UNIVERSIDADE DE LISBOA

FACULDADE DE PSICOLOGIA

EMOTIONAL AUTHENTICITY PERCEPTION IN BLIND INDIVIDUALS: BEHAVIORAL AND ERP EVIDENCE

João Pereira Sarzedas

MESTRADO EM NEUROPSICOLOGIA CLÍNICA E EXPERIMENTAL

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Dissertação orientada pela Investigadora Doutora Tatiana Conde e Magro e pela Professora Ana Patrícia Pinheiro

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Abstract

In blind individuals, the loss of vision and the subsequent need to rely more heavily on the remaining senses results in important neuroplastic alterations. Current evidence suggests that these alterations lead to the enhancement of specific auditory abilities but can also lead to no alterations or even impaired auditory perception. Regarding vocal emotional perception, the impact of blindness on the behavioral and neural mechanisms underpinning emotional authenticity perception is still unexplored. Therefore, in the current study, we used behavioral and event-related potentials (ERP) measures to study whether and how blindness influences the perception of emotional authenticity in nonverbal vocalizations. Furthermore, we also aimed to understand whether and how the age of blindness onset (early vs. late) and task focus manipulation (attention directed to authenticity vs. emotional properties of the voice) affected these mechanisms. Fifty-one individuals with different visual conditions (17 early blind, 17 late blind, 17 sighted controls) completed two experimental tasks while electrophysiological data was continuously recorded. In these tasks, participants heard laughs and cries varying in authenticity (spontaneous vs. volitional) and emotional quality (sadness vs. amusement). The N1, P2, and late positive potential (LPP) ERP components were analyzed. Our results demonstrated authenticity effects in early sensory (N1) and late cognitive evaluative stages (LPP) of vocal emotion processing in early blind listeners. They additionally showed that both early and late blindness modulated a processing stage associated with the detection of emotional salience (P2). At a behavioral level, blindness did not affect the recognition and evaluation of vocal emotion. However, the late blind group was generally less accurate at detecting the authenticity of vocalizations than the sighted group. Overall, our findings suggest that blindness modulates the temporal course of emotional authenticity perception, particularly in early blind listeners. They additionally suggest that late-, but not early-onset blindness, deteriorates emotional authenticity perception.

Keywords: Blindness; vocal emotion perception; emotional authenticity; event-related potentials; neuroplasticity.

Resumo

A ausência de visão e a consequente maior dependência dos outros sentidos causa importantes alterações neurofisiológicas. Por essa razão, a cegueira tem muitas vezes sido utilizada como modelo para investigar processos de neuroplasticidade. Potencialmente relacionado com estes fenómenos, vários estudos têm reportado uma melhor performance por parte de indivíduos cegos, em comparação com indivíduos normovisuais, em tarefas que examinaram capacidades de processamento auditivo, olfativo e táctil. Contudo, existe uma parte da literatura que reporta ausência de diferenças ou até pior performance de indivíduos cegos em tarefas que investigaram outras capacidades específicas de perceção auditiva, olfativa e tátil. No campo da perceção vocal emocional, o impacto da cegueira na perceção de autenticidade emocional e os mecanismos neurofisiológicos que estão na base destes processos ainda não foram devidamente explorados.

Os escassos estudos que investigaram o processamento vocal emocional em indivíduos cegos não são consensuais, não sendo ainda claro se os cegos desenvolvem capacidades de perceção vocal emocional compensatórias ou se a visão é necessária para um eficiente desenvolvimento de faculdades de processamento emocional vocal. É também de salientar que na maioria destes estudos estes processos foram investigados numa amostra de cegos precoces. Estudar os mecanismos de perceção vocal emocional em cegos tardios poderá ser útil para compreender de que modo é que a idade de início da cegueira afeta o desenvolvimento destas capacidades. Além disso, a literatura sobre processamento vocal emocional em cegos tem como limitação o facto destes processos apenas terem sido estudados com recurso a estímulos emocionais não autênticos (i.e., emoções produzidas voluntariamente por atores).

Que seja do nosso conhecimento, não existe nenhum estudo publicado que tenha explorado perceção de autenticidade emocional em cegos. No entanto, nos últimos anos tem havido um interesse crescente em estudar perceção de autenticidade emocional em indivíduos normovisuais, sendo que nesta literatura têm sido reportadas diferenças na perceção e no processamento neuronal entre estímulos autênticos e não autênticos.

Recentemente, dois estudos que investigaram a perceção de autenticidade emocional de risos e choros utilizando a técnica de potencias evocados por eventos (*Event-Related*

Potentials - ERP) encontraram efeitos de autenticidade em três componentes de ERP: N1, P2 e *late positive potential* (LPP). Estes componentes de ERP refletem diferentes estádios de processamento de informação emocional vocal relacionados com processamento sensorial precoce (N1), deteção de saliência (P2) e avaliação cognitiva (LPP). Esta técnica oferece uma informação mais detalhada sobre o *timing* dos processos neuronais, sendo um método ideal para explorar o modo como os diferentes estádios de processamento de autenticidade emocional são afetados pela cegueira.

No presente estudo, foram utilizadas medidas comportamentais e ERP para estudar o modo como a cegueira influencia a perceção de autenticidade emocional de risos e choros. Adicionalmente foi também explorado o modo como a idade de início da cegueira e a manipulação do foco atencional afetam estes mecanismos. Devido ao carácter inovador do presente estudo, as nossas hipóteses sobre os efeitos da cegueira na perceção de autenticidade emocional foram exploratórias.

Neste estudo, foram recolhidos dados de cinquenta e um participantes, incluindo 17 cegos precoces, 17 cegos tardios e 17 indivíduos normovisuais. Todos os participantes realizaram duas tarefas enquanto dados eletroencefalográficos eram recolhidos. Numa das tarefas os participantes foram instruídos a discriminar a autenticidade emocional dos estímulos (forçados vs. autênticos) e na outra tarefa a discriminar a emoção (tristeza vs. alegria). Em ambas as tarefas os participantes foram expostos aos mesmos estímulos – 80 vocalizações não-verbais de quatro condições diferentes: 20 risos autênticos, 20 risos forçados, 20 choros autênticos e 20 choros forçados.

Após a realização destas duas tarefas, os participantes realizaram uma tarefa comportamental onde foram instruídos a avaliar as mesmas 80 vocalizações em termos de autenticidade, valência e *arousal*.

No que diz respeito aos resultados do presente estudo, nos cegos precoces, foram encontrados efeitos da autenticidade em estádios do processamento sensorial precoce (N1) e em estádios do processamento mais tardios, associados com a avaliação cognitiva de informação emocional vocal (LPP). Mais especificamente, no grupo de cegos precoces, foi encontrada: uma amplitude de N1 mais negativa para choros autênticos (vs. choros forçados) na tarefa de deteção de autenticidade, mas não na tarefa de discriminação emocional; uma amplitude de LPP mais positiva para expressões autênticas (vs. forçadas) na tarefa de

discriminação emocional, mas não na tarefa de deteção de autenticidade. Estes resultados sugerem que a cegueira precoce leva a uma reorganização cortical nestes dois estádios do processamento de autenticidade emocional. Num estádio de processamento associado à deteção de saliência emocional (P2), foi encontrada uma amplitude de P2 mais positiva para expressões forçadas (vs. autênticas) tanto no grupo de cegos precoces como no grupo de cegos tardios. Este resultado sugere que a cegueira, independentemente da idade em que esta ocorre, leva a uma reorganização cortical neste estádio do processamento de autenticidade emocional. Por fim, os resultados comportamentais revelam diferenças entre grupos no julgamento de autenticidade, mas não na capacidade de discriminação emocional de risos e choros. Mais especificamente, o grupo de cegos tardios, em comparação com o grupo de indivíduos normovisuais, foi genericamente menos preciso na deteção de autenticidade das vocalizações. Contudo, não foram encontradas diferenças significativas entre a performance dos cegos precoces e a performance dos indivíduos normovisuais, o que sugere que a cegueira tardia, mas não a cegueira precoce, deteriora a perceção de autenticidade emocional.

Palavras-chave: Cegueira; perceção de emoção vocal; autenticidade emocional; potenciais evocados por eventos; neuroplasticidade.

1. Introduction

1.1. Blindness and neuroplasticity

Conventionally, vision is seen as the most important of the human senses. The dominant role of vision over other sensory modalities is supported by the well-known Colavita (Hirst et al., 2018; Sinnett et al., 2007) and ventriloquist effects (Alais & Burr, 2004; Vroomen et al., 2001), which show that in multisensorial experimental paradigms visual information overrides audition. Additionally, the dominant role of vision is highlighted by studies of spatial cognition and object recognition (Eimer, 2004; Thinus-Blanc & Gaunet, 1997), which demonstrate the relevance of this modality for multisensorial and sensorimotor integration (Putzar et al., 2007). The strong relevance of the visual domain is even marked in common linguist expressions such as: “Nice to see you”, “Love at first sight” or “I see what you mean” (Kupers & Ptito, 2014). To understand and successfully interact with the environment, sighted individuals extract a lot of valuable information from visual cues. Hence, it becomes clear that blind individuals need to make significant adjustments in everyday life to compensate for their visual loss and to successfully cope with their environment.

In blind individuals, the lack of vision and the subsequent need to rely more heavily on the remaining senses results in important neurophysiological changes (Fine & Park, 2018). Specifically, neurophysiological changes derived from blindness have been reported across multiple measures. They may include changes in neurotransmitter regulation, metabolic function, white matter pathways, cortical expansion, local synaptic connectivity, and Blood-oxygen-level-dependent imaging (BOLD) responses (for a review, see Castaldi et al., 2020; Fine & Park, 2018). Blindness has been extensively used as a model system for probing neuroplasticity, which refers to the reorganization ability of the brain to change and adapt in response to injuries, physiological alterations, new environmental challenges, and sensory experiences (Castaldi et al., 2020; Pascual-Leone et al., 2005). Evidence for neuroplastic changes in blind humans has been shown by several studies that report cross-modal activation of the occipital cortex (a brain region traditionally associated with visual information processing) while blind individuals perform different nonvisual tasks such as sound localization (Gougoux et al., 2005), tactile perception (Burton et al., 2004; Gagnon et al., 2010), spatial navigation (Gagnon et al., 2010; Kupers et al., 2010), olfactory perception (Kupers et al., 2011), and even more complex tasks such as higher-order tasks tapping language (Bedny et al., 2015; Striem-Amit et al., 2012) and memory processing (Raz et al., 2007). Consistent with the results found in humans, studies with animal models that were visually deprived after birth also provided evidence for functional reorganization in multisensory brain areas (e.g., superior colliculus) that integrate visual, auditory, and somatosensory spatial information (Hyvärinen et al., 1981; Rauschecker & Harris, 1983; Rauschecker & Korte, 1993; Vidyasagar, 1978).

