (Portuguese adaptation by Castiajo & Pinheiro, 2017; Bentall & Slade, 1985). The LSHS is one of the most used instruments to measure HP in nonclinical samples (Allen et al., 2004; Badcock & Chhabra, 2013; Bentall & Slade, 1985; Johns et al., 2014; Laroí & Van Der Linden, 2005; Siddi et al., 2019). It is composed of 16 items tapping into hallucinations in different sensory modalities and sleep-related experiences. The total score ranges between 0 and 64 (higher scores represent higher hallucination predisposition), with responses provided on a 5-point Likert scale (0 = “certainly does not apply to me”; 1 = “possibly does not apply to me”; 2 = “unsure”; 3 = “possibly applies to me”; 4 = “certainly applies to me”). This scale has been validated in many languages, establishing a cross-cultural validation of the hallucination predisposition construct (Castiajo & Pinheiro, 2017; Siddi et al., 2019). Its Portuguese adaptation has a high internal consistency (Castiajo & Pinheiro, 2017). The total LSHS scores of the recruited sample varied between 1 and 37 ($M = 17.30$; $SD = 10.02$).

2.3. Stimuli

Stimuli included 35 words with negative content (e.g., “funeral”), 35 words with neutral content (e.g., “chair”) and 35 words with positive content (e.g., “joyful”). The proportion of nouns and adjectives was equivalent in the three conditions. Words were tested for frequency, number of letters and number of syllables based on the online database for Portuguese words P-PAL (Soares *et al.*, 2010). Emotional ratings (i.e., valence and arousal) were obtained from the norms for 1043 Portuguese words (Soares, Comesaña, Pinheiro, Simões, & Frade, 2012). Additionally, to confirm these ratings, 28 students (who did not participate in the EEG experiment) provided ratings of valence and arousal for each of the 105 words using a 9-point Likert scale. There were no differences between word valence categories regarding number of letters, number of syllables and frequency ($p > .05$; see Table 1 and Appendix A). Moreover, there were no differences in arousal between negative and positive words ($p > .05$), even though emotional words were characterized by higher arousal ratings compared to neutral words. As expected, valence of neutral words was higher than the valence of negative words ($p < .001$), but lower than the valence of positive words ($p < .001$).

Table 1

Psycholinguistic and affective properties of the words used in the experiment

	Negative <i>M(SD)</i>	Neutral <i>M(SD)</i>	Positive <i>M(SD)</i>	F, <i>p</i>
Frequency	13.40 (14.45)	15.32 (16.67)	15.63 (19.39)	0.161, .842
Number of letters	6.80 (1.64)	7.06 (1.86)	7.26 (2.17)	0.552, .538
Number of syllables	2.97 (0.82)	3.14 (0.77)	3.26 (1.01)	1.014, .360
Valence	2.30 (1.38)	5.15 (1.30)	7.64 (1.32)	3390.887, <.001*
Arousal	5.86 (2.19)	4.20 (1.91)	5.73 (2.28)	34.187, <.001*

Note. M= Mean; SD= Standard Deviation. The ratings of valence and arousal range between 1 and 9.

* $p < .001$.

2.4. Procedure

Each participant enrolled in two experimental sessions. The first session involved the recording of the participant's voice, whereas the EEG recording took place in the second session.

2.4.1. Voice Recording

Each participant was asked to read aloud a list of 105 words with neutral or emotional content (self-voice condition). The words were shown in the center of a computer screen, one at a time. Before seeing the word, participants were instructed to listen to that same word pronounced by a 'voice-model' (age=24) using neutral prosody. They were then instructed to match the loudness and neutral prosody of each target word as spoken by the 'voice-model' at a constant voice intensity. The inclusion of a voice-model served to reduce variability between participants in speech rate, voice loudness and pitch. Recordings were made in an echoic studio with a Roland R-16 recorder, with a sampling rate of 44,100 kHz and 16-bit quantization. The electroencephalogram (EEG) was not recorded in this stage of the study.

For the non-self-voice condition, the same 105 words were recorded by a male (age=23) or female (age=25) native speaker of European Portuguese unknown to the participants. The words were spoken with neutral intonation and constant voice intensity, following the same procedure as described above. After the recording session, the following steps were applied. First, acoustic noise was reduced using a Fourier-based noise reduction algorithm (noise reduction = 12 dB; frequency smoothing= 3 Hz; attack/decay time = 0.15s) implemented in Audacity 2.2.1 software (<http://audacity.sourceforge.net/>). Then, each word was segmented using Praat software (Boerms & Weenink, 2013). The segmentation of the words was done in order to ensure only the beginning and the ending of the sound were included, removing the maximal amount of silence from the soundtrack. Finally, the intensity of the voice stimuli was normalized to 70 dB, using a Praat script. The mean pitch and duration of each word (see Table 2) were computed and used in subsequent statistical analysis.

Table 2

Acoustic properties of the speech stimuli per participant's gender.

	Negative <i>M(SD)</i>	Neutral <i>M(SD)</i>	Positive <i>M(SD)</i>
Duration (ms)	S-M: 755.75 (68.49) NS-M: 836.57 S-F: 778.69 (40.76) NS-F: 825.14	S-M: 755.37 (71.13) NS-M: 851.71 S-F: 788.02 (42.94) NS-F: 828.28	S-M: 794.04 (70.03) NS-M: 879.14 S-F: 829.14 (44.07) NS-F: 869.71
Mean F0 (Hz)	S-M: 111.19 (18.57) NS-M: 115.44 S-F: 195.67 (18.21) NS-F: 192.24	S-M: 111.80 (19.07) NS-M: 114.81 S-F: 193.98 (18.86) NS-F: 193.21	S-M: 111.97 (19.17) NS-M: 114.92 S-F: 196.64 (19.28) NS-F: 192.21

Note. M= Mean; SD=Standard Deviation; S-M= SV male; NS-F= NSV female.

