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PROBING THE INTERACTIONS BETWEEN SPEECH, IDENTITY, AND EMOTION

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(Secção de Psicologia Clínica e da Saúde / Núcleo de Psicoterapia Cognitiva-Comportamental e Integrativa)

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Dissertação orientada pela Professora Doutora Ana P. Pinheiro

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Abstract

Auditory verbal hallucinations (AVH) are a core symptom of psychotic disorders such as schizophrenia, although similar experiences have been widely reported in nonclinical samples. Due to these observations, a dimensional approach to the understanding of these symptoms has been in discussion: the continuum model of psychosis. One of its assumptions is that the experiences observed in both clinical and nonclinical groups rely on similar cognitive and neural mechanisms. For example, psychotic patients reveal impairments in the recognition of their own speech, often attributing it to an external source, particularly when it carries negative content. This could also be the case in nonclinical samples experiencing hallucinations, although more studies probing voice perception in these individuals are needed, to assess the existence of similar impairments. We recruited nonclinical participants with different scores on the Launay-Slade Hallucination Scale-Revised. They pre-recorded words and vocalizations that were subsequently used in a set of tasks. We assessed voice identity processing at both the discrimination and recognition levels, while taking into account the interactions between the three main voice dimensions: speech, identity, and emotion (Experiment 1). We also wanted to explore if these potential differences could be related to differences in the emotional evaluation of the voice stimuli (Experiment 2). Our results suggest that hallucinatory predisposition is associated with differences in the voice recognition processes: there was an association between lower performance in recognizing one's own speech and a higher predisposition for auditory hallucinations, particularly when listening to vocalizations not carrying semantic content. We did not find an association between these impairments and negative emotional content of the auditory stimuli, as observed in previous studies with patients. However, our study suggests that the processes involved in the recognition of self-produced vocal stimuli could underlie the experience of auditory hallucinations in nonclinical individuals.

Keywords: schizophrenia; auditory hallucinations; hallucination-proneness; voice discrimination; voice recognition

Resumo

Nos últimos anos, tem surgido um interesse cada vez maior no estudo de manifestações sintomáticas observadas em camadas não-clínicas da população (e.g., Broyd et al., 2016; Powers, Kelley, & Corlett, 2016). Este tipo de sintomas ou experiências, cuja descrição surge habitualmente ligada a perturbações diagnosticáveis, nem sempre estão associados a um mal-estar significativo nos indivíduos ou a uma necessidade de ajuda psicoterapêutica ou psiquiátrica (e.g., Daalman, Diederen, Hoekema, Lutterveld, & Sommer, 2016). Assim, ainda não é claro se estas manifestações – ou quais delas – estão associadas a fases mais precoces de uma perturbação, ou constituem simplesmente traços ou estados dos indivíduos sem um risco clínico (e.g., Johns et al., 2014; Yung et al., 2009). A progressão sintomática varia fortemente de indivíduo para indivíduo, e isto tem levado ao surgimento de novas abordagens dimensionais que possam alargar o estudo da psicopatologia além das categorias já existentes, contribuindo assim para a exploração da emergência transdiagnóstica dos sintomas (e.g., Nelson, McGorry, Wichers, Wigman, & Hartmann, 2017; iniciativa RDoC em Yee, Javitt, & Miller, 2015).

As perturbações psicóticas têm sido um foco deste tipo de abordagens mais dimensionais, uma vez que experiências habitualmente associadas a perturbações como a esquizofrenia – por exemplo, experiências anómalas na perceção de voz, similares a alucinações auditivas – têm vindo a ser observadas na população em geral, muitas vezes sem mal-estar associado (e.g., Strauss, 1969; van Os, 2003; Yung et al., 2009). Uma destas abordagens, que tem sido sujeita a uma vasta discussão na literatura científica, é o modelo do contínuo das experiências psicóticas (e.g., Badcock & Hugdahl, 2012; van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009). Este modelo sugere que a experiência deste tipo de sintomas se distribui ao longo de um contínuo entre o funcionamento saudável e o funcionamento psicopatológico, não estando necessariamente associada à presença de perturbação (van Os et al., 2009). Além disso, o modelo sugere também que os sintomas das populações clínica e não-clínica poderão ter subjacentes os mesmos mecanismos cognitivos e neurológicos (Badcock & Hugdahl, 2012). Contudo, são necessários mais estudos que ajudem a esclarecer se estamos a discutir o mesmo tipo de experiências, com as mesmas origens, nestas diferentes camadas da população.

Um dos sintomas comuns em perturbações psicóticas, como a esquizofrenia, que tem sido reportado em indivíduos sem perturbação são as alucinações auditivas verbais (e.g., Daalman et al., 2011; Sommer et al., 2010). Vulgarmente descritas como "ouvir vozes", estas experiências ocorrem sem qualquer estimulação externa (American Psychiatric Association, 2013). Embora existam vários modelos explicativos para a sua origem, um dos mais relevantes é o que associa estas experiências a anomalias no processamento da voz, particularmente da voz do próprio indivíduo (ver Conde, Gonçalves, & Pinheiro, 2016a para uma revisão). Estudos com pacientes com esquizofrenia, e que sofrem de alucinações auditivas, têm revelado que estes têm maior dificuldade em reconhecer a sua própria voz quando ouvem excertos auditivos da mesma, muitas vezes atribuindo-a a uma fonte externa (e.g., Allen et al., 2004; Johns et al., 2001). Este viés externalizante parece ainda acentuar-se com a severidade das alucinações destes pacientes, bem como quando o conteúdo dos excertos ouvidos é negativo ou injurioso (Pinheiro, Rezaii, Rauber, & Niznikiewicz, 2016). Este é um exemplo do tipo de anomalias de perceção de voz que requer estudos com amostras não-clínicas que reportem experiências alucinatórias semelhantes. É importante averiguar a existência do mesmo tipo de alterações no processamento da voz destes sujeitos, de forma a perceber se os mesmos mecanismos cognitivos e neurológicos lhes estão subjacentes.

Ao estudar perceção de voz, devem ser tidos em conta não só diferentes níveis de processamento, como também os diferentes tipos de informação contida nos estímulos vocais (e.g., Belin, Fecteau, & Bédard, 2004; van Lancker & Kreiman, 1987). Vários estudos com pacientes que sofreram lesões cerebrais sugerem que a discriminação e o reconhecimento da identidade da voz podem ser vistos como dois níveis de processamento distintos, podendo ser estudados em separado (e.g., van Lancker & Kreiman, 1987; van Lancker, Kreiman & Cummings, 1989). A discriminação de voz é maioritariamente feita com recurso às propriedades acústicas dos estímulos vocais (processos mais *bottom-up*; e.g., Chhabra, Badcock, Maybery, & Leung, 2014), enquanto que o reconhecimento envolve a integração de informação específica sobre a identidade de quem produziu esses estímulos vocais, recrutando mais recursos atencionais (processos mais *top-down*; e.g., Conde, Gonçalves, & Pinheiro, 2015; Sohoglu, Peelle, Carlyon, & Davis, 2012). No processamento da voz estão ainda envolvidos diferentes tipos de informação linguística e paralinguística, que dizem respeito ao discurso/conteúdo semântico, à identidade, e à emocionalidade (e.g., Belin et

al., 2004; Schirmer & Adolphs, 2017). O nosso estudo teve em conta todos estes aspetos, estudando a perceção de voz de uma amostra não-clínica e composta por participantes com níveis variados de predisposição para experiências alucinatórias.

Neste estudo participaram 32 indivíduos recrutados através das suas pontuações (baixas, intermédias e altas) na Escala de Alucinações de Launay-Slade Revista (adaptação portuguesa de Castiajo & Pinheiro, 2017; Larøi & van der Linden, 2005; originalmente desenvolvida por Launay & Slade, 1981). Este é um instrumento que tem sido usado previamente em estudos sobre a prevalência de experiências alucinatórias nas populações clínica e não-clínica (e.g., Morrison et al., 2000; Serper, Dill, Chang, Kot, & Elliot, 2005). Numa primeira sessão, os participantes gravaram excertos da sua própria voz, que envolviam tanto palavras como vocalizações. Mais tarde, numa segunda sessão, os participantes realizaram duas experiências comportamentais com recurso a um computador. Na Experiência 1, foi pedido aos participantes que discriminassem ou reconhecessem a identidade de excertos de voz, que incluíam a sua própria voz e a voz de uma outra pessoa desconhecida. Nesta experiência, os julgamentos eram feitos explicitamente sobre a identidade dos estímulos, com as dimensões do discurso/conteúdo semântico e da emocionalidade dos estímulos a serem analisadas de forma implícita. Na Experiência 2, foi pedido aos participantes que avaliassem as propriedades emocionais dos estímulos apresentados. Nesta experiência, os julgamentos eram feitos explicitamente sobre as propriedades emocionais dos estímulos, com as dimensões do discurso/conteúdo semântico e da identidade dos estímulos a serem analisadas de forma implícita.

No que diz respeito à primeira experiência (foco na identidade dos estímulos), os nossos resultados apontam para diferenças nos processos de discriminação e reconhecimento da identidade da voz, relacionadas com os diferentes tipos de informação contida nos estímulos vocais. Na discriminação, os participantes apresentaram melhor desempenho quando ouviam palavras, do que quando ouviam vocalizações. Também apresentaram melhor desempenho quando os estímulos vocais envolviam a sua própria voz e quando envolviam conteúdo positivo. Estas diferenças não foram influenciadas pela variabilidade individual na predisposição para experiências alucinatórias. Contudo, foram também encontradas diferenças nos processos de reconhecimento da identidade da voz, essas sim influenciadas pela variabilidade na predisposição para experiências alucinatórias da nossa amostra. Uma análise de correlações subsequente revelou que, quanto maior a predisposição para

alucinações – particularmente, alucinações auditivas –, pior o desempenho no reconhecimento de vocalizações positivas e produzidas pelo próprio indivíduo.

Finalmente, no que diz respeito à segunda experiência (foco nas propriedades emocionais dos estímulos), os nossos resultados sugerem que existe uma tendência para avaliar de forma mais extrema (mais positiva ou mais negativa) vocalizações que envolvem a voz do próprio. Estas diferenças nos julgamentos dos participantes não foram, contudo, influenciadas pela variabilidade individual na predisposição para experiências alucinatórias.

Em suma, os nossos resultados têm implicações importantes para a discussão do modelo do contínuo das experiências psicóticas (e.g., Badcock & Hugdahl, 2012; van Os et al., 2009), particularmente no que diz respeito ao reconhecimento da identidade da voz e ao conteúdo semântico ou não dos estímulos. Os resultados apontam para uma associação entre o pior desempenho no reconhecimento de estímulos vocais produzidos pelo próprio – particularmente vocalizações, sem conteúdo semântico – e uma maior predisposição para alucinações. Isto vai ao encontro da observação prévia de défices nos processos de reconhecimento em pacientes psicóticos (e.g., Allen et al., 2004; Johns et al., 2001) e sugere que o reconhecimento da identidade da voz poderá ser um mecanismo subjacente tanto em grupos clínicos, como não-clínicos, que experienciam alucinações auditivas. Contudo, não foi encontrada uma associação entre a predisposição para experiências alucinatórias e um pior reconhecimento de estímulos com emocionalidade negativa, algo que foi previamente observado em estudos com pacientes (Pinheiro et al., 2016). Ainda assim, isto está também em linha com evidência prévia que sugere que a experiência de alucinações auditivas poderá estar mais relacionada com o processamento das dimensões da identidade e do discurso/conteúdo semântico, do que com o processamento da emocionalidade (ver Conde et al., 2016a para uma revisão).