Putatively related to neuroplasticity mechanisms, several studies reported superior auditory (e.g., Amedi, 2003; Dufour et al., 2005; Gougoux et al., 2004; Lessard et al., 1998; Wan et al., 2010), olfactory (e.g., Cuevas et al., 2009; Rosenbluth et al., 2000), and tactile (e.g., Goldreich & Kanics, 2003; Legge et al., 2008) processing skills in blind individuals compared to sighted controls. For example, in the auditory modality, the evidence shows that early blind listeners are better than late blind and sighted individuals at detecting the direction of pitch changes for different temporal and spectral levels (Gougoux et al., 2004). These evidences provide empirical support to the compensatory hypothesis, which predicts the development of superior auditory abilities to deal with the loss of sight (Pascual-Leone et al., 2005). However, there are also some studies that have found no differences (e.g., Rosenbluth et al., 2000; Zwiers et al., 2001) or even impaired performance of blind individuals (e.g., Sterr et al., 1998; Zwiers et al., 2001) in specific tasks probing auditory, olfactory, and tactile skills. For instance, no differences were found between early blind and sighted controls in a multiple-choice paradigm of odor identification (Rosenbluth et al., 2000), as well as in a sound source localization task conducted in a simple acoustic environment (Zwiers et al., 2001). Moreover, Zwiers, Opstal, and Cruysberg (2001) found a worse performance of blind participants when the sound source localization task was conducted in a complex acoustic environment. This study shows that blind individuals are less able to extract elevation-related spectral cues in a noisy environment, and thus, demonstrates that visual feedback might be essential for the full development of specific auditory functions, such as sound localization (Zwiers et al., 2001). This finding supports the general-loss hypothesis, which posits that the loss of sight is detrimental for the development of auditory perception functions (Pascual-Leone et al., 2005).

In light of such evidence, three not mutually exclusive hypotheses arise to explain neuroplasticity mechanisms and cross-modal reorganization occurring after prolonged visual deprivation: 1) Cortical reorganization is mainly compensatory, and more robust enhancements may arise from underexplored auditory functions (Singh et al., 2018); 2) Cortical reorganization results from the unmasking of connections already present and does not cause significant cross-modal behavioral enhancements (Singh et al., 2018); 3) Cortical reorganization is not intended to achieve compensatory enhancement, but primarily to avoid potentially damaging alterations in cortical and physiological dynamics caused by the absence of normal visual input (Singh et al., 2018).

A useful way to address these hypotheses is to examine whether blind individuals exhibit an improved performance in unexplored auditory functions. In this domain, the human voice is one of the most important and salient sounds in our environment (Belin et al., 2004; Latinus & Belin, 2011), carrying a lot of meaningful information that guides us in daily social interactions and communication. It allows to process speech, but also to extract information about the speaker's age, sex, identity, emotional state, and body size (Belin et al., 2004, 2011). For sighted individuals, technological advances and the increasing predominance of long-distance relationships have increased the number of "audio-only" communications (e.g., cell phone calls and *WhatsApp* audios). Such tendency highlights the importance of these abilities for sighted individuals, and especially for blind individuals, to whom the capacity to extract meaningful information from vocal cues is even more essential. However, vocal perception mechanisms involving emotional processing in blind individuals remain largely unknown.

1.2. Vocal emotional perception in blind individuals

The ability to perceive the emotional states of others plays a fundamental role in human social interactions. We live in a multisensory world, and humans express emotions through facial expressions, body language, and by using their voices. A sighted individual can retrieve information from all these multimodal cues, but blind individuals must rely mainly on vocal cues to perceive the emotional state of others. Nonetheless, whether and how long-term visual deprivation affects vocal emotion processing remains largely unknown.

Vocal emotional information is expressed through emotional prosodic cues (i.e., speech patterns) and nonverbal emotional vocalizations (i.e., non-speech emotional expressions such as laughs and cries) (Frühholz et al., 2016). The few existing studies that probed these mechanisms in blind individuals have shown inconsistent findings (Chen et al., 2022; Gamond et al., 2017; Klinge et al., 2010; A. T. Martins et al., 2019; Oleszkiewicz, Pisanski, Lachowicz-Tabaczek, et al., 2017). For instance, a functional magnetic resonance imaging (fMRI) study that investigated the role of the amygdala on auditory emotion processing found that, when compared with sighted controls, a group of blind participants showed increased amygdala activation for fearful and angry prosodic stimuli compared to neutral ones. The participants of the blind group were also faster and more accurate at an emotion discrimination task than sighted controls (Klinge et al., 2010). On the other hand, some recent studies reported different findings. Early blind individuals were found to be as accurate as sighted controls in vocal emotion detection of happy (i.e., laughs) and sad (i.e., cries) nonverbal vocalizations (Gamond et al., 2017). Likewise, no differences were found between blind and sighted children in mean accuracy ratings of emotional prosody recognition (Chen et al., 2022), whereas a worse performance of adult early blind individuals was found in a task requiring the evaluation of conflicting emotional prosody sentences (i.e., emotional semantic content could be congruent or incongruent with emotional prosody) (A. T. Martins et al., 2019). These inconsistencies might be related to differences in the tasks (e.g., implicit *vs*. explicit processing) and stimuli (e.g., prosodic *vs*. nonverbal emotional cues) used in the above-mentioned studies, but also to differences in the characteristics of the samples, such as the age of onset of the visual loss or the duration of the visual impairment.

Based on the above-mentioned evidence, it is still not clear if blind individuals develop compensatory vocal emotion perception abilities or if vision is necessary for the adequate development and functioning of vocal emotional processing abilities.

It is noteworthy that, except for the study by Chen and colleagues (2022), the available studies on vocal emotion only included early blind participants (Gamond et al., 2017; Klinge et al., 2010; A. T. Martins et al., 2019) but studying these processes in late-onset blindness is important because of the increasing aging population. Also, brain functional reorganization differences between congenital and late-onset blind individuals regarding auditory-driven activity in the primary visual cortex were reported, which highlight the crucial role of the developmental period of visual deprivation (Collignon et al., 2013). Furthermore, evidence for age-related changes in vocal emotion recognition (e.g., large improvements from childhood to adolescence and a decline in older adulthood) suggests that vocal emotion recognition is an early developing mechanism (Amorim et al., 2021). In light of these findings, it seems likely that early blind listeners can develop more robust brain compensatory mechanisms than individuals with late onset of blindness. Thus, exploring vocal emotion processing mechanisms in early and late-onset blind individuals might be a useful way to understand whether the age of blindness onset affects the development of this ability, and to clarify how the brain can reorganize its functional processes to cope with new sensory loss after years of previous normal visual experience.

Furthermore, the available evidence with blind individuals (as well as most studies with sighted individuals) might be limited by the fact that volitional expressions (i.e., posed emotions) are used as experimental stimuli. An increasing number of recent studies have found perceptual (e.g., Anikin & Lima, 2018), acoustic (e.g., Pinheiro et al., 2021), and neural (e.g., Lavan et al., 2017) differences between volitional and spontaneous emotional expressions (i.e., involuntary emotionally driven expressions obtained through emotional induction or field observation). Such findings highlight the importance of using more ecological stimuli (i.e., spontaneous expressions) when studying emotional processing.

1.3. Perception of emotional authenticity

In social interactions, the ability to discriminate genuine emotional expressions from deceitful imitations is a valuable social skill (Anikin & Lima, 2018; Gervais & Wilson, 2005). Humans have a remarkable ability to both spontaneously and deliberately produce complex vocal patterns. We can spontaneously produce idiosyncratic expressions of felt emotions (e.g., spontaneous crying in response to the death of a close relative), but we are also able to regulate and suppress our emotions to produce unfelt emotional expressions (e.g., volitional crying to persuade others and obtain privileges). For blind individuals, this is a crucial skill because they cannot rely on visual facial cues to decipher others' true underlying affect and intentions, and they often need to trust others across a wide range of circumstances in daily life, such as when asking for guidance in an unknown street (Oleszkiewicz, Pisanski, & Sorokowska, 2017).

As far as we know, there is no published study exploring emotional authenticity perception in blind individuals. Nevertheless, in recent years there has been growing research interest in the study of emotional authenticity perception in sighted individuals (e.g., Anikin & Lima, 2017; Bryant & Aktipis, 2014; Namba et al., 2017; Pinheiro et al., 2021; Zloteanu et al., 2018; Zloteanu & Krumhuber, 2021). In the auditory modality, research has shown that sighted individuals are able to discriminate spontaneous from volitional vocalizations with accuracy levels above chance across several emotions (Anikin & Lima, 2018; Sauter & Fischer, 2018), including amusement (Bryant & Aktipis, 2014; Cosme et al., 2021; Lavan et al., 2016; Lima et al., 2021; Pinheiro et al., 2021) and sadness (Cosme et al., 2021; Lima et al., 2021; Pinheiro et al., 2021). Most research has, however, focused on laughter authenticity (Pinheiro et al., 2021). The available evidence demonstrates that spontaneous laughs are perceived as more authentic (Billing et al., 2021; Cosme et al., 2021; Lavan et al., 2016; Lavan & McGettigan, 2017; Neves et al., 2018; Pinheiro et al., 2021), positive (Lavan et al., 2016; Lavan & McGettigan, 2017; Pinheiro et al., 2021), contagious (Billing et al., 2021; Cosme et al., 2021; Neves et al., 2018), trustworthy (Pinheiro et al., 2021) and higher in arousal (Cosme et al., 2021; Lavan et al., 2016; Lavan & McGettigan, 2017; Pinheiro et al., 2021) than volitional ones. Spontaneous cries are also perceived as more authentic (Cosme et al., 2021; Lima et al., 2021; Pinheiro et al., 2021), contagious (Cosme et al., 2021), trustworthy (Pinheiro et al., 2021), and higher in arousal (Cosme et al., 2021; Pinheiro et al., 2021) than their volitional counterparts. However, contrary to laughs, no significant differences in valence ratings were found between spontaneous and volitional cries (Pinheiro et al., 2021).