2.4.2. EEG experiment

The EEG session took place at least three days after the voice recording session. Two hundred and ten words were presented: 105 previously recorded by the participant, and 105 previously recorded by a speaker unknown to the participant. There were 35 words for each of the six combinations (self-voice positive, self-voice neutral, self-voice negative, non-self-voice positive, non-self-voice neutral, non-self-voice negative), varying in emotion and identity. The six stimulus categories were pseudorandomized and presented in two lists, with the limitation of no more than three consecutive trials of the same condition. Half of the participants received the lists in a fixed sequence, and the other half in the inverse sequence.

While the EEG was recorded, all participants completed two tasks. In both tasks, they had to respond by choosing one of three alternatives. In the first task, they were instructed to attend to the identity of the voice and decide whether the voice they heard was their own voice, the voice of another person or if they were unsure (Identity focus task; Figure 1). In the second task, they were instructed to identify the emotional quality of the words, i.e. to decide whether the words were positive, negative or had a neutral quality (Emotional focus task; Figure 2). The order of the buttons was counterbalanced. Stimuli were presented through headphones at a sound level comfortable for each

participant and were not repeated during the experiment. Before the beginning of the experiment, the procedure was explained to the participants.

Each participant was seated at an 80 centimeters distance from a computer monitor in a soundproof booth (<http://www.demvox.com/>). Before each sound onset, a fixation cross was presented in the center of the screen for 2500 ms and was kept during sound presentation (1500 ms) to minimize eye movements. Then, a question mark appeared for 1000 ms (inter-stimulus interval) signaling the beginning of the response time. The options were then presented in the middle of the screen at the end of each trial and the participants pressed one of the response buttons (maximum response time = 5 seconds). The experimental task was conducted with Presentation® software (Version 20.1, Neurobehavioral Systems, Inc., Berkeley, CA, www.neurobs.com), a tool used for presenting stimuli in behavioral and physiological experiments.

The participants listened to the same stimuli in both tasks. The only difference was the attention focus: either the identity (Experiment 1) or the emotional quality (Experiment 2) of the voice.

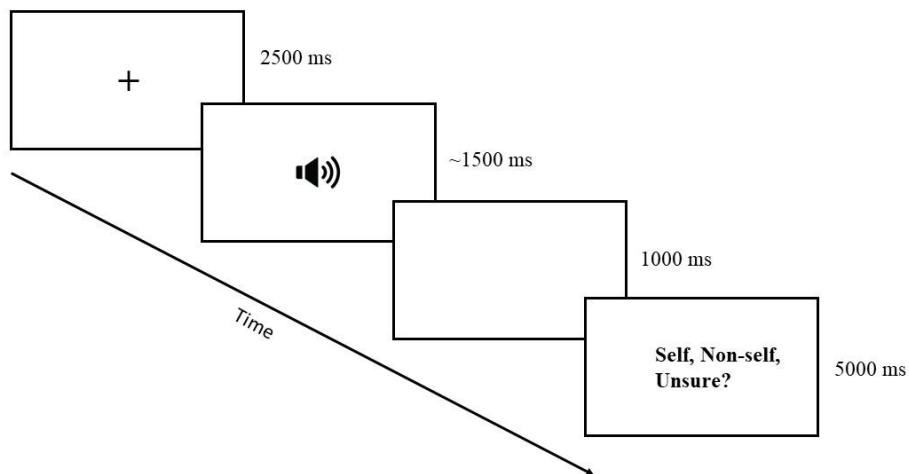


Figure 1. Illustration of an experimental trial in the identity focus task

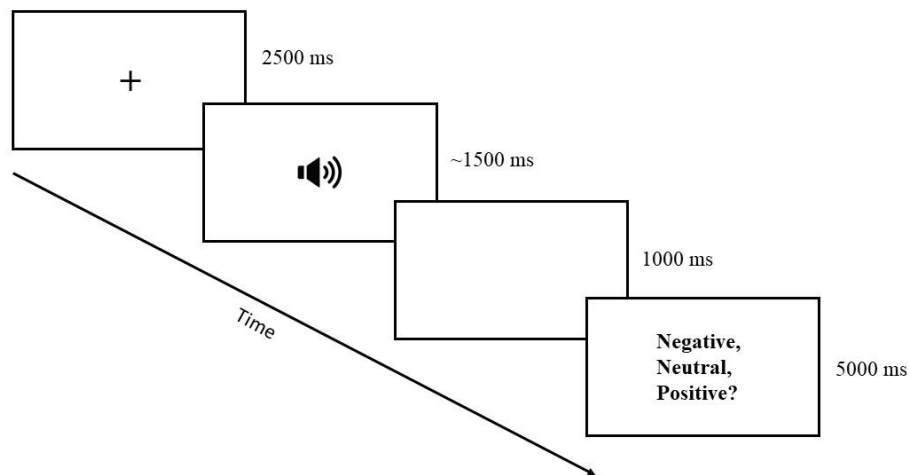


Figure 2. Illustration of an experimental trial in the emotional focus task

2.5. Acquisition and analyses of EEG data

The EEG was recorded with 64 pin-type active-electrodes (Biosemi B.V, Amsterdam, Netherlands) set on a head cap and following the expanded 10-20 system (American Electroencephalographic Society, 1991). Five flat-type active-electrodes were attached to the participant's face. Two were placed on the external canthus of both eyes and one below the left eye, in order to record horizontal and vertical ocular movements respectively. The other two were placed in the left and right mastoids to serve as offline reference. A conductive gel was used to lower the electrical impedance, which was kept below 30 μ V. The EEG was acquired in a continuous mode at a digitization rate of 512 Hz.