Palavras-chave: esquizofrenia; psicoticismo; alucinações auditivas; perceção de voz; discriminação de voz; reconhecimento de voz

Contents

1. Introduction

1.1. Current debates on the onset of psychopathology

Recent years have seen a growing interest in the study of nonclinical manifestations of symptoms commonly observed in diagnosable disorders, though not necessarily posing a need for psychological healthcare (e.g., Broyd et al., 2016; Powers, Kelley, & Corlett, 2016). By focusing on individuals experiencing symptoms that do not meet the criteria for a DSM-V (American Psychiatric Association [APA], 2013) or ICD-10 (World Health Organization [WHO], 1992) diagnosis at a given moment, researchers have been trying to model and predict which subjects will progress to a diagnosable disorder (e.g., Cannon et al., 2016; Fusar-Poli & Schultze-Lutter, 2016). However, it remains unclear which of these manifestations are associated with prodromal stages of well-studied disorders, or that may simply represent transitory or stable traits not signaling clinical risk (e.g., Daalman, Diederen, Hoekema, Lutterveld, & Sommer, 2016; Johns et al., 2014; Yung et al., 2009). So far, research aiming to predict the onset of psychological disorders has mainly relied on single baseline assessments of a group of variables (e.g., clinical, neurocognitive, neurobiological, etc.) that may signal the level of risk for the emergence of a diagnosable disorder in the future (e.g., Cannon et al., 2016; Fusar-Poli & Schultze-Lutter, 2016). Some authors also highlight the need for more studies on psychopathological comorbidity, as well as of protective and risk factors (e.g., social and environmental) interacting with such nonclinical manifestations of symptoms (e.g., Binbay et al., 2012; Kounali et al., 2014; Peters et al., 2016; Powers et al., 2016).

In sum, the highly dynamic and changeable nature of psychopathology, and the observation of substantial variation in symptom development across individuals, has led to the discussion of novel approaches that can broaden the existing notion of independent and discrete categories and contribute to the exploration of a transdiagnostic emergence of symptoms (e.g., Nelson, McGorry, Wichers, Wigman, & Hartmann, 2017; RDoC iniciative in Yee, Javitt, & Miller, 2015).

Psychotic disorders have been in the scope of this more dimensional view, after years of observations of nonclinical unusual perceptual experiences (e.g., auditory hallucinations) within the non-help-seeking population (e.g., Strauss, 1969; van Os, 2003; Yung et al., 2009). One of the most prominent frameworks taking into account

the great individual variability of these experiences is the continuum model of psychosis, which has been subject to diverse conceptualizations and extended debate (e.g., Baumeister, Sedgwick, Howes, & Peters, 2017; Chhabra, Badcock, Maybery, & Leung, 2014; Lawrie, Hall, McIntosh, Owens, & Johnstone, 2010).

1.2. A continuum of psychotic experiences

Due to the observation of psychotic-like experiences in healthy subjects, a dimensional approach to the understanding of these symptoms has been in discussion. Based on the idea that positive psychotic symptoms exist on a continuum, with a disorder such as schizophrenia at one end and healthy functioning at the other, this approach is also commonly referred to as the continuum model of psychosis (e.g., Badcock & Hugdahl, 2012; van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009).

One of the assumptions of this model is that experiencing symptoms such as delusions (fixed beliefs about persecution, grandiosity, somatization, etc., that are resistant to change) and hallucinations (perceptive experiences that occur with no external stimulation) is not inevitably associated with the presence of a diagnosable disorder (APA, 2013; van Os et al., 2009). Empirical evidence suggests that association with a disorder might be dependent on symptom factors such as intrusiveness, frequency and psychopathological co-morbidities on the one hand, and personal/cultural factors such as coping, societal tolerance and degree of associated impairment on the other hand (Johns & van Os, 2001; van Os et al., 2009).

Another important assumption of the continuum model of psychosis is that the experiences in clinical and nonclinical samples, though varying in severity, rely on similar cognitive and neural mechanisms (e.g., Esterberg & Compton, 2009). Thus, studying hallucinatory experiences in nonclinical samples could help to unveil the essential cognitive and neural mechanisms underlying patients' hallucinations, with the advantage of avoiding confounding effects associated with medication, hospitalization and mental deterioration (Badcock & Hugdahl, 2012).

Although auditory verbal hallucinations are a core symptom of disorders such as schizophrenia (APA, 2013), similar abnormal voice perception experiences have been widely reported within the general population (e.g., Strauss, 1969; van Os, 2003; Yung

et al., 2009), raising the debate of whether they have the same underlying mechanisms (e.g., Badcock & Hugdahl, 2012).

1.3. Auditory verbal hallucinations and their expression at nonclinical levels

Hallucinations are defined as perception-like experiences that occur without external stimulation or voluntary control (APA, 2013). They are vivid and clear experiences that may occur in any sensory modality, despite not having corresponding sources in the external world (APA, 2013).

In the auditory modality, hallucinations are a heterogeneous phenomenon as they include a variety of phenomenological experiences (environmental sounds, noises, and musical hallucinations; e.g., Cole, Dowson, Dendukuri, & Belzile, 2002). However, auditory verbal hallucinations (AVH) represent their most common type (reviewed in Conde, Gonçalves, & Pinheiro, 2016a).

AVH are a core symptom of schizophrenia that can be persistent and resistant to antipsychotic medication (e.g., Shergill, Murray, & McGuire, 1998). They are most commonly experienced as familiar or unfamiliar voices, with usually more than one single voice being reported (APA, 2013; Larøi et al., 2012). Subjects more often report hearing words, although hallucinations may also consist of sentences and full conversations (Larøi et al., 2012). Even though no one is actually speaking, they are perceived as being distinct from the individual's own thoughts, giving them an intrusive character (APA, 2013). Hallucinated voices frequently have self-referential content, assuming the form of commands, criticisms or comments on patients' thoughts and actions (Nayani & David, 1996). Regarding the emotional content of AVH, voices heard by psychotic patients typically have a negative emotional tone (Freeman & Garety, 2003). In sum, similarly to externally generated voices, AVH carry information related to speech, identity and affect (Belin, Bestelmeyer, Latinus, & Watson, 2011; Belin, Fecteau, & Bédard, 2004; reviewed in Conde et al., 2016a).

However, it should be noted that AVH are not an exclusive symptom of schizophrenia. In fact, they are present in different types of disorders, such as psychiatric (e.g., depression and bipolar disorder; Rossell, Toh, Thomas, Badcock, & Castle, 2015), neurological (e.g., epilepsy; Serino et al., 2014), and personality-related disorders (e.g., borderline personality disorder; Slotema et al., 2012). Interestingly, it is now relatively accepted that hallucinations are also reported by individuals without a

diagnosed disorder (e.g., Daalman et al., 2011; Sommer et al., 2010) in what is commonly referred to as hallucinatory proneness (e.g., Chhabra et al., 2014) or hallucinatory predisposition (e.g., Morrison, Wells, & Nothard, 2000). Most of these hallucinatory experiences are transitory, although some persist and increase the risk of transition to clinical psychosis (van Os et al., 2009).

In a recent study, Castiajo and Pinheiro (2017) probed hallucination predisposition in a large Portuguese sample of non-help-seeking individuals (N = 354 college students). They relied on an adaptation of the Launay-Slade Hallucination Scale-Revised (Larøi & van der Linden, 2005; originally developed by Launay & Slade, 1981), which is a useful instrument to measure hallucinatory predisposition in both nonclinical (e.g., Morrison et al., 2000) and clinical individuals (e.g., Serper, Dill, Chang, Kot, & Elliot, 2005). The authors found out that 10% of the sample reported significant hallucinatory experiences (score > 35), with auditory hallucinations being reported by 13% of the subjects. The results also pointed to a relationship between hallucination predisposition and clinical symptomatology (schizotypal tendencies and negative mood), which might represent increased psychotic risk.

It is currently unclear if AVH in clinical and nonclinical individuals are indeed the same phenomenon. Interestingly, phenomenological comparisons between clinical and nonclinical AVH have been contributing to the discussion with mixed results. Some AVH features do not significantly differ between clinical and nonclinical groups: the perceived location of voices, the number of voices, loudness and attribution to a real person (Daalman et al., 2011). However, some studies suggest that several other features, such as frequency, emotional valence of beliefs and content, experience of control, age of onset and preponderance of male voices, distinguish AVH in patients with schizophrenia from those experienced by non-psychotic adults (e.g., Daalman et al., 2011; Lawrence, Jones, & Cooper, 2010). Another interesting feature of AVH in nonclinical individuals is that they are not necessarily associated with distress (Lawrence et al., 2010). For instance, hypnagogic and hypnopompic hallucinations, which respectively occur while falling asleep or waking up, are relatively common in the general population (APA, 2013). Hallucinations can even be a normal part of religious experience in certain cultural contexts (APA, 2013).

Taken together, the current data suggests that there may be only partial overlap in the AVH experiences of clinical and nonclinical samples. Further research is

necessary to shed light on the origin of these experiences, particular with nonclinical participants.

1.4. Voice information about speech, identity, and emotion

The analysis of vocal auditory stimuli relies on linguistic and paralinguistic cues related to the different dimensions of speech, identity and affect (see Figure 1; Belin et al., 2011; Belin et al., 2004; reviewed in Conde et al., 2016a). Evidence from neuroimaging studies suggest that these different types of vocal information might be processed in partially dissociated functional pathways (e.g., Belin & Zatorre, 2003; Morris, Scott, & Dolan, 1999; Scott, Blank, Rosen, & Wise, 2000). Therefore, the study of voice perception involves much more than exploring speech perception and the message it contains. A better understanding of the identity and affect dimensions is also essential (e.g., Belin et al., 2004).

Invariant voice features such as timbre, a quality directly influenced by physical factors such as age and gender, carry important information related to the identity of the speaker (e.g., Hartman & Danhauer, 1976; Lass, Hughes, Bowyer, Waters, & Bourne, 1976). Other types of cues that are more variable, such as regionally different accents, also allow us to infer particular features of the speaker (Belin et al., 2004). Furthermore, voices are a critical tool for the communication of emotion through prosodic modulations of the voice (e.g., Schirmer & Adolphs, 2017).

In the field of schizophrenia and auditory verbal hallucinations, there is evidence supporting an association between an altered voice-processing and psychotic symptoms such as AVH (e.g., behavioral studies by Johns, Gregg, Allen, & McGuire, 2006; Kerns, Berenbaum, Barch, Banich, & Stolar, 1999; neuroimaging studies by Allen et al., 2007; Plaze et al., 2006; reviewed in Conde et al., 2016a). The existing research suggests that the association between dysfunctional voice-processing and AVH in schizophrenia patients is apparently stronger for the identity and speech dimensions, than for the affective one. However, more studies are needed probing all three dimensions.