Acoustically, spontaneous laughs have a longer total duration, shorter burst duration, higher and more variable fundamental frequency, brighter timbre, a higher percentage of unvoiced segments, higher and more variable harmonics-to-noise-ratio in voiced frames, greater general variability, and lower mean intensity than volitional laughs (Anikin & Lima, 2018; Lavan et al., 2016; Pinheiro et al., 2021). Spontaneous and volitional cries are slightly less distinct acoustically than laughs. Nevertheless, spontaneous cries have a slightly higher pitch, more variable timbral brightness, and less voicing than volitional cries (Pinheiro et al., 2021).

Regarding the neural correlates of emotional authenticity detection, in an fMRI study, it was found that passively listening to spontaneous laughter elicited greater activation in bilateral superior temporal gyri, while passively listening to volitional laughter elicited greater activation in the anterior medial prefrontal cortex, suggesting stronger engagement of mentalizing processes in response to non-authentic vocalizations (McGettigan et al., 2015). A subsequent study, using the fMRI data collected by McGettigan and colleagues (2015), explored the neural correlates of the affective properties of spontaneous and volitional laughs (Lavan et al., 2017). They found an association between an increased response of the bilateral auditory cortices and higher ratings of perceived valence, arousal, and authenticity. They also reported an association between a decreased response of the anterior medial prefrontal cortex and higher ratings of perceived valence and authenticity. This association was inferred to be related to increased involvement of these regions in response to laughs of greater social ambiguity. More recently, a functional near-infrared spectroscopy (fNIRS) study found that activation in the pre-supplementary motor area predicted the differences in authenticity and contagion ratings for spontaneous compared to volitional laughter (Billing et al., 2021). While these studies probed the neural processes involved in the perception of laughter authenticity, fewer studies have explored cortical sensitivity to crying authenticity. However, two recent studies have explored the time course of emotional authenticity perception of both laughs and cries (Conde et al., 2022; Kosilo et al., 2021). The event-related potential (ERP) technique offers more detailed information about the timing of neural processes and is an ideal method to explore whether and how the early sensory and late processing stages of emotional authenticity perception are affected by blindness.

1.4. The temporal course of emotional authenticity perception

The previous studies that explored the temporal course of emotional authenticity perception (Conde et al., 2022; Kosilo et al., 2021) examined the mean amplitudes of the auditory N1, P2, and late positive potential (LPP) ERP components. These ERP components reflect early sensory and late higher-order stages of vocal emotional processing related to early sensory acoustic processing (N1), salience detection (P2), and cognitive evaluation (LPP) (Jessen & Kotz, 2011; Schirmer & Kotz, 2006).

Both studies found an influence of authenticity in different stages of vocal emotion processing (Conde et al., 2022; Kosilo et al., 2021). In an early sensory processing stage, one study found a more negative N1 amplitude for volitional (vs. spontaneous) laughs (Conde et al., 2022), while the other found a larger N1 in response to spontaneous (vs. volitional) cries (Kosilo et al., 2021). These modulations at sensory stages might likely reflect differences in the acoustic properties of the stimulus (Conde et al., 2022). The auditory N1 is a fronto-centrally distributed component that negatively peaks at approximately 100 ms after sound onset (Näätänen & Picton, 1987). A more negative N1 for neutral than for emotional nonverbal vocalizations has been reported by previous studies (Castiajo & Pinheiro, 2021; Jessen & Kotz, 2011; Liu et al., 2012; I. Martins et al., 2022) and may reflect facilitated acoustic processing of emotionally relevant (vs. neutral) stimuli (Conde et al., 2022; I. Martins et al., 2022).

At salience detection processing stages, both studies found a more positive P2 for volitional compared with spontaneous laughs in a standard visual condition, but Conde and colleagues (2022) also found an increased P2 for spontaneous (vs. volitional) cries. These findings suggest that authenticity information of vocalizations is encoded at early sensory and salience detection processing stages. The auditory P2 is a fronto-centrally distributed component that positively peaks at approximately 200 ms after stimulus onset, and indexes stimulus classification and salience detection processes of emotionally salient (vs. neutral) stimuli (Conde et al., 2022; Crowley & Colrain, 2004). Several studies have reported a more positive P2 for emotional (prosody and nonverbal vocalizations) than for neutral stimuli (Castiajo & Pinheiro, 2021; Iredale et al., 2013; Jessen & Kotz, 2011; Liu et al., 2012; I. Martins et al., 2022; Sauter & Eimer, 2010; Schirmer et al., 2013).

At later stages associated with cognitive evaluation of emotional stimuli, Conde and colleagues (2022) reported authenticity effects of laughter (700 -1000 ms) and crying (1000 - 1400 ms) on the LPP response, but Kosilo and colleagues (2021) found no effects (500 - 1000 ms). The LPP is a prolonged positive deflection that typically emerges 400 ms post-stimulus onset and is maximal at centroparietal and occipitoparietal electrodes (Hajcak & Foti, 2020; Moran et al., 2013). This component indexes sustained attention allocation and cognitive evaluation of relevant information (Jessen & Kotz, 2011; Pell et al., 2015). Effects of the emotional content of nonverbal vocalizations on the LPP have been previously reported. For example, one study found an increased LPP amplitude for angry compared to sad and happy volitional vocalizations (Pell et al., 2015), while another study found a larger LPP for spontaneous laughter compared to spontaneous crying (Proverbio et al., 2020). Others reported more positive LPP amplitudes for volitional laughs and cries compared to neutral vocalizations (I. Martins et al., 2022), but no differences were found between neutral and volitional vocalizations of fear and anger (Jessen & Kotz, 2011). The fact that the ERP studies probing emotional authenticity (Conde et al., 2022; Kosilo et al., 2021) used different experimental tasks may have contributed to differences in findings. Both studies used spontaneous and volitional laughs and cries, but Kosilo and colleagues (2021) also used neutral vocalizations as stimuli. In the study of Conde and colleagues (2022) each participant completed two tasks, one involving the detection of authenticity and the other the detection of emotion. This study also explored the effects of visual deprivation, having two different conditions: a visual deprivation condition with blindfolded participants, and a standard visual condition. In the study of Kosilo and colleagues (2021), participants were instructed to passively listen to the neutral vocalizations and to rate the perceived authenticity of the emotional vocalizations using a 7 -point Likert scale, ranging from 1 (authentic) to 7 (posed).

1.5. The current study

In the current study, we used behavioral and electrophysiological measures to study whether and how blindness influences the perception of emotional authenticity and emotional quality in nonverbal vocalizations (laughs and cries). Furthermore, we also aimed to understand whether and how the age of blindness onset (early vs. late) affected these mechanisms. Although task focus manipulation (attention directed to authenticity vs. emotional properties of the voice) did not affect neural responses to vocalizations in sighted individuals (Conde et al., 2022), the same might not be true for blind participants. Therefore, we also wanted to understand whether emotional authenticity perception was modulated by task focus in blind individuals.

Due to the innovative character of the present study, our hypotheses regarding the effects of blindness on emotional authenticity perception were exploratory. Regarding emotional authenticity perception, four different hypotheses can be postulated: 1) If cortical reorganization is compensatory and the spared vocal emotional processing functions are improved to compensate for the lack of vision, then improved perception of emotional authenticity in early blind compared with late blind and sighted individuals should be observed (i.e., behaviorally: increased accuracy in early blind vs. late blind vs. sighted control groups; ERPs: more prominent differences in the neural responses to spontaneous and volitional vocalizations in early blind vs. late blind vs. sighted control groups); 2) If visual and vocal emotional processing abilities develop independently from one another, no significant behavioral and ERP differences between groups should be observed; 3) If vision is needed to calibrate the adequate development of vocal emotion perception, then impaired processing in early blind compared with late blind and sighted individuals should be observed (i.e., behaviorally: decreased accuracy in early blind vs. late blind vs. sighted control groups; ERPs: less prominent differences in the neural responses to spontaneous and volitional vocalizations in early blind vs. late blind vs. sighted control groups); 4) If prolonged visual deprivation impairs vocal emotion perception, but early cortical reorganization triggers compensatory mechanisms that avoid potentially damaging alterations when blindness occurs in the first years of development, then impaired emotional authenticity perception in late blind compared with early blind and sighted individuals should be observed (i.e., behaviorally: decreased accuracy in late blind vs. early blind and sighted control groups; ERPs: less prominent differences in the neural responses to spontaneous and volitional vocalizations in late blind vs. early blind and sighted control groups). If the putative differences between groups are related to changes in early sensory processing of emotional authenticity or emotional salience detection mechanisms, the differences will be observed in the N1 and P2 time windows, respectively. If the supposed between-group differences are more related to the cognitive evaluation of emotional authenticity, the differences will be observed in the latter processing stages indexed by the LPP component or in the behavioral performance of the authenticity detection task (spontaneous vs. volitional).

2. Method

2.1. Participants

Fifty-one individuals participated in the study, including 17 early blind individuals (14 male; age range: 19 – 65 years of age; M_{age} = 42.94, SD = 13,98; 3 left-handed), 17 late blind individuals (10 male; age range: 26 – 62 years of age; M_{age} = 47.06, SD = 9.00; 2 left-handed) and 17 sighted controls (9 male; age range: 24 – 65 years of age; M_{age} = 44.24, SD = 12.94; 2 left-handed). The average number of completed years of education was 12.35 for the early blind group, 11.71 for late blind group, and 13.00 for the sighted group. There were no differences in the mean age (p = .604) and mean years of education (p = .328) of the three groups. In line with previous studies (Scheller et al., 2021), eight years was chosen as the cut-off age between the early (age of blindness onset before 8 years of life) and late (age of blindness onset after 8 years of life) blind groups. This choice is supported by studies suggesting that the first 8 years of life are a critical period for cross-modal calibration (Cappagli et al., 2017; Scheller et al., 2021). The clinical and demographic characteristics of the early and blind groups are depicted in Table 1.

Participants were recruited by word of mouth with the following inclusion criteria: normal hearing, no history of electroconvulsive treatment, neurological illness, drug or alcohol abuse, and no current medication with potential impact on the electroencephalogram. For the sighed control group, the inclusion criteria also included normal or corrected to normal vision. For the early and late blind groups, the inclusion criteria included total blindness or no more than rudimentary sensitivity for brightness without pattern recognition.

All participants had the procedures explained to them and signed an informed consent form to confirm their willingness to attend the study. This study was approved by the ethics committee of the Faculty of Psychology of the University of Lisbon. All the experimental sessions were conducted in the Faculty of Psychology of the University of Lisbon. This study is part of a research project supported by BIAL Foundation Grants programme for Scientific Research 2018/2019 (Voice Perception in the Visually Deprived Brain: Behavioral and Electrophysiological Insights, reference nº 148/18).