The EEG analyses were done using Letswave 6 (<https://www.letswave.org/>). A band-pass filter with 0.1 Hz and 30 Hz, low and high cutoff frequency, was applied. The EEG channels were referenced offline to the average of the left and right mastoids. Individual ERP epochs were created for each stimulus category (self-voice positive, self-voice neutral, self-voice negative, non-self-voice positive, non-self-voice neutral, non-self-voice negative), with -200 to 1000 ms, pre and post-stimulus epoch. A baseline correction was applied in the -200 to 0 ms pre-stimulus interval. Both vertical and horizontal eye movements were removed using the method of Gratton, Coles, and

Donchin (1983). EEG epochs exceeded ± 100 were excluded. After artifact rejection, at least 70% of the trials per condition per participant entered the analyses. Finally, ERP epochs were averaged, and then grand average waveforms were created for each of the six categories (see Figure 3 and Figure 4). The mean amplitude for each component was measured in a specific time window, following prior studies (Pinheiro, Rezaii, Nestor, et al., 2016): 120-190 ms (N1), 220-290 ms (P2) and 500-700 ms (LPP), respectively. The amplitudes were extracted from three regions of interest (ROI) following prior studies (Pinheiro, Rezaii, Nestor, et al., 2016): left medial (FC3, C3, CP3), right medial (FC4, C4, CP4) and midline (FCz, Cz, CPz).

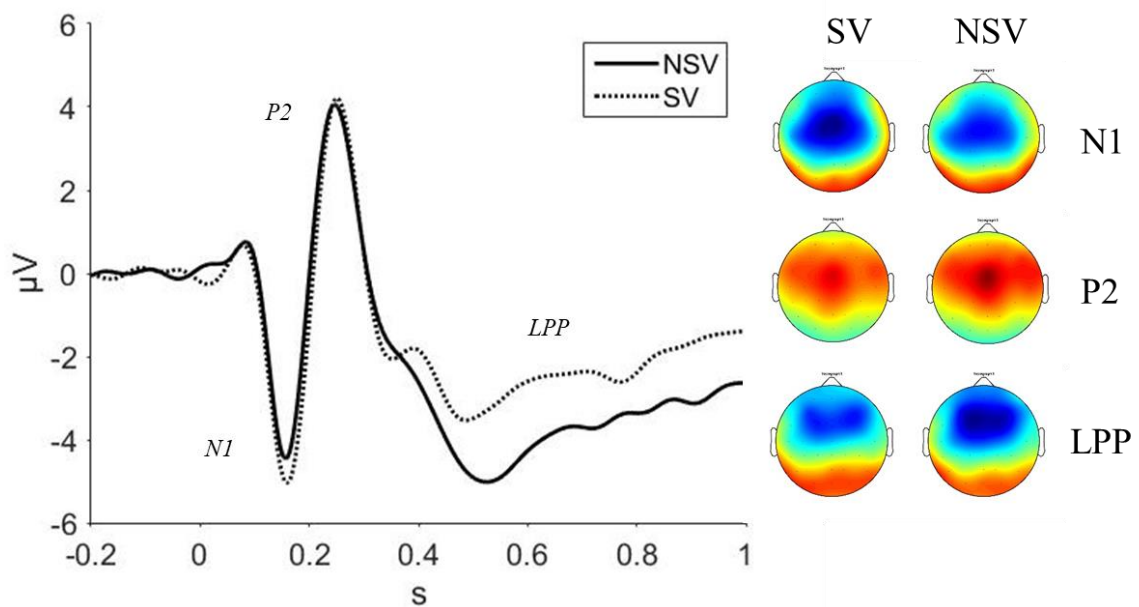


Figure 3. Grand average waveform showing contrasts between self-voice and non-self-voice conditions in the identity focus tasks, at electrode Cz. Topographic maps of N1 (120-190 ms), P2 (220-290 ms) and LPP (500 – 700 ms) are shown.