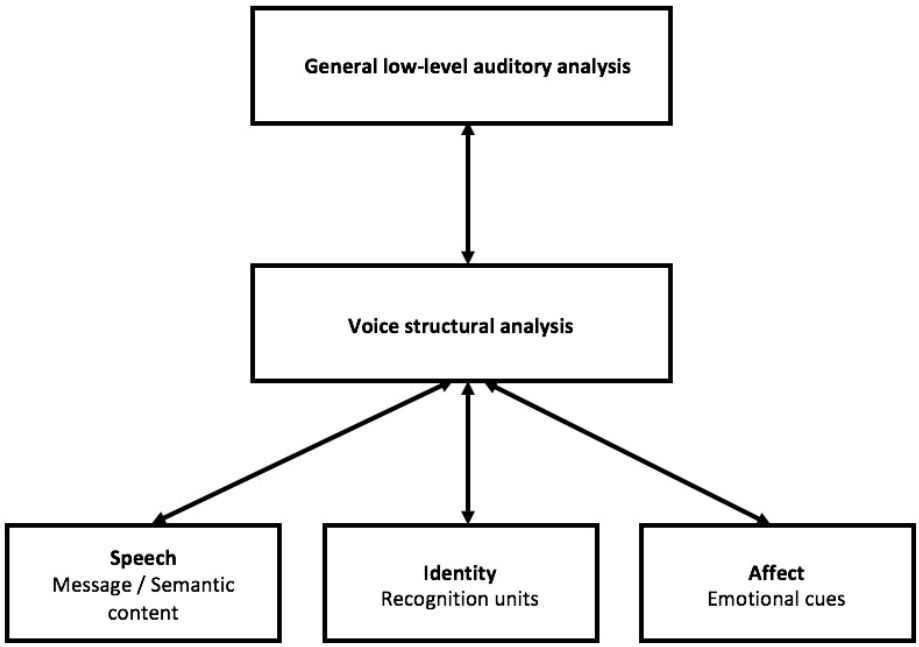

Figure 1. The model of voice perception proposed by Belin and his collaborators (2004), in which three partially dissociable functional pathways (that interact during normal voice processing) are engaged in the processing of three main types of vocal information: speech, identity, and affect. Adapted from Belin et al. (2004).

1.5. Voice recognition and discrimination processes: impairments associated with AVH

Taking into account the different types of cues carried by the voice, it can be useful to distinguish between different levels of voice processing when studying its underlying mechanisms. Voice discrimination and voice recognition processes can be conceptualized as two separate levels of processing (e.g., van Lancker & Kreiman, 1987; van Lancker, Kreiman & Cummings, 1989). Studies conducted with subjects suffering from brain lesions indicate that recognizing a familiar voice and discriminating among unfamiliar voices can be separately impaired functions. In a study by van Lancker and Kreiman (1987), familiar voice recognition was specifically impaired in cases of damage to the right hemisphere, while impaired unfamiliar voice discrimination was observed in cases of damage to either hemisphere. In another study, van Lancker and collaborators (1989) compared the recognition of familiar voices and discrimination of unfamiliar voices between patients with brain lesions and normal controls. The authors reported deficits in the recognition of familiar voices that were

significantly correlated with right-hemisphere damage. Discrimination of unfamiliar voices was worse in both clinical groups than in normal controls. Computerized tomographic scans indicated that right parietal-lobe damage was significantly correlated with a deficit in voice recognition, while temporal-lobe damage of either hemisphere was associated with a voice discrimination deficit.

Also, discrimination processes and recognition processes can be distinguished as respectively recruiting more *bottom-up* or more *top-down* processes (e.g., Conde, Gonçalves, & Pinheiro, 2015; Sohoglu, Peelle, Carlyon, & Davis, 2012). Whereas discrimination of two different auditory stimuli is generally based on their acoustic properties, recognition involves the integration between vocal stimuli and prior knowledge about the identity of the speaker (e.g., Sohoglu et al., 2012). Self-generated voice stimuli are processed differently from non-self stimuli, recruiting more attentional resources and having greater affective salience (Conde et al., 2015). Stimulus type (e.g., words vs. vocalizations) also appears to modulate the magnitude of attentional orientation to self- and non-self voices (Conde, Gonçalves, & Pinheiro, 2016b).

A prominent area of investigation into the origin of AVH explores deficits in verbal self-monitoring. Studies comparing schizophrenia patients experiencing hallucinations with healthy control subjects reveal that the former have more difficulty recognizing the source of their own speech, often attributing it to an external source (e.g., Allen et al., 2004; Johns et al., 2001). Johns and collaborators conducted a comparative study with schizophrenia patients, in which a group reported both auditory verbal hallucinations and delusions (*hallucinators*) and the other only experienced delusions (*non-hallucinators*) (Johns et al., 2001). Patient groups were compared with each other and with a control group of healthy subjects, in a task in which they should read single adjectives aloud. They were assigned to one of four randomized conditions: 1) reading aloud, 2) reading aloud while hearing an acoustic distortion of their own voice, 3) reading aloud while hearing someone else's voice as feedback, and 4) reading aloud while hearing an acoustic distortion of someone else's voice as feedback. Immediately after reading each adjective and simultaneously listening to voice feedback, they were asked to decide about the source of the speech they heard (*self* vs. *other* vs. *unsure*), by pressing a button. Both *hallucinators* and *non-hallucinators* revealed impaired verbal self-monitoring when reading aloud and simultaneously receiving distorted feedback of their own voice. However, *hallucinators* (patients with both AVH and delusions) were particularly prone to misattributing their own voice to

someone else when the voice stimuli were distorted. This group was also more likely to provide a wrong answer when the words presented were derogatory. The authors suggested that this tendency could reflect an impaired awareness of internally generated verbal material.

Another prominent study investigating the impaired self-monitoring hypothesis came from Allen and collaborators, some years later (Allen et al., 2004). The researchers suggested that the deficits reported in behavioral studies due to impaired self-monitoring could also result from an externalizing response bias. Participants in this study were patients with hallucinations and delusions, patients not currently experiencing hallucinations and delusions, and healthy control subjects. They were asked to make judgments about the source of pre-recorded speech, which consisted of words recorded by the participant himself or somebody else. These speech stimuli were either distorted or undistorted. After hearing each word, participants should decide if the speech they heard was or was not their own, by pressing a button (buttons were marked as *self* vs. *other* vs. *unsure*). Allen and his colleagues argued that since the task did not involve the generation of verbal material (speaking/reading) in the moment, performance did not require verbal self-monitoring. Patients with hallucinations and delusions were more likely to make external misattributions about the source of their own distorted speech than controls and patients not experiencing hallucinations and delusions. In this study, the tendency to misattribute distorted self-generated speech to an external source was strongly associated with hallucinations as opposed to delusions or positive symptoms in general. The authors concluded that hallucinations and delusions are related to an externalizing bias in the processing of sensory material, being not solely a function of defective self-monitoring. However, they also noted that they could not exclude the possibility that subjects may have been covertly generating the words as they heard them.

Recently, Pinheiro and collaborators conducted a study that probed the interactions between voice identity, voice acoustic quality, and semantic valence in a self-other voice recognition task (Pinheiro, Rezaii, Rauber, & Niznikiewicz, 2016). They compared schizophrenia patients with healthy control subjects in a task involving methodological aspects present in experiments such as the one's from Johns and collaborators (2001) or Allen and his colleagues (2004). Participants' voice was recorded in a first session, in which they read aloud a list of adjectives with emotional or neutral content. In a second session, they were asked to perform a behavioral task in

which they heard the recorded adjectives and had to indicate if they were spoken in their own voice, another person's voice, or if they were unsure. Manipulation was based on identity (self vs. non-self), acoustic quality (undistorted vs. distorted), and semantic valence (negative vs. positive vs. neutral). A particular difference emerged in the recognition of self-generated speech associated with emotional content: the externalizing bias reported in patients was only significant in the case of speech with negative content. The authors argue that this supports a negativity bias in the misattribution errors of voice recognition in schizophrenia, with the externalizing errors reported in previous studies (e.g., Allen et al., 2004) not being generalizable to all types of self-generated speech. This is an emotion-specific finding that suggests that patients experiencing auditory hallucinations may be particularly prone to attribute negative speech to an external source (as also suggested in Johns et al., 2001). Additionally, it is worth noting that the results pointed to an association between this impairment and the severity of the auditory hallucinations of the patients: the greater the severity, the greater the impairment.

However, abnormalities in voice identity processing might be specific of schizophrenia patients experiencing AVH. For example, in a different study by Chhabra and collaborators (2014), the authors probed voice discrimination processes in hallucination-prone individuals. Identity perception was compared between high and low hallucination-prone individuals, in a task in which they were asked to discriminate between different unfamiliar voices presented in pairs. The authors did not find significant differences in identity discrimination when comparing the two groups, thus arguing that nonclinical individuals with hallucinatory predisposition do not show the impairments observed in schizophrenia patients. This challenges the continuum model of psychotic symptoms, particularly its assumption that hallucinations in different groups would share the same underlying mechanisms. Although this study is important for testing nonclinical individuals, there are still few studies examining voice recognition in this population.

1.6. **Processing of different types of voice stimuli**

Speech information carried by the voice (e.g., semantic content of words) is essential for human communication. However, speech is relatively recent in human evolution (Belin et al., 2004). Before that, vocalizations that did not involve verbal or

semantic content were already important in communication, carrying different types of information (Belin et al., 2004; Petkov et al., 2008). These vocalizations are still commonly heard in everyday-life and help us to process relevant information: if we hear a non-verbal vocalization, even though it does not contain speech information, we are still able to extract information about the identity and the affective state of the person producing it (Belin et al., 2004; Russ, Ackelson, Baker, & Cohen, 2008).

Emotions are not only communicated via verbal and semantic information (e.g., semantic valence), but also through prosodic modulations of the voice. As discussed in a recent review by Schirmer and Adolphs (2017), vocal expressions such as screams, sobs, and laughs (often referred to as vocalizations) can be dissociated from verbal content and are often affected by physiological changes such as breathing and muscle tone (Banse & Scherer, 1996; Shirmer & Adolphs, 2017). Some acoustic parameters associated with vocalizations, such as loudness, melody, and voice quality (e.g., roughness), show a robust relationship with perceived speaker affect (e.g., Bänziger, Hosoya, & Scherer, 2015). Moreover, emotional vocalizations produce greater activation in voice areas than do neutral vocalizations (e.g., Mothes-Lasch, Mentzel, Miltner, & Straube, 2011).

More studies using vocalizations as stimuli are needed to explore differences in voice perception as a function of verbal vs. non-verbal content, thus testing the speech dimension of the voice. This is particularly relevant in the case of subjects experiencing auditory hallucinations or abnormal voice perception.