2.2. Stimuli

The stimuli included 80 non-verbal vocalizations representative of four different conditions: 20 spontaneous laughs, 20 volitional laughs, 20 spontaneous cries, and 20 volitional cries. These stimuli were produced within a sound-proof anechoic chamber at University College London (Lavan et al., 2015; McGettigan et al., 2015). In each condition, 10 stimuli were generated by three male speakers and 10 by three female speakers (aged between 24 - 48 years).

Table 1.

Clinical and demographic characteristics of the early and late blind groups.

ID	Age	Gender	Handness	Years of education	Age of blindness onset	Cause of blindness	Vision Group
EB01	34	M	Left	15	Birth	Congenital Glaucoma	Early Blind
EB02	43	M	Right	12	Birth	Unknown	Early Blind
EB03	65	M	Right	9	Birth	Rubella	Early Blind
EB04	35	M	Right	15	Birth	Childbirth complications	Early Blind
EB05	53	M	Right	12	Birth	Coloboma and several corneal conditions	Early Blind
EB06	33	M	Right	12	1 year	Cancer	Early Blind
EB07	36	F	Right	12	First mounths	Impact injury	Early Blind
EB08	38	M	Right	9	Birth	Retrolental fibroplasia	Early Blind
EB09	39	M	Right	12	Birth	Retrolental fibroplasia	Early Blind
EB10	33	M	Right	12	Birth	Congenital Glaucoma	Early Blind
EB11	62	M	Right	15	3 years	Glaucoma	Early Blind
EB12	65	M	Right	15	Birth	Retrolental fibroplasia; Leber's hereditary optic neuropathy	Early Blind
EB13	43	F	Right	12	Birth	Rubella	Early Blind
EB14	51	M	Right	15	Birth	Rubella	Early Blind
EB15	23	M	Left	12	Birth	Retrolental fibroplasia	Early Blind
EB16	58	F	Right	9	5 years	Measles	Early Blind
EB17	19	M	Left	12	Birth	Congenital Glaucoma	Early Blind
LB01	26	M	Right	12	10 years	Glaucoma	Late Blind
LB02	46	M	Right	11	25 years	Glaucoma	Late Blind
LB03	52	F	Right	12	19 years	Glaucoma	Late Blind
LB04	34	F	Right	12	18 years	Retinitis pigmentosa; Retinal detachment	Late Blind
LB05	62	M	Right	12	36 years	Retinitis pigmentosa	Late Blind
LB06	45	F	Right	12	39 years	Glaucoma	Late Blind
LB07	46	M	Right	6	30 years	Impact injury	Late Blind
LB08	55	M	Right	12	30 years	Unkown genetic disease	Late Blind
LB09	51	M	Right	9	43 years	Retinal Atrophy/Glaucoma	Late Blind
LB10	51	F	Right	12	20 years	Retinopathy/Glaucoma	Late Blind
LB11	40	F	Right	17	38 years	Retinopathy	Late Blind
LB12	50	M	Right	15	24 years	Retinitis pigmentosa	Late Blind
LB13	37	F	Left	17	14 years	Retinal detachment/Coats' disease	Late Blind
LB14	48	F	Right	10	18 years	Retinal detachment	Late Blind
LB15	58	M	Right	9	26 years	Glaucoma	Late Blind
LB16	45	M	Left	12	35 years	Postoperative complications	Late Blind
LB17	54	M	Right	9	19 years	Impact injury	Late Blind

To elicit spontaneous laughter, the experimenters used an amusement induction procedure in a social interactive setting. In this setting, the speakers were instructed to watch video clips that they had earlier identified as amusing and that would easily make them laugh (see McGettigan et al., 2015). The experimenters were well acquainted with the speakers and interacted with them during the recording session to promote the social nature and spontaneity of the laughs. Spontaneous crying was also elicited with an emotional induction procedure (see Lavan et al., 2016). Speakers were asked to recall upsetting events from their past and/or start producing posed cries to prompt a transition into a genuine sad experience, characteristic of authentic crying. Importantly, the six speakers reported feelings of amusement and sadness throughout and after the recording of the authentic vocalizations. For volitional laughter and crying, the same speakers were instructed to simulate these expressions in the absence of a corresponding emotional eliciting event. In line with the procedure typically used for the recording of acted stimuli, the speakers tried to make the vocalizations sound as credible and natural as possible (Lavan et al., 2015; McGettigan et al., 2015).

These stimuli have been used in previous behavioral and neuroimaging studies (e.g., Conde et al., 2022; Lavan et al., 2015, 2016; Lima et al., 2021; Neves et al., 2018; Pinheiro et al., 2021).

2.3. Procedure

Each participant was tested individually in a single experimental session lasting approximately 2 hours (breaks included) and completed two tasks while electrophysiological data was recorded.

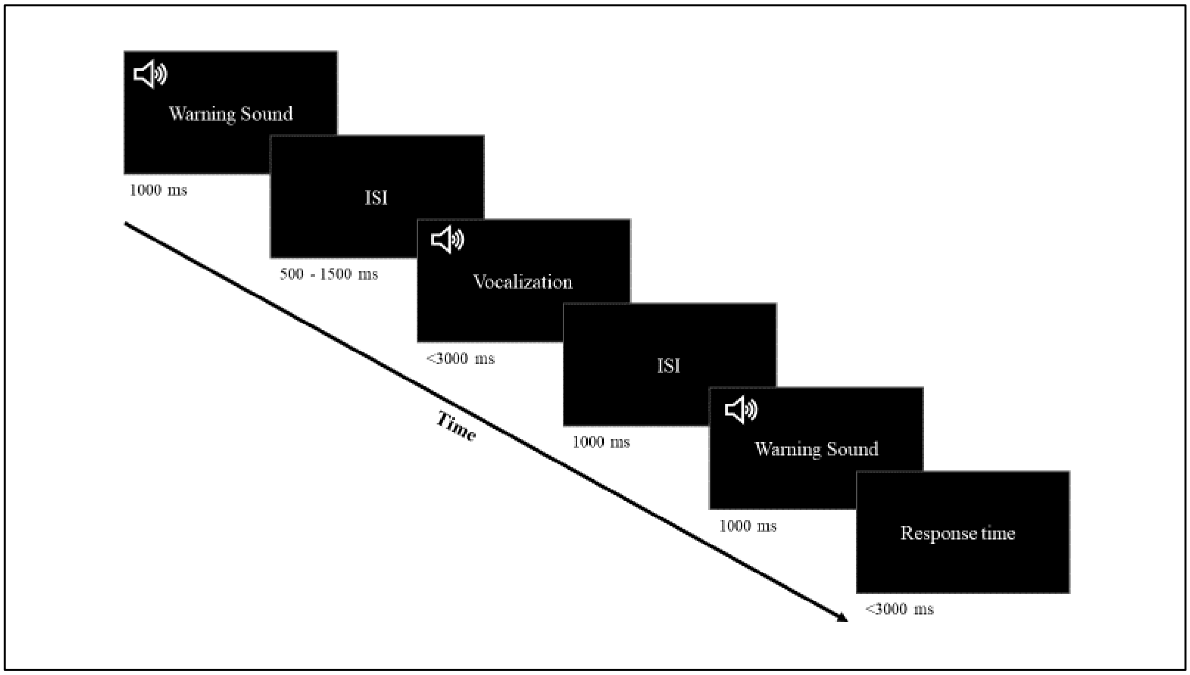
Participants were seated in a comfortable chair inside an electrically shielded and sound attenuated room (http://www.demvox.com/). They performed two tasks, one focusing on the detection of emotional authenticity (volitional *vs.* spontaneous) and the other on the discrimination of emotion (sadness *vs.* amusement). The vocal stimuli were presented through headphones and at a sound level comfortable for each participant. The experiment was developed and presented using Presentation® software (Version 20.1, Neurobehavioral Systems, Inc., Berkeley, CA, www.neurobs.com), a tool used for presenting stimuli in behavioral and physiological experiments. Responses were given through button presses. The order of the buttons and task display was counterbalanced across participants. During the experiment, all participants were asked to keep their eyes closed and all lights were turned off.

In each task, the 80 vocalizations were randomly presented twice, originating a total of 160 trials per task. The trial structure was the following: 1) a warning sound lasting 1000 ms indicated the beginning of each trial; 2) a varying inter-stimulus interval (ISI; 500 – 1500 ms) was presented; 3) participants heard a vocalization for less than 3000 ms; 4) a ISI was presented during 1000 ms; 5) a 1000 ms warning sound was presented to signal the beginning of the response time; 6) participants had 3000 ms to answer (see Figure 1) .

After completing the EEG tasks, participants performed a behavioral task presented in *Qualtrics* software (https://www.qualtrics.com). In this task, participants heard the same 80 vocalizations and were instructed to rate the sounds regarding the dimensions of emotional authenticity, valence, and arousal, in a nine-point Likert scale ranging from 1 (minimum) to 9 (maximum).

Figure 1.