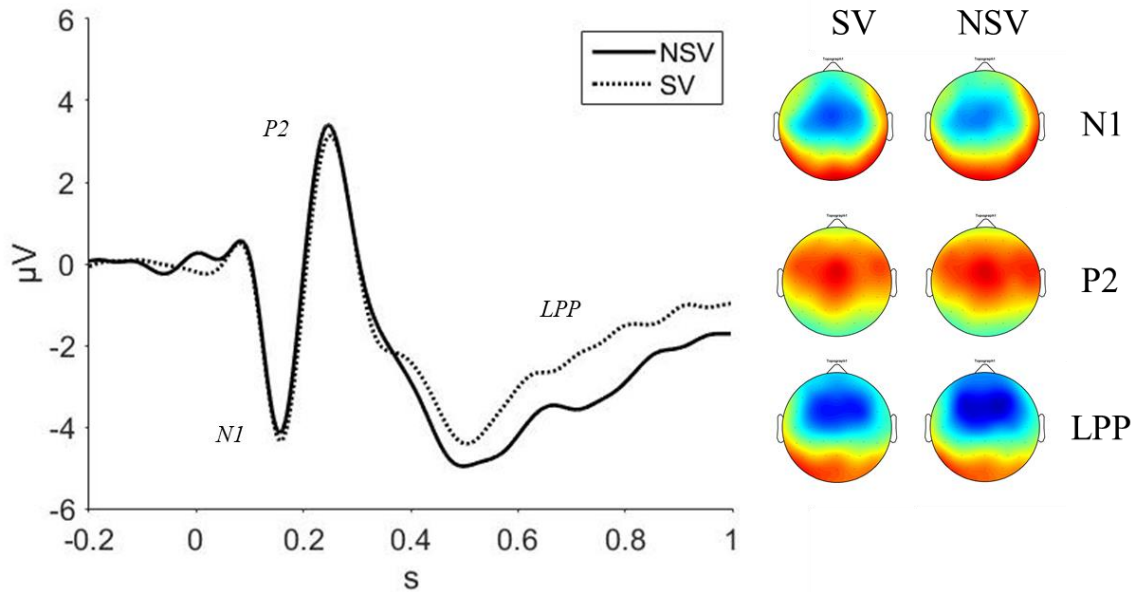


Figure 4. Grand average waveform showing contrasts between self-voice and non-self-voice conditions in the emotional focus tasks, at electrode Cz. Topographic maps of N1 (120-190 ms), P2 (220-290 ms) and LPP (500 – 700 ms) are shown.

2.6. Statistical Analyses

The statistical analysis was performed with IBM SPSS software (Version 25, SPSS Inc., Chicago, IL, USA).

2.6.1. Behavioral data

For both tasks, a repeated-measures ANOVA with identity (self-voice, non-self-voice) and emotion (negative, neutral, positive) as within-subject factors was computed. In the identity focus task, the dependent measures were identity recognition accuracy (correct recognition of self-voice and non-self-voice) and number of unsure responses. In the emotional focus task, the dependent measure was the number of words tagged as negative, neutral or positive. Hallucination predisposition was added as a covariate in a separate analysis.

2.6.2. ERP data

A repeated-measures ANOVA with identity (self-voice, non-self-voice), emotion (negative, neutral, positive), ROI (left medial, right medial, midline), task (identity focus task, emotional focus task) as within-subject factors was computed. The dependent measures were the mean amplitudes of N1, P2 and LPP components. Hallucination predisposition was added as a covariate in a separate analysis.

The analyses were corrected for non-sphericity using the Greenhouse–Geisser method, when the Mauchly’s test indicated that the assumption of sphericity had been violated. Therefore, degrees of freedom (df) and p -values were adjusted when needed (F-ratio remains unchanged). Main effects and interactions were examined with pairwise comparisons using Bonferroni correction for multiple comparisons. Covariate effects were explored through parameter estimates.

3. Results

3.1. ERP results

3.1.1. Task 1: Identity focus task

3.1.1.1. N1 component

We found a main effect of identity [$F(1, 29) = 4.285; p = .047, partial \eta^2 = .129$]. Bonferroni *post hoc* test revealed a larger N1 amplitude for the self-voice condition compared to the non-self-voice condition ($p = .047$). We also found a main effect of ROI [$F(2, 58) = 15.945; p < .001, partial \eta^2 = .355$] which revealed a larger N1 amplitude in the midline region in comparison with the left medial and right medial regions ($p < .001$). No significant effects of emotion [$F(2, 58) = 1.376; p = .261$] or interaction effects between identity and emotion [$F(2, 58) = .531; p = .579$] were found. The effect of the covariate was not significant [$F(1, 28) = .377; p = .544$].

3.1.1.2. P2 component

A main effect of ROI [$F(2,58)=18.627; p < .001, partial \eta^2 = .391$], reflected in a larger P2 amplitude in the midline region compared to the other two regions, was observed ($p < .001$).

Main effects of voice identity [$F(1,29)=.126$; $p=.726$], emotion [$F(2,58)=.050$; $p=.943$] and interaction effects between them [$F(2,58)=.420$; $p=.658$] did not reach statistical significance. The effect of the covariate was not significant [$F(1,28)=.068$; $p=.797$].

3.1.1.3. LPP component

Voice identity manipulations significantly affected the LPP component [$F(1,29) = 13.154$; $p < .001$, *partial* $\eta^2 = .312$]. A larger LPP was observed in response to the self-voice in comparison with non-self-voice ($p < .001$). The effects of emotion [$F(2,58) = 1.548$; $p = .222$], ROI [$F(2,58) = 1.293$; $p = .282$] and interactive effects of identity and emotion [$F(2,58) = 1.659$; $p = .200$] did not reach statistical significance. The effect of the covariate was not significant [$F(1,28) = 1.140$; $p = .295$].

3.1.2. Task 2: Emotional focus task

3.1.2.1. N1 component

A main effect of ROI [$F(2, 58) = 16.458$; $p < .001$, *partial* $\eta^2 = .362$] was found, reflected in a more negative N1 amplitude at the midline region compared to the left medial ($p < .001$) and right medial regions ($p = .002$). Identity [$F(1, 29) = .235$; $p = .632$], emotion [$F(2, 58) = 1.078$; $p = .346$] and the interaction between them [$F(2, 58) = .364$; $p = .689$] did not reach statistical significance. The effect of the covariate was not significant [$F(1, 28) = .132$; $p = .719$].