1.7. The current study and hypotheses

The goal of this study was to explore differences in voice identity processing of a sample of individuals varying in hallucinatory predisposition. Additionally, we also wanted to explore if these potential differences could be related to differences in the emotional evaluation of the voice stimuli. For that, we conducted two experiments: one in which we analyzed accuracy rates in voice discrimination and voice recognition tasks; a different one in which we analyzed participants' emotional ratings of the stimuli.

Our first experiment aimed at exploring if individual variability in hallucinatory predisposition modulates voice identity perception at two different levels: discrimination and recognition. Individual predisposition was assessed using the

Portuguese adaptation of the Launay-Slade Hallucination Scale-Revised (Castiajo & Pinheiro, 2017). Interactions between the three main voice dimensions of speech, identity, and affect were taken into account in all tasks.

Discrimination and recognition processes are thought to recruit different *bottom-up* and *top-down* resources, respectively. Besides, recognizing one's own voice is critical for successful verbal self-monitoring (e.g., Conde et al., 2016b). Following previous studies, although there may not be differences in discrimination processes (e.g., Chhabra et al., 2014), we expect differences in the voice recognition domain, as reflected in an association between higher hallucinatory predisposition and lower accuracy in voice recognition tasks. Impairments in voice recognition processes, associated with a higher hallucinatory predisposition, would match the observations in schizophrenia patients experiencing hallucinations (e.g., Allen et al., 2004; Johns et al., 2001; Pinheiro et al., 2016), thus having important implications for the comprehension of hallucinatory predisposition as a *continuum* (e.g., Badcock & Hugdahl, 2012; van Os et al., 2009).

Following previous studies with psychotic patients, we also expected an interaction between voice identity and emotion, with lower accuracy in the recognition processes of self-produced stimuli with negative content, modulated by hallucinatory predisposition (e.g., Johns et al., 2001; Pinheiro et al., 2016).

Finally, we used words and vocalizations in both discrimination and recognition tasks to probe the effects of stimulus type. We expected differences in the voice processing of these two types of stimuli, allowing a dissociation between semantic and non-semantic content (e.g., Hartman & Danhauer, 1976; Lass et al., 1976; Russ et al., 2008; reviewed in Schirmer & Adolphs, 2017). Vocalizations were expected to be associated with lower discrimination and recognition accuracy rates, due to the fact that they do not carry the speech information contained in words (e.g., Belin et al., 2004; Russ et al., 2008).

In our second experiment, we aimed at understanding whether potential differences in voice identity processing in Experiment 1 were related to differences in the emotional evaluation of the voice stimuli. Thus, we asked participants to explicitly rate the emotionality of the voice stimuli used in Experiment 1. We expected more extreme valence ratings on self-produced speech (negative stimuli rated as more negative and positive stimuli rated as more positive), following previous studies suggesting that it can be more affectively salient (e.g., Conde et al., 2015). We also

expected that individual hallucinatory variability influenced participants' judgments, with higher hallucinatory predisposition being associated with more negative and more positive valence ratings for self-generated stimuli.

2. Method

2.1. Participants

Participants were recruited based on total scores of the Launay-Slade Hallucination Scale-Revised (Portuguese adaptation by Castiajo & Pinheiro, 2017; Larøi & van der Linden, 2005; originally developed by Launay & Slade, 1981).

Before, a total of 481 participants filled in an online version of the scale, which was developed using the Qualtrics platform and disseminated through email and social networks. Participants gave their informed consent prior to participation and were told that the study aimed at adapting and validating a questionnaire for the Portuguese population, and that some of them would be randomly invited to participate in a second study about voice perception. To encourage participation, a voucher was drawn.

The questionnaire had a total of 33 items, that included the Portuguese adaptation of the Launay-Slade Hallucination Scale-Revised (LSHS; 16 items; see Appendix A). Items on the LSHS tap into different forms of hallucinations: auditory, visual, olfactory, tactile, hypnagogic, and hypnopompic. The Portuguese adaptation of the LSHS is characterized by high internal validity, as well as by high internal consistency and reliability (Castiajo & Pinheiro, 2017). This scale is appropriate to objectively assess hallucinatory experiences in the nonclinical population and it was previously adapted for various other languages (e.g. Dutch by Aleman, Nieuwenstein, Böcker, & de Hann, 2001; Spanish by Fonseca-Pedrero et al., 2010; French by Larøi, Marczewski, & van der Linden, 2004; Italian by Vellante et al., 2012).

Total scores were calculated considering the items tapping into hallucinatory experiences and ranged between 0 and 64, with higher scores indicating higher hallucination predisposition. After responding to all items, participants were asked if the experiences for which they had reported higher scores occurred under the influence of one or more substances such as medication, alcohol, cannabis/marijuana, hashish or other narcotic products. Participants were excluded if they were under the age of 18 years or if they reported consumption of medication/drugs.

From the pool of online answers obtained, 32 participants participated in the study (M_{age} = 28.88, SD_{age} = 8.55, 22 females, 10 males). LSHS scores varied between low and high total scores (*Min* = 0; *Max* = 61). All participants reported normal hearing and had European Portuguese as their native language. They were contacted via email

or phone to participate in two individual sessions, and a general explanation of the procedures was given prior to participation.

2.2. Experimental sessions

Session 1 was dedicated to voice recording and clinical evaluation of the participants. The total duration of the session was of approximately 60 minutes. Participants gave their written consent for participation (according to the Declaration of Helsinki; World Medical Association [WMA], 2001), as well as for the recording of their voices in digital audio format. They were then asked to read a set of words that were previously validated on their affective properties, as well as to produce different types of emotional vocalizations while their voice was being recorded for use in the next session. At the end, participants were asked to fill in the Brief Symptoms Inventory (BSI; Portuguese adaptation by Canavarro, 1999; Derogatis & Spencer, 1982) and the Schizotypal Personality Questionnaire (SPQ; Raine, 1991; Portuguese adaptation by Santos, 2011). See Appendix B for a description of individual scores on the clinical instruments.

In Session 2, participants performed six different behavioral tasks in a computer, divided in two experiments. The duration of this session was of approximately 90 minutes, with several breaks to minimize fatigue and distraction. Computer tasks were programed using the E-Prime 2.0 software (Psychology Software Tools).

Both sessions were conducted in a sound-isolated studio, in different days. There was not a defined interval of days between the first and the second session.

2.3. Material

2.3.1. Stimuli

The set of stimuli recorded in Session 1 and used in the experimental tasks of Session 2 was composed of words and vocalizations.

Sixty words were selected based on valence ratings (20 positive, 20 neutral, 20 negative), from a pool of 192 previously validated words. Mean valence ratings were obtained through an online form developed using the Qualtrics platform and disseminated through email and social networks. A total of 130 participants filled in the

survey, in which they were asked to subjectively rate a set of words on their affective dimensions (valence, arousal, and dominance) using a pictorial 9-point *Likert* scale (Self-Assessment Manikin; Bradley & Lang, 1994)[1], a process previously used in other word validation studies (e.g., English words by Bradley & Lang, 1999; Spanish words by Ferré, Guasch, Moldovan, & Sánchez-Casas, 2012; Portuguese Words by Soares, Comesaña, Pinheiro, Simões, & Frade, 2012). Selected words were then controlled for frequency, number of letters, and number of syllables. A one-way ANOVA was computed using the IBM SPSS Statistics software to ensure that the selected words did not differ significantly ($p>.05$) on these properties across conditions.

Forty vocalizations per subject (20 positive/20 negative; 10 anger/10 sadness/10 happiness/10 pleasure) were obtained in Session 1, in which participants reacted to videos or sentences that depicted situations of everyday life. Vocalizations' duration did not exceed 2 seconds.

2.3.2. Recording material

Recordings were conducted in a sound-isolated studio, using a M-Audio NOVA large-capsule condenser microphone connected to a computer via a M-Audio Firewire 410 recording interface. A pop filter was attached to the microphone in order to reduce noise caused by the mechanical impact of fast moving air during speech production. Adobe Audition 1.5 software was used for audio recording. All audio files were recorded with a sampling rate of 44,100 kHz and 16-bit quantization. When listening to sound, participants wore a pair of Sennheiser HD 265 Linear headphones.

2.4. Procedure

2.4.1. Voice recording

Participants were comfortably sat in front of a computer screen, wearing headphones. First, they were asked to record the pre-selected 60 words (see Appendix C). Words were presented individually and in written form in the center of the screen.

[1] The norms obtained with this validation study will be used to expand an existing dataset (ANEW; Bradley & Lang, 1999; validated for the European Portuguese by Soares et al., 2012) and will be published elsewhere.

Before seeing each word, participants heard an audio reproduction by a 22-year-old male 'voice-model' who read it at a regular speed, regular volume, and with neutral intonation. Participants were asked to match the model's reading of the words and to read each one a minimum of three times. The aim was to control for prosody variability in participants' recordings and to select the utterance that better matched the voice-model.

After recording the words, participants were asked to record a set of vocalizations differing in emotional category. A set of six videos and six written sentences illustrating real-life scenarios were presented on a computer screen to facilitate the production of such vocalizations (see Appendices D and E). This is a procedure previously used in other studies in which batteries of vocalizations were created and validated (e.g. Lima, Castro, & Scott, 2013). Both videos and sentences were labeled with the corresponding emotion: Anger, Disappointment, Sadness, Happiness, Amusement, or Pleasure.

Participants were asked to produce vocalizations in response to the videos or after reading each sentence. They were reminded that the sounds should not include words or have any type of verbal content[2]. If the videos and sentences did not spontaneously elicit an emotional reaction, participants were asked to imagine themselves in that situation and to react with the sounds they would normally produce in such conditions. To minimize discomfort or embarrassment, as well as to enhance realness of vocalizations, the experimenter was not present during production and previously informed participants about the sound-isolation properties of the recording room.

Prior to participants' recruitment, two participants were invited to record their voice using the same procedure (a 22-year-old male voice for male participants, and a 20-year-old female voice for female participants). These voices were unknown to the other participants and were used as 'non-self' voices in the experimental tasks. The same voice-model was used for all recordings.

[2] Interjections such as *hey, yeah*, or *epá* are commonly used to express emotion as part of an individual's speech. However, since they may be considered as having verbal content, participants were asked to avoid them.

2.4.2. Sound editing

After the voice recording session, recordings of each word and vocalization were segmented using Praat software. For each word, the utterance that better matched the voice-model was selected. Each vocalization was selected to match the duration of the Non-Self vocalizations, to prevent and control for differences in voice perception motivated by different stimulus duration across conditions. Independent Samples *t*-tests were computed with the IBM SPSS Statistics software to ascertain that vocalizations' duration did not differ significantly ($p>.05$) between conditions. When duration times did not follow a normal distribution, the corresponding non-parametric Mann-Whitney U test was used.

Audacity software was used for noise reduction and voice stimuli were normalized according to peak amplitude by means of a Praat script.

2.4.3. Experiment 1: Focus on voice identity

In these tasks, participants were asked for explicit judgments of the Identity properties of stimulus. Effects of information related to Emotion and Speech (verbal vs. non-verbal content) were analyzed implicitly.