Illustration of an experimental trial



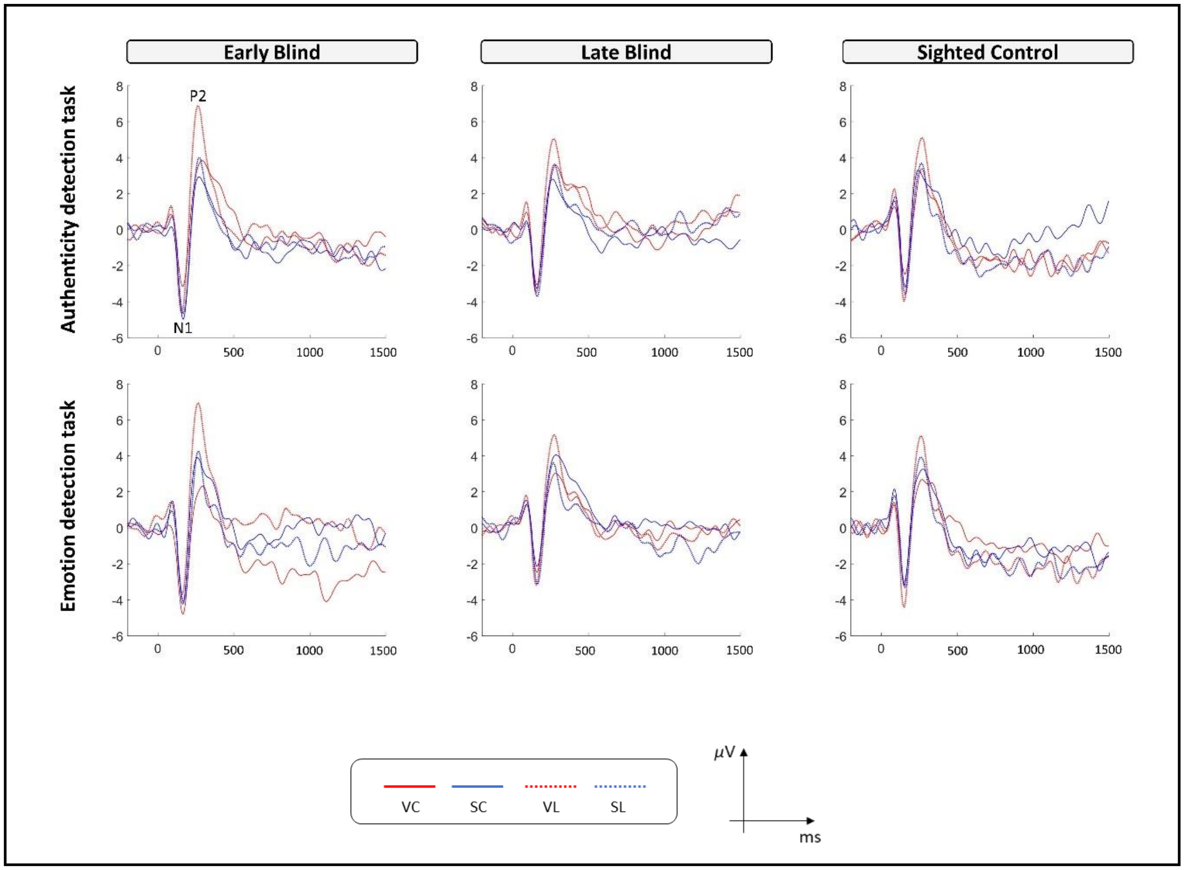
2.4. EEG data acquisition

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

The Letswave 7 software (https://www.letswave.org/) was used for offline analyses of EEG data. A band-pass filter with 0.1 Hz and 30 Hz, low and high cutoff frequency, was applied and EEG channels were referenced offline to the average of the left and right mastoids. Individual ERP epochs were created for each stimulus category (spontaneous laughter, spontaneous crying, volitional laughter, volitional crying), with -200 to 1500 ms, pre- and post-stimulus epoch. A baseline correction was performed in the -200 to 0 ms pre-stimulus interval. Ocular artifacts were corrected based on the method of Gratton, Coles, and Donchin (1983) and individual epochs containing excessive ocular artifacts (± 100 mV) were excluded from the analysis. After artifact rejection, for each condition and participant, a minimum of 70% of the trials entered the individual ERP averages (early blind [authenticity detection condition: volitional crying – 39.29 ± 1.10; volitional laughter – 39.35 ± 0.93; spontaneous crying – 39.53 ± 0.80; spontaneous laughter - 39.18 ± 1.24; emotion detection condition: volitional crying – 39.35 ± 1.00; volitional laughter – 39.06 ± 1.14; spontaneous crying – 39.29 ± 1.45; spontaneous laughter - 39.00 ± 1.17]; late blind [authenticity detection condition: volitional crying – 38.47 ± 3.12; volitional laughter – 38.76 ± 2.02; spontaneous crying – 39.24 ± 1.56; spontaneous laughter - 38.76 ± 1.79; emotion detection condition: volitional crying – 38.24 ± 3.19; volitional laughter – 37.88 ± 3.20; spontaneous crying – 38.53 ± 2.92; spontaneous laughter - 38.06 ± 2.84]; sighted control [authenticity detection condition: volitional crying – 39.82 ± 0.73; volitional laughter – 39.76 ± 0.44; spontaneous crying – 39.76 ± 0.44; spontaneous laughter - 39.71 ± 0.85; emotion detection condition: volitional crying – 39.65 ± 0.61; volitional laughter – 39.82 ± 0.39; spontaneous crying – 39.76 ± 0.44; spontaneous laughter - 39.76 ± 0.49]. The number of epochs included in the averages did not differ per group and per condition ($p > .05$). Finally, grand average ERP waveforms were created for each of the four stimulus categories in each group (see Figure 2 and Figure 3).

Figure 2.

Grand average ERP waveforms for spontaneous and volitional vocalizations in the authenticity and emotion detection tasks, at electrode Cz.

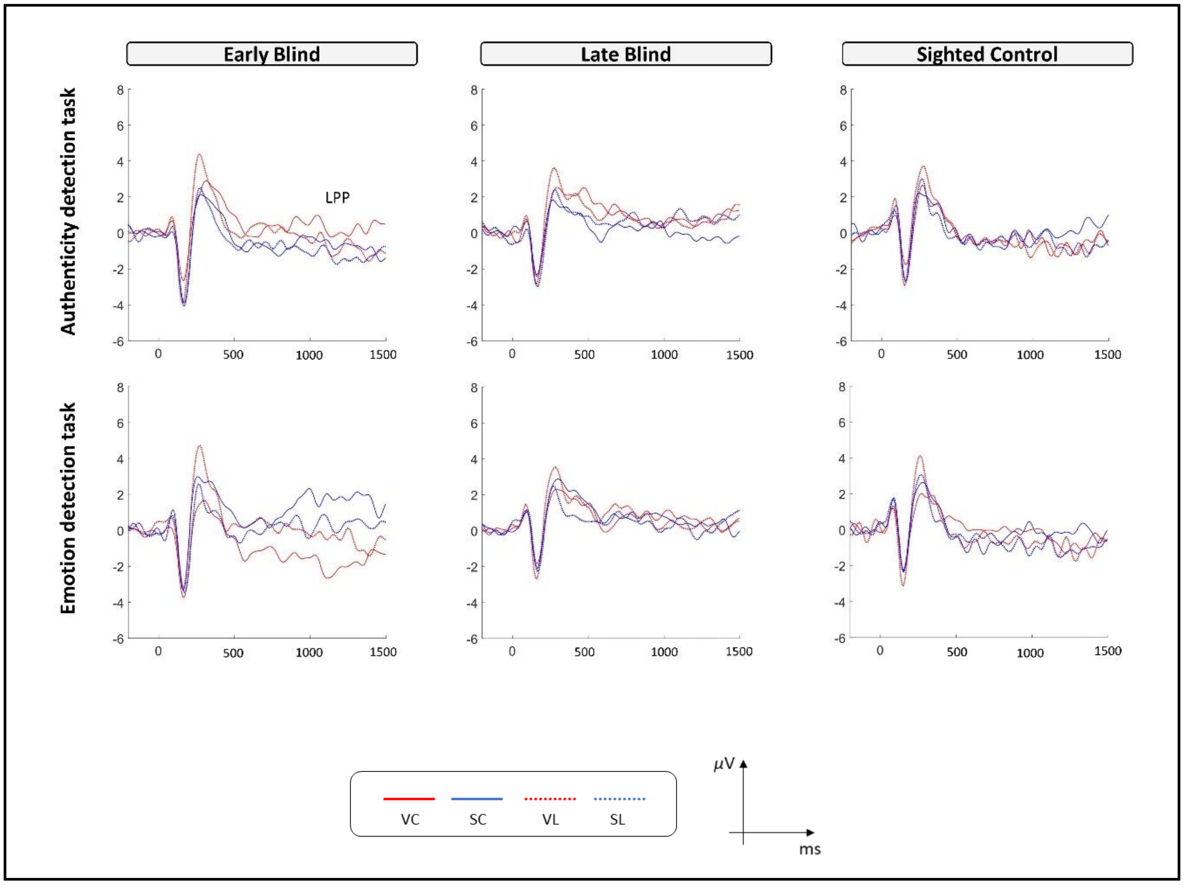


Note. VC = Volitional Cries; SC = Spontaneous Cries; VL = Volitional Laughs; SL = Spontaneous Laughs.

Based on visual inspection of grand-averaged waveforms and following previous studies (Conde et al., 2022; Pinheiro et al., 2016, 2017), the mean amplitude for each component was measured in a specific time window: 130 – 210 ms (N1), 215 – 320 ms (P2), 450 – 700 ms (early LPP), 700 – 1000 ms (middle LPP), 1000 – 1400 (late LPP). For the N1 and P2 components, consistent with previous studies (Conde et al., 2022; Pinheiro et al., 2017) both fronto-central (FC1, FCz, FC2) and central (C1, Cz, C2) electrodes were included in the analysis. For the LPP, the analysis included centro-parietal (CP1, CPz, CP2), parietal (P1, Pz, P2) and parieto-occipital (PO3, POz, PO4) channels (Conde et al., 2022; Pinheiro et al., 2017). See Figure 4 and Figure 5 for the scalp distributions of the ERP components.

Figure 3.

Grand average ERP waveforms for spontaneous and volitional vocalizations in the authenticity and emotion detection tasks, at electrode CP1.



Note. VC = Volitional Cries; SC = Spontaneous Cries; VL = Volitional Laughs; SL = Spontaneous Laughs.

2.5. Statistical analyses

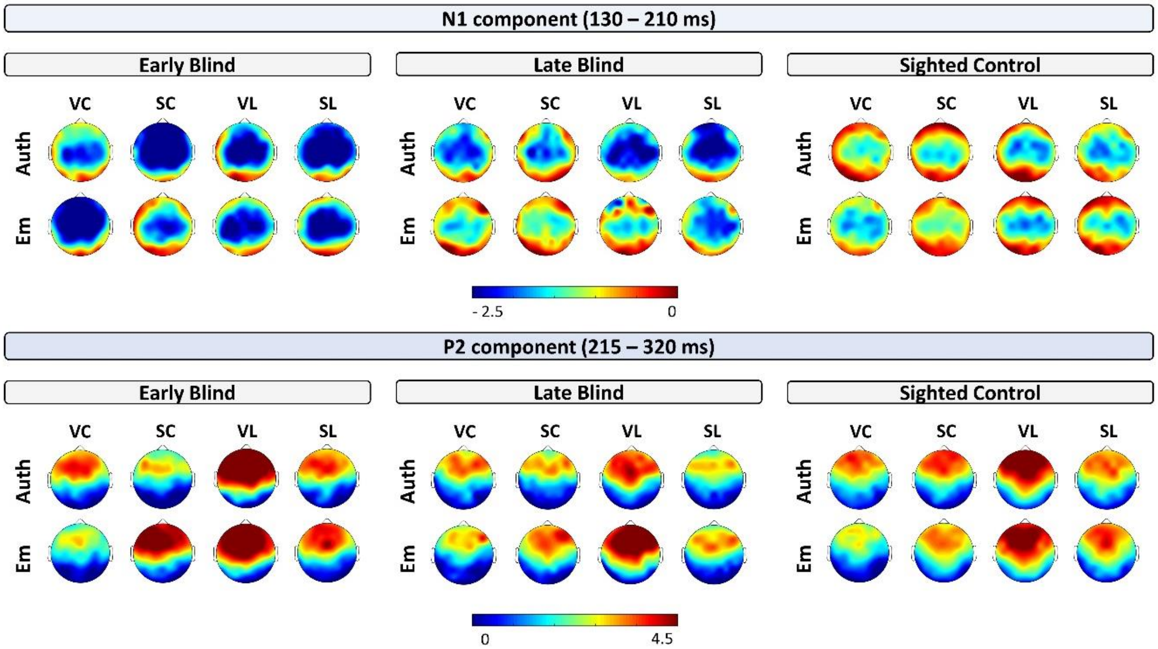
For both Behavioral and ERP data, repeated-measures analyses-of-variance (ANOVAs) were computed, using IBM SPSS software (Version 27, SPSS Inc., Chicago, IL, USA). In these statistical analyses, the Greenhouse–Geisser method was used when Mauchly's test indicated that the assumption of sphericity had been violated. Main effects and interactions were examined with pairwise comparisons, using Bonferroni correction for multiple comparisons. Effect sizes for significant effects were reported using the partial eta squared method (ηp2), and interactions with the variable group were followed by computing within-group ANOVAs.