3.1.2.2. P2 component

A main effect of ROI [$F(2, 58) = 20.825$; $p < .001$, *partial* $\eta^2 = .418$] was detected. The P2 amplitude was more positive in the midline region relative to the other two regions ($p < .001$). Identity [$F(1, 29) = .874$, $p = .358$], emotion [$F(2, 58) = .744$, $p = .477$] and the interaction between them [$F(1.68, 48.60) = 1.002$; $p = .362$] did not reach statistical significance. The effect of covariate was not significant [$F(1, 28) = .104$; $p = .749$].

3.1.2.3. LPP component

The amplitude of the LPP component was significantly modulated by voice identity [$F(1, 29) = 5.572$; $p = .025$, $partial \eta^2 = .161$]: A more positive LPP was observed in response to the self-voice than to non-self-voice ($p = .025$). A marginally significant effect of emotion was observed [$F(2, 58) = 2.662$; $p = .086$, $partial \eta^2 = .084$]. Pairwise comparisons with Bonferroni correction revealed a trend for a larger LPP amplitude in response to negative relative to neutral speech ($p = .051$). The main effect of ROI [$F(2, 58) = .851$; $p = .420$] and interaction effects of identity and valence [$F(2, 58) = .385$; $p = .681$] did not reach statistical significance.

Of note, the effect of the covariate on identity perception was marginally significant [$F(1, 28) = 3.049$; $p = .092$; $partial \eta^2 = .098$]. Planned contrasts revealed that LPP amplitude tended to be smaller in response to the self-voice the greater the hallucination predisposition, i.e. the total LSHS score [$t(28) = -1.93$, $p = .064$].

3.1.3. The effects of Task

The amplitudes of the N1 [$F(1, 29) = 3.955$; $p = .056$; $partial \eta^2 = .120$] and P2 [$F(1, 29) = 3.770$; $p = .062$, $partial \eta^2 = .152$] tended to be larger when attention was focused on voice identity compared to the emotional quality of the voice. Considering the N1, an interaction between task and identity was found [$F(1, 29) = 1.926$; $p = 0.36$; $partial \eta^2 = 0.62$]. Pairwise comparisons with Bonferroni correction revealed a larger N1 for self-voice on the identity focus task ($p = .47$). Hallucination predisposition did not significantly modulate the N1 [$F(1, 28) = .333$; $p = .568$] or P2 [$F(1, 28) = .234$; $p = .633$]. No main effect of task was observed in the LPP component [$F(1, 29) = .129$; $p = .722$; $partial \eta^2 = .004$]. However, hallucination predisposition modulated the interaction of task and voice identity [$F(1, 28) = 4.968$; $p = .034$; $partial \eta^2 = .151$]. Planned contrasts revealed that, when attention was focused on the emotional quality of the voice, the LPP amplitude tended to be smaller in response to self-voice the higher the hallucination predisposition, i.e. the total LSHS scores [$t(28) = -1.93$, $p = .064$].

3.2. Behavioral results

Table 3 shows the mean percentage of correct and unsure responses in the identity recognition task.

3.2.1. Recognition accuracy

Participants' recognition accuracy was similar for the self-voice and non-self-voices [$F(1, 29) = .179, p = .676$], and did not differ as a function of emotion [$F(2, 58) = .717, p = .481$]. The interaction between identity and emotion did not reach statistical significance [$F(2, 58) = 2.246, p = .117$]. The effect of the covariate was not significant [$F(2, 56) = .154, p = .852$].

3.2.2. Number of unsure responses

No significant main effects of identity [$F(1, 29) = .801, p = .378$] or emotion [$F(1.53, 44.26) = 1.961, p = .162$] were found. No interaction effect was found between identity and emotion [$F(2, 58) = .626, p = .538$]. The effect of the covariate was not significant [$F(2, 56) = .864, p = .427$].

3.2.3. Emotional evaluation of the words

There was no effect of HP on the emotional evaluation of the words [$F(2, 56) = 2.172; p = .136$].

Table 3

Mean percentage of correct and unsure responses in the identity recognition task

Identity	Emotion <i>M(SD)</i>	Correct Responses <i>M(SD)</i>	Unsure responses <i>M(SD)</i>
Self	Negative	96.19 (6.45)	2.10 (4.42)
	Neutral	96.48 (5.41)	1.52 (2.63)
	Positive	96.00 (7.54)	1.71 (3.73)
Nonself	Negative	94.67 (14.60)	1.33 (2.63)
	Neutral	94.57 (15.14)	1.33 (3.52)
	Positive	96.10 (11.46)	0.76 (1.80)

Note. M = Mean; SD= Standard Deviation.

4. Discussion

In the current study, we probed how attention focus impacts upon the interaction between identity and emotion in voice perception, and how HP modulates these interactions, using a high temporal resolution technique (ERP). For that purpose, two ERP experiments were conducted: an identity focus task (self-voice, non-self-voice) and an emotional focus task (negative, neutral, positive). Our results show the impact of the attentional focus on the perception of voice identity. Importantly, we observed a tendency for high HP to predict an altered perception of the self-voice, but only when participants' attention was focused on the emotional quality of the voice.

4.1. N1 – Sensory processing of the voice

At this early processing stage, no interactive effects of identity and emotion were found (i.e., larger N1 amplitude for self-voice with neutral content). However, an interaction between task and identity was observed. That is, attention focus modulated self-voice perception. Specifically, we observed a larger N1 amplitude for self- relative to non-self-voice when participants' attention was focused on the identity of the voice. This finding is in line with previous studies that report differences between self and non-self-voices in early processing stages, when the attentional focus is on voice identity (e.g., Conde et al., 2015).