2.4.3.1. Task 1: Voice discrimination using words

In this task, participants listened to a total of 180 pairs of words that included the 60 pre-selected words. Before listening to each pair of words, a fixation cross was presented in the center of the screen for 1500 milliseconds (ms), and it was kept during audio presentation. Then, participants heard two different words and were asked to decide if the same voice/person produced both words, as illustrated in Figure 2, by pressing one of two keys marked with "=" (same voice/person) or "≠" (different voices/persons). A question mark appeared on the screen after word presentation, indicating that participants could give their response. There was a 6 seconds (s) response period and a 1000 ms inter-stimulus interval that preceded the presentation of the next pair of words. Participants were given five practice trials with response feedback, as well as a resting pause every 20 trials.

Pairs of words were arranged to fulfill both specific Identity and Valence

conditions. There were three different Identity conditions: for each pair, participants either heard 1) their own voice on both words (congruent Self condition; 60 pairs), 2) the Non-self voice on both words (congruent Non-self condition; 60 pairs), or 3) one of these voices on each word (incongruent condition; 60 pairs). Three different Valence conditions were also present within these pairs: participants either heard 1) a pair of positive words (60 pairs), 2) a pair of neutral words (60 pairs), or 3) a pair of negative words (60 pairs).

All conditions were manipulated at the within-subjects level, with participants hearing and responding to all of the 180 pairs of words. Pairs were presented in a randomized manner and their arrangement made sure that both words were different to prevent a facilitation effect related with hearing the same word repeatedly or in the same voice. Incongruent pairs were divided into pairs beginning with the participants' own voice (Self - Non-self) or with the Non-self voice (Non-self – Self).

2.4.3.2. Task 2: Voice recognition using words

In this task, participants listened to a total of 120 individual words. Before listening to each word, a fixation cross was presented in the center of the screen for 1500 ms, and it remained on the screen during sound presentation. Then, participants heard a single word and were asked to decide if they had listened to their own voice, to another person's voice, or if they were unsure, as illustrated in Figure 2. They were instructed to press one of three keys marked with "E" (*Eu*, the Portuguese word for *Me*), "O" (*Outro*, the Portuguese word *for Other*), or "NS" (*Não sei*, the Portuguese translation of *I don't know*). A question mark appeared on the screen after word presentation, indicating that participants could give their response. There was a 6 s response period and a 1000 ms inter-stimulus interval that preceded the presentation of the next word. Participants were given five practice trials with response feedback, as well as a resting pause every 20 trials.

Words were arranged to fulfill both specific Identity and Valence conditions. There were two different Identity conditions: for each word, participants either heard 1) their own voice (Self condition; 60 words), or 2) the Non-self voice (Non-self condition; 60 words). Three different Valence conditions were also present within these words: participants either heard 1) a positive word (40 words), 2) a neutral word (40 words), or 3) a negative word (40 words).

All conditions were manipulated at the within-subjects level, with participants hearing and responding to all of the 120 words. Words were randomly presented.

2.4.3.3. Task 3: Voice discrimination using vocalizations

In this task, participants listened to a total of 120 pairs of vocalizations. Presentation and response procedures were the same used in Task 1 (voice discrimination using words), as illustrated in Figure 2. The arrangement of pairs of vocalizations also followed the same procedure used in Task 1.

They were arranged to fulfill specific Identity, Valence, and Emotional Category conditions. There were three different Identity conditions: for each pair, participants either heard 1) their own voice in both vocalizations (congruent Self condition; 40 pairs), 2) the Non-self voice in both vocalizations (congruent Non-self condition; 40 pairs), or 3) one of these voices for each vocalization (incongruent condition; 40 pairs). Two different Valence conditions were present: participants either heard 1) a pair of positive vocalizations (60 pairs), or 2) a pair of negative vocalizations (60 pairs). Within the Valence condition, participants also heard pairs of vocalizations pertaining to different emotional categories: Anger (30 pairs), Sadness (30 pairs), Happiness (30 pairs), and Pleasure (30 pairs).

All conditions were manipulated at the within-subjects level, with participants hearing and responding to all of the 120 pairs of vocalizations. Pairs were presented in a randomized manner.

2.4.3.4. Task 4: Voice recognition using vocalizations

In this task, participants listened to a total of 80 vocalizations. Presentation and response procedures were the same used in Task 2 (voice recognition using words), as illustrated in Figure 2.

Vocalizations were arranged to fulfill specific Identity, Valence, and Emotional Category conditions. There were two different Identity conditions: for each vocalization, participants either heard 1) their own voice (Self condition; 40 vocalizations), or 2) the Non-self voice (Non-self condition; 40 vocalizations). Two different Valence conditions were presented: participants either heard 1) a positive vocalization (40 vocalizations) or 2) a negative vocalization (40 vocalizations). Within

the Valence condition, participants also heard vocalizations pertaining to different emotional categories: Anger (20 vocalizations), Sadness (20 vocalizations), Happiness (20 vocalizations), and Pleasure (20 vocalizations).

All conditions were manipulated at the within-subjects level, with participants hearing and responding to all of the 80 vocalizations. Vocalizations were presented in a randomized manner.

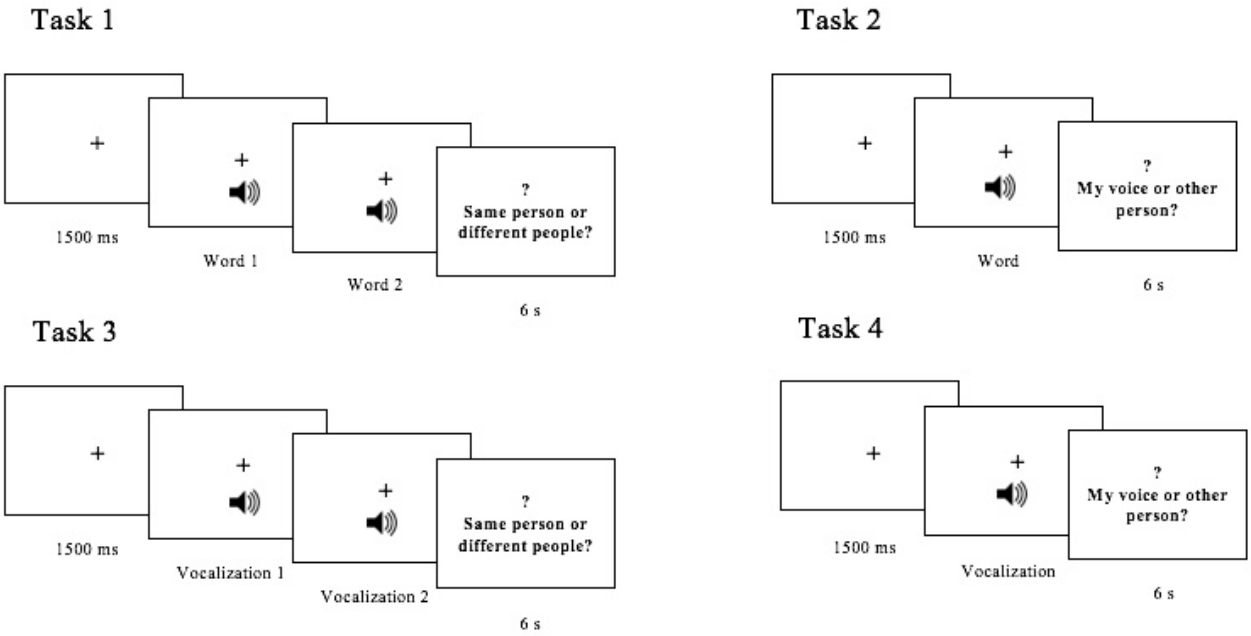

Figure 2. Presentation paradigm used for the behavioral tasks of Experiment 1.

2.4.4. Experiment 2: Focus on emotion

Whereas in Experiment 1 participants were asked for judgments on the source of the voice stimuli (with the effects of emotional properties being analyzed implicitly), in this experiment they were asked for an explicit judgment of the emotional properties of stimuli. The first goal was to obtain participants' semantic valence ratings of the words used in this study. Participants' mean ratings for positive, neutral, and negative words were then compared with mean ratings obtained in the previous validation of those words. A second goal was to obtain participants' valence ratings of the vocalizations

used in this study, while also exploring the existence of differences related with previously defined emotional and identity properties.

2.4.4.1. Task 1: Ratings of words' valence

In this task, participants were asked to assess each of the 60 different words they had listened to on their emotional valence.

Each word was presented on the screen, individually and in written form. Beneath each word, the question "How would you rate this word?" was presented, accompanied by a 9-point *Likert* scale. The scale ranged from 1 (Extremely negative) to 9 (Extremely positive).

Participants were asked to provide their own subjective ratings, as opposite to the ratings they felt people would commonly use. There was no time-limit for the response. Participants were given a resting pause every 20 trials.

2.4.4.2. Task 2: Ratings of vocalizations' valence

In this task, participants were asked to assess each of the 80 different vocalizations they had listened to in valence.

Before listening to each vocalization, a fixation cross was presented in the center of the screen for 1500 ms, and it remained on the screen during sound presentation. Then, the question "How would you rate this vocalization?" was presented, accompanied by a 9-point *Likert* scale. The scale ranged from 1 (Extremely negative) to 9 (Extremely positive).

Participants were asked to provide their own subjective ratings, as opposite to the ratings they felt people would commonly use. There was no time-limit for the response. Participants were given a resting pause every 20 trials.

2.5. Statistical analyses

2.5.1. Experiment 1

All analyses for the accuracy rates across conditions were performed using the IBM SPSS Statistics software. Trials in which participants did not provide an answer

before the time limit, as well as "unsure" responses, were not included in the analyses. Accuracy data were analyzed with repeated-measures analyses of variance (ANOVAs). In the analysis of voice discrimination, the within-subject factors (independent variables) of Identity (Self – Self, Non-self – Non-self, Self – Non-self) and Emotion (Positive, Neutral, Negative for words; Positive, Negative for vocalizations[3]) were tested. In the analysis of voice recognition, the within-subject factors of Identity (Self, Non-self) and Emotion (Positive, Neutral, Negative for words; Positive, Negative for vocalizations) were examined.

Additionally, we tested the effect of Stimulus Type (words and vocalizations) on accuracy rates. An additional repeated-measures ANOVA examined the within-subject factors of Stimulus Type (Words, Vocalizations), Identity (Self, Non-self), and Emotion (Positive, Negative), for both voice discrimination and recognition.

Participants' individual total scores on the LSHS were included as a covariate in all analyses.

2.5.2. Experiment 2

For the valence ratings of words, two paired-samples t-tests were performed. First, a paired-samples *t*-test compared participants' mean ratings for positive words, neutral words, and negative words. Then, an additional paired-samples *t*-test compared both the mean valence ratings previously obtained in our validation and the mean valence ratings obtained from the participants.

For the valence ratings of vocalizations, a repeated-measures ANOVA was performed with participants' valence ratings for vocalizations as the dependent variable. The within-subjects factors (independent variables) considered were Emotion (Positive, Negative) and Identity (Self, Non-self). Participants' individual total scores on the LSHS were included as a covariate.