2.5.1. ERP data

The mean amplitudes of N1, P2, and LPP (early, middle, and late LPP time windows) were subjected to separated ANOVAs, with the variable group (early blind vs. late blind vs. control) as a between-subjects factor, and authenticity (volitional, spontaneous), emotion (sadness, amusement), and task focus (authenticity, emotion), as within-subjects factors.

Figure. 4.

Topographic maps showing the scalp distribution of N1 and P2 voltage for spontaneous and volitional vocalizations in the authenticity and emotion detection tasks.



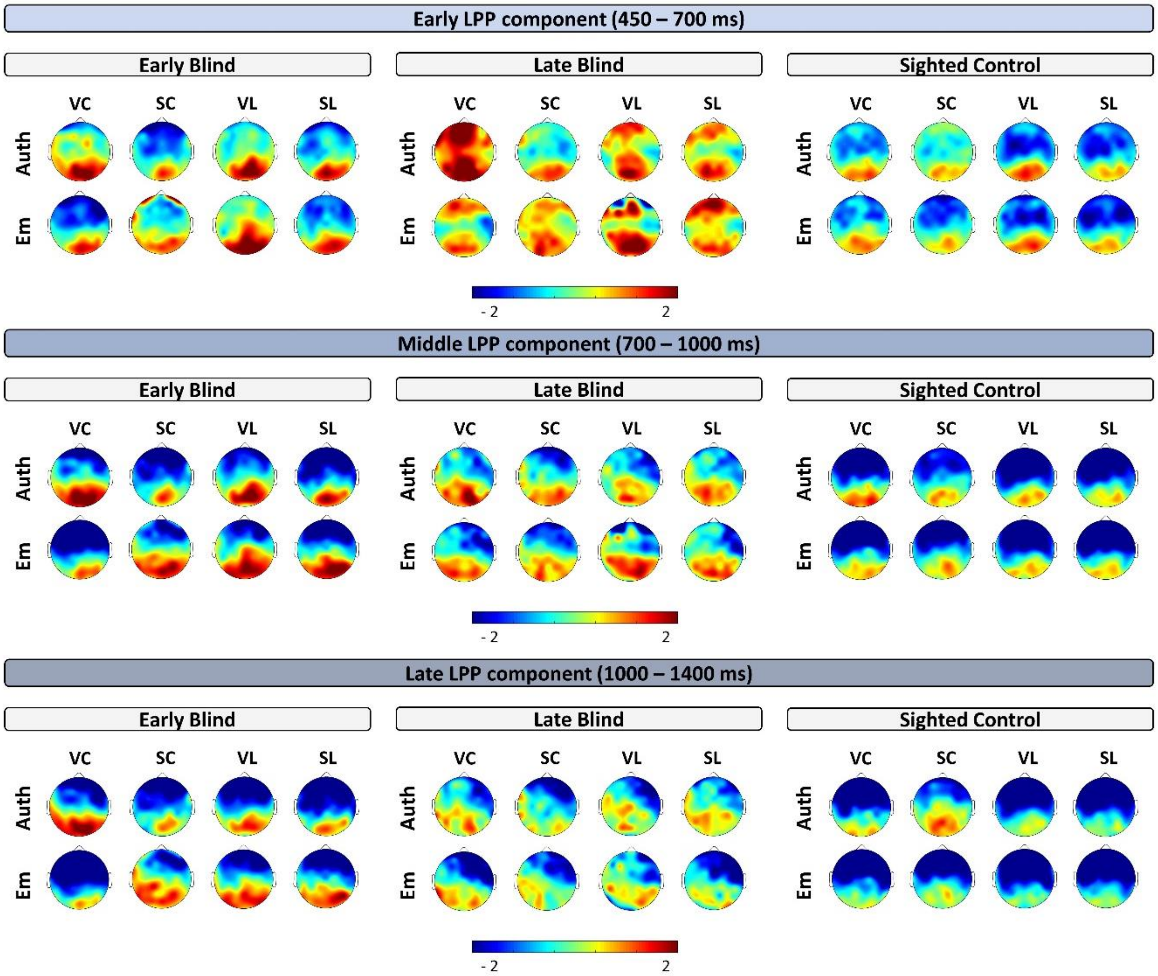
Note. Auth – Emotional authenticity task; Em = Emotional detection task; VC = Volitional crying; SC = Spontaneous crying; VL = Volitional laughter; SL = Spontaneous laughter.

2.5.2. Behavioral data

The accuracy of authenticity and emotion detection, as well as the affective ratings of authenticity, valence, and arousal, were subjected to separated ANOVAs, with the variable group (early blind vs. late blind vs. control) as a between-subjects factor, and authenticity (volitional, spontaneous) and emotion (sadness, amusement) as within-subjects factors.

Figure. 5.

Topographic maps showing the scalp distribution of LPP voltage for spontaneous and volitional vocalizations in the authenticity and emotion detection tasks.



Note. Auth – Emotional authenticity task; Em = Emotional detection task; VC = Volitional crying; SC = Spontaneous crying; VL = Volitional laughter; SL = Spontaneous laughter.

3. Results

3.1. ERP data

All main effects and interactions computed for the N1, P2, early LPP, middle LPP and late LPP components are summarized in Table 2.

3.1.1. N1 component

We found no main effects of Authenticity, *F* (1, 48) = 1.740, *p* = .378, Emotion, *F* (1, 48) = 2.270, *p* =.138, Task, *F* (1, 48) = 3.341, *p* =.074, or interactions involving these factors (lowest *p* = .152; see Table 2). Furthermore, the effect of group, *F* (2, 48) = .796, *p* = .457, was not statistically significant. Nonetheless, an interaction between Authenticity, Emotion, Task, and Group, *F* (2, 48) = 2.697, *p* = .078, η_p^2 =.101, approached significance. To clarify this trend, we explored within-group effects. No interactions between Authenticity, Emotion, and Task, were found in both the late blind, *F* (1, 16) = .185, *p* = .673, and sighted groups, *F* (1, 16) = .008, *p* = .931. However, in the early blind group, interactions between Authenticity, Emotion, and Task, *F* (1, 16) = 5.724, *p* = .029, η_p^2 =.263, reached statistical significance. Pairwise comparisons showed that, in the early blind group, a more negative N1 was elicited by spontaneous crying (vs. volitional crying) in the authenticity detection task (*p* =.013), but not in the emotion task (*p* = .112).

Table 2.

Main effects and interactions of the ERP data.

	N1			P2			Early LPP			Middle LPP			Late LPP		
	F -value	*p* -value	η_p^2	*F* -value	*p* -value	η_p^2	*F* -value	*p* -value	η_p^2	*F* -value	*p* -value	η_p^2	*F* -value	*p* -value	η_p^2
Authenticity	.790	.378	.016	**26.562**	**< .001**	**.356**	**7.589**	**.008**	**.137**	.187	.668	.004	.376	.542	.008
Emotion	2.270	.138	.045	**33.388**	**< .001**	**.410**	2.621	.112	.052	.064	.801	.001	.422	.519	.009
Task	3.341	.074	.065	.148	.702	.003	1.311	.258	.027	.086	.771	.002	.348	.558	.007
Group	.796	.457	.032	.115	.892	.005	1.501	.233	.059	.518	.599	.021	.334	.717	.014
Authenticity * Emotion	.585	.448	.012	**31.167**	**< .001**	**.394**	1.409	.241	.029	.050	.824	.001	.699	.407	.014
Authenticity * Task	3.311	.075	.065	3.983	.052	.077	3.654	.062	.071	2.564	.116	.051	2.369	.130	.047
Authenticity * Group	1.234	.300	.049	**3.333**	**.044**	**.122**	1.059	.355	.042	.039	.961	.002	.643	.530	.026
Emotion * Task	2.122	.152	.042	.697	.408	.014	2.171	.147	.043	.435	.513	.009	.480	.492	.010
Emotion * Group	1.126	.333	.045	1.887	.163	.073	1.342	.271	.053	1.577	.217	.062	.817	.448	.033
Task * Group	2.039	.141	.078	.886	.419	.036	.110	.896	.005	.440	.647	.018	.191	.827	.008
Authenticity * Emotion * Task	1.840	.181	.037	3.491	.068	.068	**5.928**	**.019**	**.110**	1.389	.244	.028	1.157	.287	.024
Authenticity * Emotion * Group	.454	.638	.019	1.469	.240	.058	.192	.826	.008	.162	.851	.007	1.263	.292	.050
Authenticity * Task * Group	2.214	.120	.084	1.096	.342	.044	.009	.991	.000	2.512	.092	.095	**3.348**	**.044**	**.122**
Emotion * Task * Group	.352	.705	.014	.362	.698	.015	.080	.924	.003	.300	.742	.012	.856	.431	.034
Authenticity * Emotion * Task * Gro	2.697	.078	.101	1.146	.327	.046	1.049	.358	.042	.685	.509	.028	1.117	.336	.044

Note. Significant effects in bold.