Studies that reported emotion-dependent modulations on the N1 component are scarce and usually reflect an interaction between emotion and lexical frequency (Citron, 2012; Scott, O'Donnell, Leuthold, & Sereno, 2009). For example, Scott et al. (2009) reported a larger N1 amplitude in response to high-frequency emotional words relative to high-frequency neutral words and a trend for a larger N1 amplitude in response to low-frequency neutral words relative to low-frequency emotional words. For that reason, differences between the lexical frequency of the words used in this study and in the study of Pinheiro et al. (Pinheiro, Rezaii, Nestor, et al., 2016), might explain the absence of interactive effects of identity and emotion.

Attention focus modulated the amplitude of the N1 component. Self-voice recordings elicited a larger N1 than non-self-voice recordings, but only in the identity focus task. Hence, it is possible that an early self/non-self-voice discrimination occurs only when identity is being explicitly processed.

4.2. P2 – Emotional salience detection of the voice

We did not find an interaction of identity and emotion at this processing stage, nor did HP predict an altered emotional salience detection.

Larger P2 amplitudes have been found for both negative and positive words compared with neutral words (e.g., Herbert et al., 2006; Kanske & Kotz, 2007; Kanske, Plitschka, & Kotz, 2011). However, whether the P2 component indexes early semantic processing or just sensorial characteristics of the acoustic input remains debatable (Pell et al., 2015). Effects of arousal (Olofsson & Polich, 2007), lexical frequency (Scott et al., 2009) and expectation (Lin et al., 2012) have also been found to modulate the amplitude of this component. Therefore, the absence of the previous found interaction might be explained by differences in the words used in this study and the words used in the study of Pinheiro and collaborators (2016).

The absence of HP effects at this stage might suggest that, contrarily to the effect observed in patients (Pinheiro et al., 2017), HP does not affect the detection of voice salience in nonclinical participants.

4.3. LPP – Sustained attentional processing of the voice

At this voice processing stage, our hypothesis was partially verified. On the one hand, we replicated the previously observed main effect of identity (Pinheiro, Rezaii, Nestor, et al., 2016). Self-voice recordings elicited a larger LPP than non-self-voice recordings. On the other hand, we did not find an interaction between identity and emotion (Pinheiro, Rezaii, Nestor, et al., 2016), nor robust emotion effects on the emotional focus task. Regarding the influence of HP, we also did not find an impact of HP on the interaction of identity and emotion. Nonetheless, we found a marginally significant impact of HP on the modulatory role of attention focus in self-voice perception. In the emotional focus task, high HP marginally predicted a reduced LPP in response to the self-voice.

The LPP component is thought to index a higher-order sustained attentional processing of the voice (Ferrari et al., 2008). Thus, an increased LPP amplitude in response to self-voice relative to non-self-voice might reflect enhanced allocation of sustained attention to self-voice. This finding is in line with previous accounts of increased attention allocation to self-voice recordings (Conde et al., 2015, 2018) and fits

well with a large body of evidence showing a preferential processing of self-referential stimuli, such as self-referential pronouns (Shi, Zhou, Han, & Liu, 2011; Zhou et al., 2010), self-face (Ma & Han, 2010; Tacikowski & Nowicka, 2010) and self-name (Tacikowski & Nowicka, 2010; Yang, Wang, Gu, Gao, & Zhao, 2013).

In the emotional focus task, we found a marginally significant difference between words with negative and neutral content: negative words tended to elicit a more positive LPP than neutral words. This result is in line with previous studies that found a larger LPP for emotional compared to neutral stimuli in an explicit attention condition (Schindler & Kissler, 2016). The lack of robust emotion effects and the absence of interactive effects of emotion and identity in the current study might be explained by methodological differences between this and prior studies. While the prior studies used only adjectives as stimuli (Pinheiro, Rezaii, Nestor, et al., 2016; Pinheiro et al., 2017), the current study included also nouns. The strongest effects of emotion on later ERPs have been found in studies using adjectives instead of other word classes, such as nouns (Citron, 2012; Herbert et al., 2008; Herbert et al., 2006). Likewise, in a recent study emotion effects indexed by the LPP component were only found for person-descriptive words (Rohr & Abdel Rahman, 2018). Adjectives are typically used to describe a person or an object, hence it is possible that they elicit more pronounced self-referential processing compared to nouns (Herbert et al., 2008).

Lastly, we did not find the expected impact of HP on the interaction of identity and emotion processing. Notwithstanding, we found a marginally significant impact of HP on the interaction between attention focus and voice identity. In the emotional focus task, a trend for an association between high HP and reduced LPP amplitude to self-voice recordings was observed. While patients exhibit a reduced LPP amplitude for self and non-self-voice recordings with negative content (Pinheiro et al., 2017), the current finding suggests that nonclinical individuals only exhibit a trend for a reduced LPP amplitude in response to self-voice recordings, irrespective of the emotional quality of the words. Moreover, this trend was only observed in the emotional focus task. That is, it was only observed in a task in which the identity of the voice was not being explicitly processed.

According to the continuum of psychosis hypothesis, the psychotic experiences reported by nonclinical individuals represent an attenuated form of the psychotic symptoms observed in patients (Baumeister et al., 2017; van Os et al., 2009). The reduced LPP amplitude for negative self and non-self-voice recordings observed in patients can be understood as an overall reduced sustained attentional processing (Ferrari et al., 2008;

Pinheiro et al., 2017) of voice identity with negative content. Likewise, the current findings point out to an association between high HP and reduced sustained attentional processing of voice identity. However, the extension of the presumed impairments is less marked. In high HP individuals, the altered perception of voice identity seems to appear only in response to self-voice recordings, irrespective of the emotional content, and when identity is not being explicitly processed (emotional focus task).