[3] The effects of *Emotion Category* with four levels for vocalizations (Anger vs. Sadness vs. Happiness vs. Pleasure) were also tested. However, this deeper level of analysis in terms of emotion did not produce any significant effects, which were not analyzed further, and are not reported here.

3. Results

3.1. Experiment 1

3.1.1. Voice discrimination

3.1.1.1. Words

There was not a significant main effect of Identity [$F(2,60)=1.251$, $p=.294$], nor significant interaction effects involving this factor ($p>.05$).

The effect of Emotion was statistically significant [$F(2,60)=4.313$, $p=.018$, *partial* $\eta^2=.126$], pointing to an increase tendency in accuracy, from pairs of negative words ($M=0.960$), to pairs of neutral words ($M=0.969$), to pairs of positive words ($M=0.971$). However, paired-samples *t*-tests were used to explore these differences, and no significant differences were found [Positive-Neutral: $t(31)=0.602$, $p=.552$; Positive-Negative: $t(31)=1.794$, $p=.083$; Neutral-Negative: $t(31)=1.364$, $p=.182$]. There were no significant interaction effects involving the Emotion factor ($p>.05$).

The effect of the covariate was not significant [$F(1,30)=0.710$, $p=.406$].

3.1.1.2. Vocalizations

The effect of Identity was statistically significant in the case of vocalizations [$F(2,60)=6.264$, $p=.003$, *partial* $\eta^2=.173$]. Paired-samples *t*-tests were used to explore these differences. Participants were significantly more accurate when discriminating voice identity in pairs of self-generated vocalizations (Self – Self; $M=0.843$) than in pairs of non-self vocalizations (Non-self – Non-self; $M=0.718$) [$t(31)=4.499$, $p<.001$]. They were also significantly more accurate when discriminating voice identity in pairs mixing self-generated and non-self vocalizations (Self – Non-self; $M=0.806$) than in pairs of non-self vocalizations (Non-self – Non-self; $M=0.718$) [$t(31)=-3.042$; $p=.005$] (see Figure 3). There were no significant interaction effects involving Identity ($p>.05$).

The effect of Emotion was also significant [$F(1,30)=5.104$, $p=.031$, *partial* $\eta^2=.145$], revealing that participants were significantly more accurate when discriminating between positive vocalizations ($M=0.825$) than between negative

vocalizations (*M*=0.751) (see Figure 3). There were no significant interaction effects involving Emotion (*p*>.05).

The effect of the covariate was not significant [*F*(1,30)=1.609, *p*=.214].

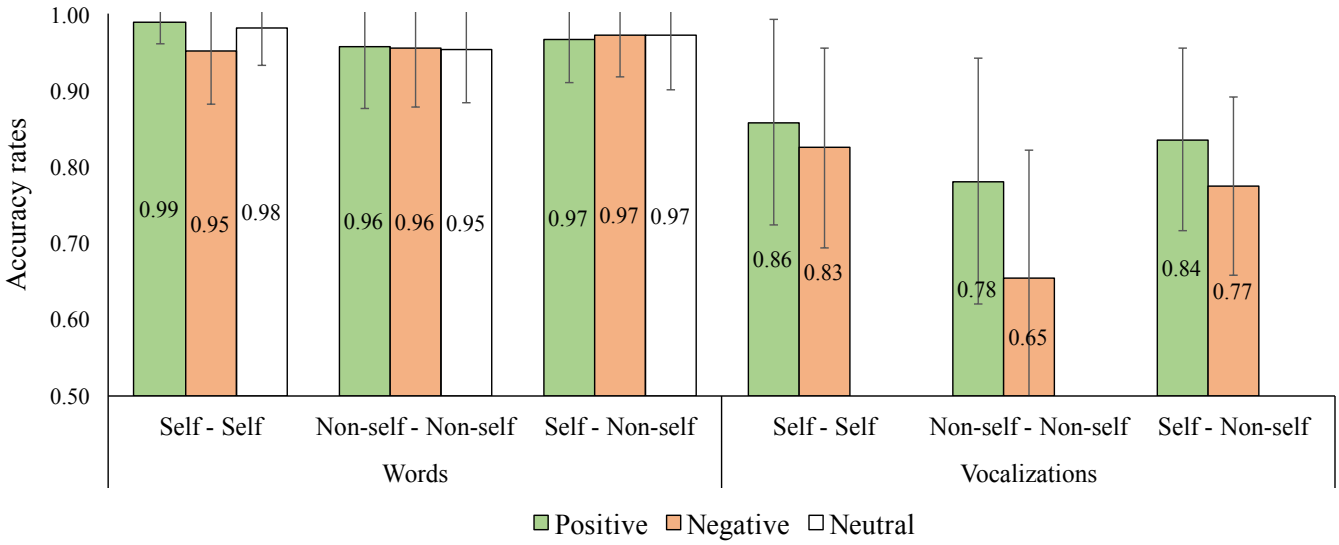

Figure 3. Accuracy rates for voice discrimination, according to condition. Note: Error bars represent Standard Deviations.

3.1.1.3. Effects of stimulus type

The effect of Stimulus Type was statistically significant [*F*(1,30)=24.332, *p*<.001, *partial* η^2=.448], revealing that participants were significantly more accurate when discriminating voice identity using pairs of words (*M*=0.964) than when using pairs of vocalizations (*M*=0.779).

There was also a significant interaction effect between Stimulus Type and Identity [*F*(1,30)=8.597, *p*=.006, *partial* η^2=.223]. To further explore the effect of Identity across both levels of Stimulus Type, paired-samples *t*-tests were used. There were only significant differences in the case of vocalizations. Participants were significantly more accurate when discriminating voice identity using pairs of self-produced vocalizations (*M*=0.843) then when using pairs of non-self-produced vocalizations (*M*=0.718) [*t*(31)=4.499, *p*<.001].

Finally, there was also a significant interaction effect between Stimulus Type, Identity, and Emotion [*F*(1,30)=6.649, *p*=.015, *partial* η^2=.181]. To further explore this interaction, paired-samples *t*-tests were used. There were only significant differences in

the cases of self-produced words and non-self produced vocalizations. Participants were significantly more accurate when discriminating their own voice in spoken words if they had positive (M=0.989) compared to negative content (M=0.952) [$t(31)=3.050$, $p=.005$]. They were also significantly more accurate when discriminating non-self vocalizations with positive (M=0.781) compared to negative content (M=0.654) [$t(31)=8.960$, $p<.001$] (see Figure 3).

The effect of the covariate was not significant [$F(1,30)=0.064$, $p=.803$].

3.1.2. Voice recognition

3.1.2.1. Words

There was not a significant main effect of Identity [$F(1,30)=1.220$, $p=.278$], nor significant interaction effects involving this factor ($p>.05$). There was also not a significant main effect of Emotion [$F(2,60)=1.465$, $p=.239$] (see Figure 4).

The effect of the covariate was not significant [$F(1,30)=0.529$, $p=.473$].

3.1.2.2. Vocalizations

There was not a significant main effect of Identity [$F(1,30)=1.546$, $p=.223$], nor significant interaction effects involving this factor ($p>.05$). There was not a significant main effect of Emotion [$F(1,30)=3.208$, $p=.083$], nor significant interaction effects involving this factor ($p>.05$).

The effect of the covariate was significant [$F(1,30)=8.705$, $p=.006$, *partial* $\eta^2=.225$], suggesting that participants' scores on the LSHS modulated voice recognition processes when using vocalizations.

3.1.2.3. Effects of stimulus type

The effect of Stimulus Type was marginally significant [$F(1,30)=3.467$, $p=.072$, *partial* $\eta^2=.104$].

Further, the effect of the covariate was significant [$F(1,30)=7.447$, $p=.011$, *partial* $\eta^2=.199$], suggesting that participants' scores on the LSHS modulated voice recognition processes.

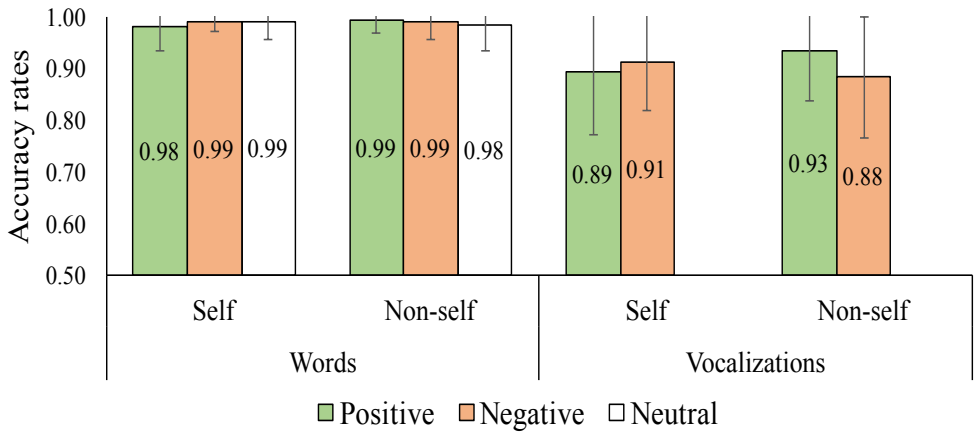

Figure 4. Accuracy rates for voice recognition, according to condition. Note: Error bars represent Standard Deviations.

3.1.3. Additional analyses

Since significant effects of the covariate (individual total scores on the LSHS) were observed in the voice recognition task, particularly when using vocalizations, we performed bivariate Spearman correlation analyses between those conditions (vocalizations varying in identity and emotional content) and participants' total scores on the auditory hallucinations items of the LSHS. There are three auditory hallucination items on the LSHS (see Appendix A). Total scores on the auditory hallucination items are calculated by summing scores on each item (*Max. per item* = 4, *Max total score* = 12).

Total scores on the auditory hallucinations items were negatively correlated with the accuracy in the recognition of vocalizations (ρ=-.414, p=.019), self-generated vocalizations (ρ=-.493, p=.004), positive vocalizations (ρ=-.477, p=.006), and self-generated positive vocalizations (ρ=-.523, p=.002).

3.2. Experiment 2

3.2.1. Ratings of words' valence

First, a paired-samples t-test was performed, comparing participants' mean ratings for positive words, neutral words, and negative words. Results revealed that participants' ratings significantly distinguished between these three valence types:

Pair 1: Mean participants' ratings for positive words (*M*=7.908) + Mean participants' ratings for neutral words (*M*=5.008) [*t*(31)=31.695, *p*<.001];

Pair 2: Mean participants' ratings for positive words (*M*=7.908) + Mean participants' ratings for negative words (*M*=2.280) [*t*(31)=31.457, *p*<.001];

Pair 3: Mean participants' ratings for neutral words (*M*=5,008) + Mean participants' ratings for negative words (*M*=2.280) [*t*(31)=21.546, *p*<.001].