3.1.2. P2 component

A main effect of Authenticity, *F* (1, 48) = 26.562, *p* < .001, η_p^2 = .356, Emotion, *F* (1, 48) = 33.388, *p* < .001, η_p^2 = .410, and an interaction between Authenticity and Emotion, *F* (1, 48) = 31.167, *p* < .001, η_p^2 = .394, reached statistical significance. Pairwise comparisons revealed a more positive P2 amplitude for volitional compared with spontaneous laughter (*p*

< .001), whereas for crying no significant authenticity effects were found (p = .069). No main effect of Task, F (1, 48) =.148, p =.702, was found.

Although no main effect of group, F (2, 48) = .115, p = .892, was found, an interaction between Authenticity and Group, F (2, 48) = 3.333, p = .044, η_p^2 = .122, reached statistical significance. To follow this interaction, we explored within-group effects. A main effect of Authenticity, reflected in a more positive P2 for volitional expressions (vs. spontaneous), was found in both the early, F (1, 16) = 17.227, p < .001, η_p^2 = .518, and late blind groups, F (1, 16) = 7.786, p = .013, η_p^2 = .327, but not in the sighted group, F (1, 16) = 2.538, p = .131.

3.1.3. Early LPP (450 – 700 ms)

A main effect of Authenticity, F (1, 48) = 7.589, p =.008, η_p^2 = .137, and an interaction between Authenticity, Emotion, and Task, F (1, 48) = 5.928, p =.019, η_p^2 = .110, were observed. Pairwise comparisons showed that, in the authenticity detection task, LPP was increased for volitional compared to spontaneous crying (p =.014), but in the emotion detection task the LPP was enhanced for spontaneous compared to volitional crying (p =.009). For laughter, however, no significant authenticity effects were found either when the task was focused on the authenticity (p = .096) or on the emotion (p = .079) of vocalizations.

Furthermore, the effect of group, F (2, 48) = 1.501, p = .233, or interactions involving this factor were not statistically significant (lowest p = .271).

3.1.4. Middle LPP (700 – 1000 ms)

No main effects of Authenticity, F (1, 48) = .187, p = .668, Emotion, F (1, 48) = .064, p =.801, Task, F (1, 48) = .086, p =.771, or interactions involving these factors were found (lowest p = .116). Besides, the effect of group, F (2, 48) = .518, p = .599, or interactions involving this factor did not reach statistical significance (lowest p = .092).

3.1.5. Late LPP (1000 – 1400 ms)

We found no main effects of Authenticity, F (1, 48) = .376, p = .542, Emotion, F (1, 48) = .422, p = .519, Task, F (1, 48) = .348, p = .558, or interactions involving these factors (lowest p = .130). Nonetheless, an interaction between Authenticity, Task, and Group, F (2, 48) = 3.348, p = .044, η_p^2 = .122, reached statistical significance. Within-group effects were computed to explore this interaction. In the early blind group, an interaction between Authenticity and Task, F (1, 16) = 7.386, p = .015, η_p^2 = .316, revealed that LPP was more positive in response to spontaneous (vs. volitional) expressions in the emotion detection task (p = .016), but not in the authenticity task (p = .243). These interactive effects between Authenticity and Task were not found in the late blind, F (1, 16) =.202, p = .659, or sighted groups, F (1, 16) =.055, p = .818.

3.2. Behavioral data

3.2.1. Authenticity detection task

The mean accuracy of authenticity detection per emotion type is presented in Table 3.

We found a main effect of emotion, F (1, 48) = 6.788, p = .012, η_p^2 = .124**,** and an interaction between Authenticity and Emotion, F (1, 48) = 18.650, p < .001, η_p^2 = .280**.** Pairwise comparisons revealed that participants, irrespective of the group, were more accurate at discriminating the authenticity of spontaneous laughs compared with volitional ones (p < .001), whereas for crying they were more accurate at discriminating the authenticity of volitional cries compared with spontaneous ones (p = .046). Further, the effect of group, F (2, 48) = 3.695, p = .032, η_p^2 = .133, reached statistical significance and showed that the sighted group was generally more accurate at discriminating the authenticity of vocalizations than the late blind group (p = .034), but did not significantly differ from the early blind group (p = .194).

3.2.2. Emotion detection task

The mean accuracy of emotion detection per emotion type is presented in Table 4.

A main effect of Authenticity, F (1, 48) = 151.669, p < .001, η_p^2 = .760, Emotion, F (1, 48) = 65.580, p < .001, η_p^2 = .577, and an interaction between Authenticity and Emotion, F

(1, 48) = 155.601, $p < .001$, $\eta_p^2 = .764$, reached statistical significance. Pairwise comparisons revealed that participants were overall less accurate at detecting the emotional category of spontaneous compared with volitional cries ($p < .001$). No between-group effects, F (2, 48) = 2.449, $p = .097$, or interactions involving this factor (lowest $p = .208$) were found.

Table 3.

Average accuracy scores in the authenticity detection task

Authenticity	Emotion	Visual condition		
		Early Blind	Late Blind	Sighted
		Hits	Hits	Hits
Spontaneous	Laughter	.81 (.18)	.71 (.20)	.82 (.11)
	Crying	.61 (.23)	.55 (.19)	.68 (.17)
Volitonal	Laughter	.60 (.28)	.59 (.26)	.69 (.13)
	Crying	.66 (.24)	.72 (.21)	.75 (.19)

Note. The value between brackets is the Standard Deviation (SD).

Table 4.

Average accuracy scores in the emotion detection task

Emotion	Authenticity	Visual condition		
		Early Blind	Late Blind	Sighted
		Hits	Hits	Hits
Laughter	Spontaneous	.95 (.07)	.94 (.05)	.96 (.06)
	Volitonal	.93 (.05)	.92 (.07)	.97 (.04)
Crying	Spontaneous	.70 (.13)	.76 (.13)	.77 (.11)
	Volitonal	.92 (.09)	.92 (.09)	.95 (.07)

Note. The value between brackets is the Standard Deviation (SD).

3.2.3. Affective ratings

Due to scheduling constraints, four late blind individuals and two sighted controls were not able to complete this task. Hence, only forty-five participants completed this task (17 early blind, 13 late blind and 15 sighted controls).

Overall, participants rated spontaneous stimuli as more authentic, F (1, 42) = 177.517, p < .001, η_p^2 = .809, positive, F (1, 42) = 137.072, p < .001, η_p^2 = .765, and arousing, F (1, 42) = 86.328, p < .001, η_p^2 = .673, than volitional stimuli (see Table 5). Participants also rated laughs as more authentic, F (1, 42) = 36.408, p < .001, η_p^2 = .464, positive, F (1, 42) = 159.48, p < .001, η_p^2 = .791, and arousing, F (1, 42) = 50.860, p < .001, η_p^2 = .548, than cries.

No between-group effects or interactions with this factor were found in the ratings of Authenticity, F (2, 42) = .190, p = .827, Valence, F (2, 42) = .005, p = .995, and Arousal, F (2, 42) = .157, thus indicating that the groups rated the affective properties in a similar way.

Table 5.

Average scores of the affective ratings

Emotion	Authenticity	Visual condition								
		Early Blind (n = 17)			Late Blind (n = 13)			Control (n = 15)		
		Auth	Val	Arou	Auth	Val	Arou	Auth	Val	Arou
Laughter	Spontaneous	6.88	6.83	6.56	6.48	6.59	6.38	6.83	7.06	6.38
	Volitonal	4.70	5.29	4.89	5.02	5.55	5.44	5.01	5.88	4.83
Crying	Spontaneous	5.58	4.32	5.00	5.10	4.30	4.99	5.76	3.75	4.97
	Volitonal	4.08	3.62	4.22	3.92	3.73	4.35	3.92	3.44	4.00

Note. Auth = Authenticity; Val = Valence; Arou = Arousal.

4. Discussion

The current study probed whether and how blindness modulates the behavioral and electrophysiological correlates of emotional authenticity perception. Our aims were to understand whether and how the age of blindness onset (early vs. late) and task focus manipulation (focus on authenticity vs. on emotion) affected these mechanisms.

4.1. Early processing stages

At a processing stage associated with early sensory acoustic processing, we found interactive effects of task, emotion, authenticity, and group. Specifically, we found a more negative N1 amplitude in response to spontaneous vs. volitional crying, in the authenticity detection task, in the early blind group only. The N1 is known to be sensitive to the physical acoustic proprieties of the stimulus (Näätänen & Picton, 1987), and is modulated by attention (Ho et al., 2015). Therefore, effects of crying authenticity on the N1 in the early blind group may suggest an enhanced sensitivity to the physical acoustic differences between spontaneous and volitional cries in early blind listeners, when compared with the other two groups. Indeed, in comparison with volitional cries, spontaneous cries have a slightly higher pitch, more variable timbral brightness and less voicing (Pinheiro et al., 2021). This finding is consistent with previous reports of enhanced early sensory acoustic processing in early blind compared with sighted individuals (Föcker et al., 2012; Topalidis et al., 2020), and might suggest that early blindness leads to cortical reorganization in the early sensory stages of emotional authenticity perception. Since there is evidence of early specialization, in the first months of life, for vocal emotion processing (Blasi et al., 2011), it seems reasonable that in early blind individuals, in order to compensate for the absence of visual emotional information, this early specialization leads to an increased sensitivity for the detection of the acoustic proprieties of crying authenticity.

The N1 enhancement for spontaneous crying found in the early blind group occurred only in a task where authenticity detection was task-relevant. Effects of attention on the early processing stages of auditory information have been previously reported (Foldal et al., 2020; Hink et al., 1978; Lange, 2013; Parasuraman, 1978). Task relevance and prediction are often associated with opposite modulations of the N1 component. While temporal predictions usually lead to an amplitude attenuation, task relevance consistently leads to enhancement of the N1 amplitude (see, Lange, 2013, for a review). Thus, the N1 enhancement found in early blind listeners might reflect a superior allocation of attentional resources to spontaneous cries (vs. volitional crying) when authenticity discrimination is required. A relationship between increased cognitive effort and larger N1 amplitudes has also been previously reported (Enge et al., 2011; Mulert et al., 2005, 2008). Hence it is possible that early blind individuals spent more cognitive effort detecting the authenticity of spontaneous cries than late blind and sighted individuals. Nevertheless, it is noteworthy that this effect is derived from a marginally significant interaction, so it should be interpreted with caution.