One of the main differences between the auditory verbal hallucinations experienced by patients and by nonclinical individuals is the speech emotional content, which is more negative in patients (Daalman et al., 2011; de Boer et al., 2016). Previous accounts indicate that emotional factors influence the perception of vocal cues in patients (Costafreda, Brébion, Allen, McGuire, & Fu, 2008; Johns et al., 2001; Johns, Gregg, Allen, & McGuire, 2006; Pinheiro, Rezaii, Rauber, et al., 2016), but not in nonclinical individuals (Pinheiro et al., 2019). In that same line, the current findings seem to show the absence of an emotional influence on the putative voice identity impairment of nonclinical individuals. Furthermore, the observed trend was only observed in the emotional focus task. Thus, this finding is in line with previous studies that show an impact of HP on attentional mechanisms (Lewis-Hanna et al., 2011; Rayner et al., 2015). Since this effect is only marginally significant, caution is needed in the interpretation of this finding.

4.4. Recognition accuracy and emotional evaluation

Contrary to our hypothesis, we did not observe an association between HP and reduced self-voice accuracy. It should be noticed that the percentage of correct responses was very high (above 90%) and almost all the participants reported no difficulties identifying their own-voice. Moreover, participants explained that they are frequently exposed to self-voice recordings (e.g., WhatsApp messages), which makes it easier to recognize the identity of the voice. Hence, the absence of an association between HP and reduced self-voice accuracy might be attributed to the observed ceiling effects.

Furthermore, compared with the current sample, Pinheiro and collaborators (2019) study had a sample of participants with higher LSHS total scores ($M = 23.17$; range = 0 – 54). Therefore, it is plausible that alterations in the recognition of self-voice recordings are easier to detect in a sample of individuals with more hallucinatory-like experiences.

As expected, HP did not affect the emotional evaluation of the words (Pineiro et al., 2019): higher HP individuals evaluated the emotional content of the words in a similar manner as those with lower HP.

4.5. Limitations and future directions

The obtained results support a tendency for a self-voice impairment, dependent on attention, in individuals with high levels of HP. In order to better understand the nature of the potential impairments, and how they are related to specific symptoms such as auditory verbal hallucinations, more studies are needed.

Our sample contains individuals with different levels of HP, but few individuals with persistent auditory verbal hallucinations. The prevalence of Portuguese nonclinical individuals with persistent auditory verbal hallucinations appears to be quite small (Castiajo & Pineiro, 2017). For that reason, is not easy to recruit participants with such characteristics. Future studies should explore similar mechanisms in nonclinical individuals with frequent auditory verbal hallucinations.

4.6. Conclusion

In this study, we probed the impact of HP on attentional mechanisms and on the perception of voice identity with emotional content. Our results show an association between HP and a trend for a reduced LPP amplitude in response to the self-voice, when attention was focused on the emotional quality of the voice. Additionally, we found early and late effects of attention and identity on self-voice perception. In an early stage, an interaction between attention and identity was reflected in a larger N1 amplitude in response to self-voice in the identity focus task. In a later stage, a main effect of identity was reflected in a larger LPP in response to the self-voice, irrespective of attention focus.

Altogether, our findings represent a contribution to the auditory perception literature and to a better understanding of the presumed voice processing alterations in individuals with high HP.

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Appendix A: List of words used as stimuli.

Word (EP)	Word (E)	Valence condition	Mean ratings		Linguistic proprieties		
			Valence	Arousal	Freq. Per million	Nr letters	Nr syllables
apavorado	panicky	Neg	2.16	6.80	0.42	9	5
asqueroso	loathsome	Neg	1.98	6.34	0.15	9	4
bruto	brute	Neg	2.46	6.38	13.46	5	2
cemitério	cemetery	Neg	2.21	5.65	21.16	9	4
cobarde	coward	Neg	2.37	5.42	1.94	7	3
cruel	cruel	Neg	2.31	6.52	9.96	5	2
demónio	demon	Neg	2.93	5.72	3.16	7	3
deprimido	depressed	Neg	2.17	4.81	1.68	9	4
derrotado	defeated	Neg	2.31	6.29	20.06	9	4
desgosto	grief	Neg	2.28	5.24	5.41	8	3
desleal	disloyal	Neg	2.06	6.48	3.86	7	3
doente	sick	Neg	2.63	5.38	38.64	6	3
egoísta	selfish	Neg	2.43	5.75	2.51	7	4
escravo	slave	Neg	2.02	6.17	2.92	7	3
falhado	loser	Neg	2.61	5.55	8.82	7	3
falso	false	Neg	2.61	6.18	19.38	5	2
funeral	funeral	Neg	1.34	6.43	12.62	7	3
ignorância	ignorance	Neg	2.56	4.63	13.28	10	4
infeliz	unhappy	Neg	1.66	5.44	11.98	7	3
lixo	garbage	Neg	2.69	5.11	40.43	4	2
mendigo	beggar	Neg	2.30	5.91	1.20	7	3
miserável	miserable	Neg	1.89	5.78	4.28	9	4
morto	dead	Neg	1.68	6.30	53.28	5	2