Then, an additional paired-samples *t*-test was also performed, using both the mean valence ratings previously obtained in our word validation and the mean valence ratings obtained from the participants. Results revealed that participants' mean ratings did not significantly differ from the mean ratings previously obtained in our validation:

Pair 1: Mean validation ratings for positive words (*M*=7.780) + Mean participants' ratings for positive words (*M*=7.908) [*t*(31)=1.554, *p*=.130];

Pair 2: Mean validation ratings for neutral words (*M*=4.990) + Mean participants' ratings for neutral words (*M*=5.008) [*t*(31)=0.283, *p*=.779];

Pair 3: Mean validation ratings for negative words (*M*=2.280) + Mean participants' ratings for negative words (*M*=2.280) [*t*(31)=-0.003, *p*=.998].

3.2.2. Ratings of vocalizations' valence

Results from the repeated-measures ANOVA revealed that there was not a significant effect of Identity [*F*(1,30)=2.199, *p*=.148]. The effect of Emotion was significant [F(1,30)=139.376, *p*<.001, *partial* η^2=.823], revealing that participants used higher valence ratings when assessing positive vocalizations (*M*=6.691) than negative vocalizations (*M*=2.987).

There was also a significant interaction effect between Identity and Emotion [*F*(1,30)=6.502, *p*=.016, *partial* η^2=.178]. To further explore the effect of Identity across both levels of Emotion, paired-samples *t*-tests were used. There were significant differences for positive vocalizations. Participants used higher valence ratings when assessing self-produced positive vocalizations (*M*=7.019) than non-self-produced positive vocalizations (*M*=6.363) [*t*(31)=4.036, *p*<.001]. The differences for negative vocalizations were also marginally significant. Participants tended to use lower valence ratings when assessing self-produced negative vocalizations (*M*=2.858) than non-self-produced negative vocalizations (*M*=3.116) [*t*(31)=-2.001, *p*=.054].

Finally, the effect of the covariate was not significant [*F*(1,30)=1.542, *p*=.224].

4. Discussion

The main goal of this study was to explore differences in voice discrimination and voice recognition of a sample of individuals varying in hallucinatory predisposition. For both discrimination and recognition, we have explored the impact of different voice dimensions in what pertains to speech, identity and emotion (Belin et al., 2004). Additionally, we explored if these potential differences could be related to differences in the emotional evaluation of the voice stimuli.

4.1. Differences in the voice discrimination processes

Differences were found across the three voice dimensions. Regarding identity, differences were found when using pairs of vocalizations, but not words: participants were significantly more accurate when discriminating voice identity in pairs of Self – Self vocalizations and Self – Non-self vocalizations, than in pairs of Non-self – Non-self vocalizations. Regarding emotion, differences were also found when using pairs of vocalizations, but not words: participants were significantly more accurate when discriminating voice identity in pairs of positive vocalizations than in pairs of negative vocalizations. Finally, when focusing on stimulus type, participants were more accurate when discriminating voice identity using words than when using vocalizations.

These results are in line with studies suggesting differences in the perception of voice stimuli carrying verbal/semantic content (words) or non-verbal content (vocalizations) (e.g., Belin et al., 2004; Conde et al., 2016b; Russ et al., 2008). Participants had more difficulty discriminating voice identity when using vocalizations, presumably due to the fact that the voice signal does not contain verbal/semantic content. The better performance in the discrimination of voice identity using self-generated vocalizations than non-self-generated vocalizations is also in line with previous studies suggesting a greater salience of the self voice, which recruits more attentional resources (e.g., Conde et al., 2015). This observation of differences between voice dimensions corroborate a partially dissociated processing of voice dimensions (proposed by Belin et al., 2004).

Importantly, the differences found in the voice discrimination processes were not related with individual hallucinatory predisposition (total scores on the Launay-Slade Hallucination Scale-Revised). This is in line with our hypotheses, motivated by

previous studies such as the one from Chhabra and collaborators (2014). These authors also found no voice identity discrimination impairments in healthy individuals with high hallucination predisposition. They argue that this might pose a challenge to the continuum model of psychotic symptoms and its assumption that hallucinatory experiences in nonclinical and clinical individuals rely on the same underlying mechanisms (e.g., Baumeister et al., 2017; Chhabra et al., 2014; Lawrie et al., 2010).

4.2. Differences in the voice recognition processes

We have discussed before how it can be useful to distinguish between voice discrimination and voice recognition processes, since neurobiological evidence indicates that recognizing a familiar voice and discriminating among unfamiliar voices can be separately impaired functions (e.g., Lancker & Kreimer, 1987; Lancker et al., 1989). We also mentioned literature pointing to differences in these processes related with the recruitment of bottom-up and top-down functions (e.g., Conde et al., 2015; Sohoglu et al., 2012). Our results reveal differences between these two levels of voice processing, and support the idea that they can be studied separately.

Participants' recognition of voice identity was significantly higher when listening to words than when listening to vocalizations. This result is relevant because vocalizations, as opposite to words, do not carry any kind of semantic information. Previously we mentioned the importance of exploring differences in voice perception as a function of verbal vs. non-verbal content, thus testing the speech dimension of the voice. Here we support that notion, suggesting that the semantic content carried by spoken words can be dissociated from other types of information carried by the voice (e.g., Hartman & Danhauer, 1976; Lass et al., 1976; Russ et al., 2008; reviewed by Schirmer & Adolphs, 2017). Again, this is in line with the voice perception model of Belin and collaborators (2004), providing further support for the partial dissociation of voice dimensions. It is also in line with our hypothesis regarding differences in the processing of different types of voice stimuli.

Furthermore, hallucinatory predisposition significantly influenced the outcome in the voice recognition tasks, particularly for vocalizations, as demonstrated by the analysis of covariance. This effect of individual hallucinatory predisposition reignites the discussion of the continuum model of psychotic symptoms (e.g., Baumeister et al., 2017; Chhabra et al., 2014; Lawrie et al., 2010). Although our study did not find

differences in the voice discrimination processes of individuals with different levels of hallucinatory-proneness (in line with previous studies; e.g., Chhabra et al., 2014), the framework changes when considering voice recognition processes.

An additional analysis pointed to a correlation between specific voice recognition processes and specific predisposition for hallucinations in the auditory modality. Our results show a negative correlation between the recognition of self-generated positive vocalizations and individual total scores on the LSHS auditory hallucination items. This suggests that, the higher the predisposition for auditory hallucinations in nonclinical individuals, the lower the ability to recognize this type of stimuli.

This particular finding has important implications for the *continuum* hypothesis (e.g., Badcock & Hugdahl, 2012; van Os et al., 2009). On the one hand, it does not replicate the interaction between self-generated voice and negative content found in psychotic patients (e.g., Johns et al., 2011; Pinheiro et al., 2016). However, when considering only the identity dimension, it does support the notion that individuals with higher hallucinatory predisposition have more difficulty in recognizing their own speech, often attributing it to an external source (as observed with psychotic patients; e.g., Allen et al., 2004). Thus, it is possible that impairments in voice recognition underlie the experience of auditory hallucinations in both clinical and nonclinical samples.

In sum, our results for voice recognition processes support the idea that the processing of self-generated voice stimuli differs across individuals with lower and higher predisposition for hallucinatory experiences in the auditory modality, being also different as a function of stimulus type (verbal vs. non-verbal stimuli). They partially confirm our hypotheses, since we did observe an association between impairments in the recognition processes and higher hallucinatory predisposition, although not observing a particular impact of negative content.

4.3. Differences in the emotional judgments

Our study also probed other processes, as described in our Experiment 2 section. Whereas in Experiment 1 participants were asked for judgments on the identity of voice stimuli (with the effects of emotional properties being analyzed implicitly), in this

experiment they were asked for an explicit judgment on the emotional properties of stimuli.

A first analysis of participants' valence ratings for words revealed that our sample specifically distinguished between positive, neutral, and negative words, consistently attributing higher ratings to positive words, intermediate ratings to neutral words, and lower ratings to negative words. A subsequent comparison with the ratings previously obtained in our validation revealed that they did not differ significantly across these three valence levels. This suggests that our sample did not perceive semantic valence differently from the general population and supports the previous classification of words in terms of their emotional properties (as seen in other studies, such as Bradley & Lang, 1999; Ferré et al., 2012; Soares et al., 2012).

We also wanted to explore if individual hallucinatory predisposition influenced emotional judgments for vocalizations. Therefore, another task aimed at obtaining participants' valence ratings for vocalizations, while the effects of the voice identity dimension were analyzed implicitly. As expected, participants used higher valence ratings when assessing positive vocalizations and lower valence ratings when assessing negative vocalizations. However, we also observed an interaction between the emotion and identity dimensions of the voice. The difference in ratings was larger when participants assessed self-generated vocalizations than vocalizations produced by an unknown speaker: positive vocalizations were rated as more positive and negative vocalizations as more negative. If individual variability in hallucination predisposition influenced these differences, that could suggest a tendency of individuals with higher hallucinatory predisposition to use more extreme valence scores (more negative and more positive) while rating samples of their own voice. However, that was not the case, and individual scores on the LSHS did not account for the observed variance. Therefore, these differences might simply be related with the greater salience of self-produced vocal stimuli, as suggested by previous studies (e.g., Conde et al., 2015).

4.4. Relevance and limitations of the present study

Several studies have examined voice discrimination and recognition processes, but few have tested these processes within the same sample and with individuals varying in hallucinatory predisposition. This study has relied on words, carrying verbal and semantic information, while enhancing further explorations of voice processing by

adding vocalizations. The use of previously studied paradigms for obtaining words and vocalizations was intended to rigorously manipulate speech, identity and emotion. The differences we found in the voice recognition processes provide important information about voice perception in healthy subjects with differences in hallucinatory predisposition.

There are also some limitations that should be mentioned and taken into consideration in future studies. Some participants felt that the voice recording paradigm could be generating words and vocalizations produced in a less realistic manner. Although the velocity of words production by the voice-model intended to avoid losses of semantic content motivated by exaggerated fast readings, some participants felt that it did not faithfully represent normal speech rate in everyday-life. Regarding the production of vocalizations, even though the instructions were the same for all participants and they were alone in a sound-isolated studio, the number and intensity of vocalizations varied across them. Some of them defined themselves as more introverted and has having more difficulty producing such vocalizations. This means that some participants may have been more comfortable than others, thus producing vocalizations that more accurately matched their natural vocalizations in everyday life. Other important aspect is that some emotional categories may more spontaneously generate vocalizations than others. This appeared to be the case for positive vocalizations, particularly for the videos that elicited laughter. These are factors that may have played a role in our voice perception tasks, and attention to them in future studies of voice processing involving recordings can help to obtain a representation of vocal stimuli as realistic as possible.

Furthermore, although we gathered a diverse group of individuals with low and high hallucinatory predisposition, it was difficult to obtain a larger sample during the time-window of this study. On the one hand, almost five hundred participants filled in our online version of the Launay-Slade Hallucination Scale-Revised, providing a large dataset of clinical and nonclinical individuals varying in hallucination-proneness, which can be subject to further analyses. On the other hand, it is important to note that, as reported in Castiajo and Pinheiro (2017), the prevalence of nonclinical hallucinations is relatively low in the Portuguese sample (as also observed in other samples; e.g., Dutch by Aleman et al., 2001; Spanish by Fonseca-Pedrero et al., 2010; French by Larøi et al., 2004; Italian by Vellante et al., 2012). This made it harder to find and recruit participants with higher scores on the scale. Social media dissemination also led to a

distribution of respondents across the country, making it difficult for some to participate in our sessions at the university. Finally, for some of the local participants, our two-sessions paradigm was time-consuming enough to prevent their participation.