At a processing stage associated with emotional salience detection indexed by the P2 component (Jessen & Kotz, 2011; Schirmer & Kotz, 2006), we found more positive amplitudes for volitional (vs. spontaneous) laughter. This finding suggests a facilitated detection of emotional salience for volitional (vs. spontaneous) laughs. Furthermore, this effect of laughter authenticity was observed in all groups and independently of task focus, which suggests enhanced automatic processing of volitional laughs. An effect that is consistent with previous evidence of automatic processing of emotionally salient information from nonverbal vocalizations (Lima et al., 2019; Pinheiro et al., 2015).

Volitional laughs are acoustically less variable and more prototypical representations of amusement than the more idiosyncratic spontaneous laughs, which have a greater spectral variability, more variable pitch, and more variable harmonics-to-noise ratio in voiced frames (Pinheiro et al., 2021). The P2 amplitude is consistently modulated by facial prototypicality, with increased amplitudes often reported for more prototypical faces (see, Schweinberger & Neumann, 2016, for a review). Considering the commonalities between face and voice perception (Belin et al., 2004, 2011), it is possible that vocal prototypicality also modulates the amplitude of the auditory P2. Therefore, the increased P2 amplitude for volitional laughs might indicate that vocal prototypicality facilitates the detection of emotional salience in laughter. This effect can also be explained by differences in arousal between volitional and spontaneous laughs. The P2 amplitude has been shown to be affected by arousal (Han et al., 2013; Olofsson & Polich, 2007; Paulmann et al., 2013) and the participants of our study perceived spontaneous laughs as more arousing than volitional ones. Although larger P2 amplitudes for emotional arousing stimuli were found by previous studies (Olofsson & Polich, 2007; Paulmann et al., 2013), the current finding is consistent with evidence of more positive P2 amplitudes for low (vs. high) arousing pseudo-sentences embedded with emotional prosody (Han et al., 2013). Other stimulus proprieties are also known to affect the amplitude of the P2 component (Crowley & Colrain, 2004), with several studies reporting larger amplitudes for low-pitch compared to high-pitch stimuli (Antinoro et al., 1969; Crowley & Colrain, 2004; Wunderlich & Cone-Wesson, 2001). The volitional laughs used as stimuli in this study have a significantly lower pitch than the spontaneous laughs (Pinheiro et al., 2021). On the other hand, spontaneous and volitional cries are less acoustically distinct, with volitional cries having only a slightly lower pitch than spontaneous cries (Pinheiro et al., 2021). Hence, the frequency differences between stimuli might explain the observed effect. The P2 enhancement for volitional compared to spontaneous laughs is consistent with previous studies probing emotional authenticity perception in sighted individuals (Conde et al., 2022; Kosilo et al., 2021).

Importantly, we found an interaction between group and authenticity reflecting a larger P2 amplitude for volitional than for spontaneous expressions in the early and late blind, but not in the sighted group. This finding suggests that in a processing stage associated with the detection of emotional salience, visual deprivation has an impact on the perception of emotional authenticity. Based on this result, we can hypothesize that blindness, independently of the age of onset, triggers compensatory mechanisms at this processing stage that lead to cortical reorganization and facilitated detection of emotional authenticity. Changes in the neural processing of vocal information indexed by modulations in this time window were previously found for congenital blind (Topalidis et al., 2020) and late blind listeners (Föcker et al., 2015).

4.2. Late processing stages

At a processing stage associated with sustained attention and cognitive evaluation of emotionally relevant information, we found an interaction between authenticity, emotion, and task in the early LPP time window. Specifically, we found a larger early LPP for volitional (vs. spontaneous) cries in the authenticity detection task and a more positive LPP for spontaneous (vs. volitional) cries in the emotion detection task. These findings might suggest that the LPP is modulated by the emotional authenticity of vocal sounds, yet the directionality of the effect depended on task focus. Enhanced LPP amplitudes are consistently elicited by emotional compared to neutral stimuli, such as pictures (see Hajcak & Foti, 2020; Moran et al., 2013 for a review), faces (see Schindler & Bublatzky, 2020 for a review), vocalizations (I. Martins et al., 2022), and words (Herbert et al., 2008; Schindler & Kissler, 2016). Several studies have reported an enhancement of the LPP component in response to threatening stimulus (Bublatzky & Schupp, 2012; MacNamara & Hajcak, 2010; Schindler &

Bublatzky, 2020; Schupp & Kirmse, 2021; Stolz et al., 2019; Wheaton et al., 2013). It is possible to argue that, when judging the authenticity of laughs and cries, volitional cries represent the most socially threatening stimuli. While volitional laughs can often be prosocial signals of politeness and can be used to express polite agreement or manifest shyness in conversations (Bryant & Aktipis, 2014; Kamiloğlu et al., 2022), volitional cries are more often used to manipulate others and to obtain privileges or gain an advantage (Dawel et al., 2019; Nakayama, 2010; van Roeyen et al., 2020; Vingerhoets & Bylsma, 2016). They are frequently used by sociopaths and narcissists as a manipulation tactic (van Roeyen et al., 2020; Vingerhoets & Bylsma, 2016), and the threatening nature of volitional cries is even marked by the commonly used expression "crocodile tears". It is possible that the observed LPP enhancement in response to volitional cries, in the authenticity detection task, reflects the cognitive evaluation of a more socially threatening stimulus. In the emotion detection task, the LPP enhancement was observed in response to spontaneous (vs. volitional) cries. In a task where the authenticity of the stimulus is not being judged, other affective proprieties such as the emotional quality of vocalizations might be more salient when evaluating the emotion of sounds. In such a task, it is possible that the superior emotional significance of spontaneous cries elicits an increase in the LPP component. The fact that the observed effect was modulated by task, is consistent with previous findings of LPP enhancements to emotional stimuli explicitly processed (Schindler et al., 2022; Schindler & Bublatzky, 2020), and further supports the sensitivity of this component to task relevance and as an index of sustained attention allocation to emotional salient stimuli (Schindler et al., 2022; Schindler & Bublatzky, 2020; Schindler & Straube, 2020).

Importantly, we found an interaction between authenticity, task, and group in a later time window (1000 – 1400 ms) of the LPP component. Specifically, in the early blind group, we observed a more positive late LPP for spontaneous compared to volitional stimuli in the emotion detection task. As far as we know, this is the first study probing vocal perception at this stage of processing in blind individuals. This LPP modulation might suggest a facilitated detection of emotional authenticity by early blind individuals, in a later stage of emotional processing. Spontaneous vocalizations are more emotionally arousing than volitional ones (Pinheiro et al., 2021), and the LPP amplitude is found to be consistently increased by highly arousing stimuli when emotion is task-relevant (Leite et al., 2012; Schupp et al., 2000;

Schupp & Kirmse, 2021). Thus, the LPP enhancement observed in the early blind group might reflect enhanced attention to the high-arousing state of the speaker's spontaneous vocalizations and might suggest that early blindness leads to cortical reorganization in late processing stages of emotional authenticity perception.

The behavioral findings of the present study shed light on the latter evaluative stages of vocal emotion perception, where an explicit response is provided. They reveal that the authenticity and emotion of the vocalizations modulated the discrimination of both authenticity and emotion information. Consistently with the findings of previous studies (Anikin & Lima, 2018; Bryant & Aktipis, 2014; Conde et al., 2022; Lavan et al., 2016), participants were better at detecting the authenticity of spontaneous laughs and volitional cries, showing an overall bias to perceive laughs as more authentic and cries as more posed. Participants were also overall less accurate at identifying the emotion of spontaneous cries.

Importantly, the behavioral findings of the present study revealed differences in how the groups judged the authenticity, but not the emotion, of laughs and cries. The late blind group was generally less accurate at detecting the authenticity of vocalizations than the sighted group, but no significant differences were found between the performance of the early blind and sighted groups. In early blind individuals, the impact of compensatory plasticity on some auditory processing abilities is well documented (Fairhall et al., 2017; Fine & Park, 2018), but this is not the case for late blind individuals to whom the evidence for compensatory plasticity is not so robust (Kupers & Ptito, 2014; Sabourin et al., 2022). The current findings fit well with the notion that, in early blind individuals, the loss of visual input before a critical period of development led to altered processing of both early and late stages of vocal emotion processing, indexed by N1, P2, and LPP modulations. It is possible to argue that these modulations reflect compensatory mechanisms that enabled early blind individuals to perform at the same level as sighted participants in a task requiring the detection of emotional authenticity. The development of vocal (Blasi et al., 2011; Chronaki et al., 2018; Shultz et al., 2014) and visual (Chronaki et al., 2015; Young et al., 2020) emotional processing abilities occurs at a relatively early stage of neural development. In late blind individuals, the loss of visual input after this critical period might help to explain the lower accuracy in the authenticity detection task. Our results suggest that, in late blind listeners, prolonged visual deprivation might lead to changes in early vocal emotion processing indexed by P2 modulations. However, it is possible that in this group the putative compensatory mechanisms were not strong enough to prevent maladaptive alterations (i.e., worse detection of emotional authenticity), which is consistent with previous reports of impaired development of multisensory integration in late-, but not in early-onset blindness (Scheller et al., 2021). The difficulties in emotional authenticity detection found in late blind individuals highlight the importance of developing auditory-based rehabilitative tools to improve vocal emotion perception in this population. Regarding vocal emotion recognition of laughs and cries, the absence of differences between blind and sighted individuals is consistent with previous findings (Gamond et al., 2017), and suggests that prolonged visual deprivation does not affect the emotional categorization of laughs and cries.

Altogether, the current findings are more in agreement with the hypothesis that prolonged visual deprivation impairs emotional authenticity perception, but early cortical reorganization triggers compensatory mechanisms that avoid potentially damaging alterations when blindness occurs in the first years of development.

4.3. Limitations and future directions

It is worth noting that the ERP analyses are exploring objective authenticity of vocalizations and not the subjective authenticity perceived by the participants. That is, due to limited number of stimulus and limitations of the ERP method, all answers were included in the analyses, even when the authenticity of the vocalization was not correctly identified. Furthermore, the high performance on the emotion detection task may represent a ceiling effect due to low task difficulty. Future studies should explore ERP modulations to perceived authenticity using different stimulus sets with more varied emotional categories and using more challenging emotion categorizations tasks.

5. Conclusions

Overall, our findings provide support for the impact of blindness on the perception of emotional authenticity. The observed ERP modulations suggest that early blindness affects neural responses to emotional authenticity at early sensory (N1) and late cognitive evaluative stages (LPP) of vocal processing. At a processing stage associated with detection of emotional salience (P2), both early and late blindness seem to influence the neural processing of emotional authenticity. Lastly, at a behavioral level the results support the notion that prolonged visual deprivation deteriorates emotional authenticity perception, but early cortical reorganization avoids potentially damaging alterations.

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