nojento	disgusting	Neg	2.26	6.39	0.37	7	3
ódio	hatred	Neg	2.00	7.28	16.17	4	2
perdido	lost	Neg	2.90	5.76	51.72	7	3
podre	rotten	Neg	2.64	5.34	3.59	5	2
raiva	rabies	Neg	2.64	6.81	8.88	5	2
rude	rude	Neg	2.77	5.63	4.69	4	2
solidão	loneliness	Neg	2.10	4.78	15.45	7	3
tédio	boredom	Neg	2.43	4.14	2.91	5	2
terrível	terrible	Neg	2.69	6.19	18.83	8	3
triste	sad	Neg	2.02	5.40	36.81	6	2
violento	violent	Neg	2.30	6.94	15.75	8	4
zangado	angry	Neg	2.26	6.26	3.37	7	3
adulto	adult	Neu	5.33	4.45	7.23	6	3
alerta	alert	Neu	4.89	6.64	37.17	6	3
avenida	avenue	Neu	5.50	4.32	22.02	7	4
bagageira	luggage	Neu	5.03	3.71	2.53	9	4
brutal	brutal	Neu	4.92	5.74	12.07	6	2
cadeira	chair	Neu	5.23	3.73	21.87	7	3
cartaz	banner	Neu	5.47	4.11	20.10	6	2
casual	casual	Neu	5.18	3.76	1.71	6	3
cesto	basket	Neu	5.16	3.96	4.70	5	2
corredor	aisle	Neu	5.08	4.13	23.25	8	3
costume	custom	Neu	5.16	3.95	19.30	7	3
espantado	astonished	Neu	5.58	6.00	3.07	9	4
expectante	expectant	Neu	5.38	5.73	1.45	10	4
explícito	explicit	Neu	5.53	4.00	5.63	9	4
garfo	fork	Neu	5.27	3.18	1.35	5	2
liso	slick	Neu	4.84	3.72	1.19	4	2
martelo	hammer	Neu	4.69	3.78	5.42	7	3
material	material	Neu	5.14	3.85	82.86	8	4

mexido	scrambled	Neu	5.58	4.69	1.02	6	3
motor	engine	Neu	4.75	5.34	35.90	5	2
navio	ship	Neu	5.49	3.48	32.85	5	3
parado	still	Neu	4.54	2.98	13.75	6	3
patente	patent	Neu	5.04	4.00	40.28	7	3
previsível	predictable	Neu	5.20	3.85	20.26	10	4
quadrado	square	Neu	5.16	3.82	8.21	8	3
quieto	still	Neu	4.95	3.13	1.94	6	3
reservado	reserved	Neu	4.66	3.33	15.91	9	4
rigoroso	rigorous	Neu	5.27	5.39	12.45	8	4
solene	solemn	Neu	5.32	3.53	13.25	6	3
tecido	tissue	Neu	5.23	4.32	18.49	6	3
temperamental	moody	Neu	4.90	5.34	0.76	13	5
tigela	bowl	Neu	5.15	3.42	1.35	6	3
tinta	ink	Neu	5.22	4.11	10.09	5	2
vigilante	vigilant	Neu	5.16	4.29	3.06	9	4
visível	visible	Neu	5.34	3.28	33.63	7	3
alegre	joyful	Pos	8.00	5.18	11.41	6	3
amado	loved	Pos	7.68	4.43	3.48	5	3
amigo	friend	Pos	8.21	4.08	73.12	5	3
animado	cheerful	Pos	7.33	6.27	10.11	7	4
apaixonado	valentine	Pos	8.11	6.91	8.02	10	5
aplausos	applause	Pos	7.72	6.72	13.13	8	3
beijo	kiss	Pos	8.02	5.74	6.19	5	2
belo	beautiful	Pos	7.26	3.46	21.03	4	2
bonito	pretty	Pos	7.40	4.36	18.25	6	3
brilhante	sparkling	Pos	7.72	5.58	22.28	9	3
brincalhão	playful	Pos	7.33	5.67	0.85	10	3
caloroso	warm	Pos	7.36	5.51	1.47	8	4
carícia	caress	Pos	7.76	4.53	0.77	7	3

comédia	comedy	Pos	7.86	5.76	19.88	7	3
contente	glad	Pos	8.00	5.24	16.19	8	3
desejo	wish	Pos	7.35	6.86	62.37	6	3
diversão	fun	Pos	8.23	6.65	6.98	8	3
doce	sweet	Pos	7.36	5.33	16.84	4	2
encantador	enchanting	Pos	7.65	5.63	1.06	10	4
entusiasmado	enthusiastic	Pos	7.42	6.94	4.32	12	6
eufórico	elated	Pos	7.19	7.09	2.06	8	4
excitação	thrill	Pos	7.14	7.44	4.48	9	4
festivo	festive	Pos	7.76	7.19	2.76	7	3
hilariante	hilarious	Pos	7.72	6.05	1.67	10	5
lindo	lovely	Pos	7.60	5.96	4.59	5	2
milionário	millionaire	Pos	7.17	5.16	6.67	10	5
paixão	passion	Pos	8.18	7.65	35.21	6	2
recompensa	reward	Pos	7.02	5.37	4.88	10	4
riso	laughter	Pos	8.03	6.12	9.09	4	2
saboroso	tasty	Pos	7.47	5.73	1.62	8	4
simpático	nice	Pos	7.62	3.82	9.23	9	4
sortudo	lucky	Pos	7.50	5.45	0.22	7	3
útil	useful	Pos	7.41	4.49	29.48	4	2
vencedor	winner	Pos	7.79	6.58	56.97	8	3
vivo	alive	Pos	7.91	5.56	60.37	4	2

Note. EP = European Portuguese; E = English; Nr = Number; Freq = Frequency; Pos = Positive; Neu = Neutral; Neg = Negative. Ratings for valence and arousal varied between 1 and 9.