4.5. Future directions

As mentioned in the beginning, nonclinical stages of psychological disorders have gathered growing interest in recent years (e.g., Broyd et al., 2016; Powers et al., 2016). This is a relatively unexplored topic that would benefit from studies with individuals reporting experiences that are typical of well-known disorders. Although categorical systems provide a useful tool for clinical assessment, a dimensional and transdiagnostic approach to symptoms might deepen our knowledge about the progression from nonclinical to clinical stages (e.g., Nelson et al., 2017; RDoC iniciative in Yee et al., 2015).

In the voice perception and auditory hallucinations research field, more studies comparing nonclinical and clinical samples are needed to test the assumptions of the *continuum* hypothesis (e.g., Badcock & Hugdahl, 2012; van Os et al., 2009). For example, other factors might interact with hallucinatory predisposition to alter voice perception. Studies such as the one by Castiajo & Pinheiro (2017) point to a relationship between hallucination predisposition and clinical symptomatology (schizotypal tendencies and negative mood), which might represent increased psychotic risk. Other clinical instruments might also be used to measure other possibly relevant variables, as well as different experimental paradigms. For example, electrophysiological studies using the EEG methodology show that schizophrenia patients experiencing hallucinations exhibit an abnormally large neural responsiveness to their own speech, where there should be an attenuation typically associated with self-generated actions (e.g., Ford, Gray, Faustman, Roach, & Mathalon, 2007). It would be interesting to explore if the same is observed in nonclinical individuals with higher hallucinatory predisposition.

4.6. Conclusions

In this study, we probed the influence of hallucinatory predisposition in the voice discrimination and voice recognition processes of a nonclinical sample. Although we found differences in the voice discrimination processes related with speech, identity, and emotion, those differences were not accounted for by individual variability in hallucinatory predisposition. However, when studying voice recognition processes, we found an association between lower performance and higher hallucinatory predisposition, particularly for self-generated and positive vocalizations, which do not carry semantic content. These results are important for the current discussion of the continuum model of psychosis.

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Appendix A: Portuguese version of the Launay-Slade Hallucination Scale-Revised.

Items
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.

Note. * Items related to auditory hallucinations.

Appendix B: Participants' individual scores in the clinical instruments. Presented data includes total scores on the Launay-Scale Hallucination Scale-Revised, total scores on the three items pertaining to auditory hallucinations in the same scale, total scores on the Psicoticism subscale of the Brief Symptoms Inventory, and total score on the Unusual Perceptual Experiences subscale of the Schizotypal Personality Questionnaire.

Participant	LSHS Total	LSHS Auditory Total	BSI Psicoticism Subscale	SPQ UPE Subscale
1	0	0	0	0
2	4	0	0	0
3	5	0	0,8	0
4	7	0	0	0
5	8	0	0,4	0
6	9	0	0	0
7	9	0	0,6	0
8	11	0	0,6	1
9	12	3	0	0
10	12	0	0,2	3
11	12	0	0	0
12	12	1	0,8	0
13	14	0	1,2	1
14	17	0	0,4	0
15	17	0	0	0
16	18	0	0,6	4
17	18	3	1	1
18	21	3	0	1
19	22	0	0	1
20	22	5	1,2	0
21	24	3	0	0
22	24	5	0,2	2
23	27	7	1,2	3
24	30	5	0	5
25	33	5	1,4	5

26	38	10	0,2	3
27	38	8	1	2
28	42	9	1,4	5
29	43	11	2,6	7
30	53	12	2,6	7
31	54	10	1	1
32	61	11	3	8

Note. LSHS = Launay-Slade Hallucination Scale-Revised; BSI = Brief Symptoms Inventory; SPQ = Schizotypal Personality Questionnaire; UPE = Unusual Perceptual Experiences.

Appendix C: Words used for voice recording and in the experimental tasks. The original European Portuguese form, English translation, mean ratings obtained after validation, and linguistic properties are presented.

				Mean ratings			Linguistic properties		
Word (EP)	Word (E)	Valence condition	Nr raters	Valence	Arousal	Dominance	Freq per million	Nr letters	Nr syllables
alegre	joyful	Pos	48	7.63	6.17	6.75	11.41	6	3
amável	kind	Pos	39	7.69	5.26	7.03	2.84	6	3
bónus	bonus	Pos	46	7.74	6.43	5.98	3.77	5	2
brincadeira	play	Pos	46	7.74	6.02	7.20	10.38	11	4
brincalhão	playful	Pos	39	7.33	5.67	6.64	0.85	10	3
caloroso	warm	Pos	39	7.36	5.51	6.05	1.47	8	4
celebração	celebration	Pos	39	7.87	6.08	6.92	18.46	10	4
comédia	comedy	Pos	38	7.92	6.05	6.42	19.88	7	4
contente	merry	Pos	46	7.93	6.22	6.89	16.19	8	3
delícia	delight	Pos	46	8.00	6.04	6.59	1.54	7	4
engraçado	funny	Pos	39	7.74	5.85	6.46	4.57	9	4
entusiasmado	excited	Pos	48	7.42	6.94	6.42	4.32	12	6
felicidade	happiness	Pos	39	8.51	6.85	6.82	17.68	10	5
feliz	happy	Pos	39	8.33	6.56	6.87	40.12	5	2

gargalhada	laughter	Pos	49	7.82	6.94	6.67	4.57	10	4
hilariante	hilarious	Pos	39	7.72	6.05	6.23	1.67	10	5
prazer	pleasure	Pos	39	8.33	6.97	6.87	36.45	6	2
riso	laugh	Pos	48	7.83	6.75	6.98	9.09	4	2
saboroso	tasty	Pos	49	7.47	5.73	6.29	1.62	8	4
sobremesa	dessert	Pos	39	7.21	5.13	6.62	2.42	9	4
avenida	avenue	Neu	39	4.97	2.97	5.85	22.02	7	4
cabide	hanger	Neu	38	4.79	2.55	6.18	0.38	6	3
caixa	box	Neu	39	5.08	2.82	6.56	52.28	5	2
camisola	sweater	Neu	49	5.37	3.37	6.45	18.39	8	4
ecrã	screen	Neu	48	5.08	3.31	5.83	23.49	4	2
estático	static	Neu	38	4.39	2.89	5.47	1.18	8	4
folha	leaf	Neu	39	5.15	2.62	6.33	18.78	5	2
gaveta	drawer	Neu	48	4.79	2.83	5.92	7.53	6	3
ingénuo	naive	Neu	38	4.24	3.97	5.37	3.93	7	4
jarra	jar	Neu	45	5.18	2.64	7.02	0.74	5	2
lavatório	sink	Neu	39	4.79	2.59	6.44	0.70	9	5
liso	flat	Neu	39	4.69	2.67	5.44	1.19	4	2

mexido	scrambled	Neu	48	5.58	4.69	5.48	1.02	6	3
normal	normal	Neu	48	5.10	3.75	5.77	61.08	6	2
parado	stopped	Neu	46	4.54	2.98	6.39	13.75	6	3
previsível	predictable	Neu	46	5.20	3.85	6.65	20.26	10	4
quieto	still	Neu	39	4.95	3.13	6.10	1.94	6	3
rigoroso	rigorous	Neu	49	5.27	5.39	6.39	12.45	8	4
toalha	towel	Neu	46	5.30	2.87	6.67	3.34	6	3
visível	visible	Neu	47	5.34	3.28	5.74	33.63	7	3
agressividade	aggressiveness	Neg	39	2.36	6.59	5.64	10.36	13	6
agressivo	aggressive	Neg	46	2.33	6.70	5.24	7.33	9	4
choro	cry	Neg	46	2.48	6.43	4.96	4.17	5	2
danado	darn	Neg	38	2.92	5.97	5.39	0.48	6	3
deprimido	depressed	Neg	39	2.03	5.31	4.97	1.68	9	4
destroçado	shattered	Neg	48	2.27	6.46	4.21	0.69	10	4
fulo	furious	Neg	43	2.49	6.37	5.02	0.17	4	2
funeral	funeral	Neg	46	1.63	6.78	4.39	12.62	7	3
inconsolável	inconsolable	Neg	46	2.17	5.67	4.33	0.79	12	5
ira	wrath	Neg	46	2.35	6.80	4.74	4.95	3	2

irritação	provocation	Neg	39	2.38	6.56	5.46	6.35	9	4
lágrima	tear	Neg	39	2.49	5.56	5.64	2.28	7	3
luto	mourning	Neg	46	1.61	6.26	4.28	9.87	4	2
miserável	miserable	Neg	46	1.89	5.78	4.65	4.28	9	4
raiva	rage	Neg	38	2.08	7.18	5.63	8.88	5	2
revoltado	revolted	Neg	46	2.80	6.83	4.93	2.36	9	4
triste	sad	Neg	46	2.22	5.78	5.13	36.81	6	2
tristeza	sadness	Neg	46	2.02	5.87	4.63	14.40	8	3
zanga	anger	Neg	49	2.73	6.57	4.96	2.03	5	2
zangado	angry	Neg	39	2.26	6.26	5.69	3.37	7	3

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

Appendix D: Description and duration of the videos used for eliciting vocalizations with emotional content.

Emotional label	Description	Duration (aprox.)
Anger	A road rage moment between two drivers, that scales up to physical aggression.	32 s
Disappointment	A soccer player nearly scores a goal, but shockingly misses the target.	25 s
Sadness	A movie scene depicting a little boy at a funeral. A little girl offers him a flower.	50 s
Happiness	A school class of young children cheers and claps along with their teachers.	14 s
Amusement	A popular Portuguese humorist in a stand-up comedy moment.	42 s
Pleasure	A girl having a delicious breakfast, which includes a sweet and soft waffle.	20 s

Note. s = seconds.

Appendix E: Sentences used for eliciting vocalizations with emotional content. The original European Portuguese text and English translation are provided.

Emotional label	Sentence (EP)	Sentence (E)
Anger	Alguém está a ser deliberadamente rude para si e, por isso, perde toda a sua paciência.	Someone is being deliberately rude to you and, for that reason, you lose all your patience.
Disappointment	Descobre que a sua equipa favorita acaba de perder o campeonato.	You discover that your favorite team just lost the championship.
Sadness	Descobre que uma pessoa muito próxima de si acaba de falecer.	You discover that a very close person just passed away.
Happiness	Está um belo dia de sol e vai passear com os seus amigos.	It is a bright sunny day and you go for a walk with your friends.
Amusement	Alguém lhe conta uma piada que é mesmo "de partir a rir".	Someone tells you a really funny joke.
Pleasure	Está a comer a sua sobremesa favorita, depois de muito tempo sem poder saboreá-la.	You are eating your favorite dessert, after a very long time without having the chance of tasting it.

Note. EP = European Portuguese; E = English.