Affect in the dark: Navigating the complex landscape of social cognition in blindness

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Abstract

Research on the consequence of blindness has primarily focused on how visual experience influences basic sensory abilities, mainly overlooking the intricate world of social cognition. However, social cognition abilities are crucial as they enable individuals to navigate complex interactions, understand others' perspectives, regulate emotions, and establish meaningful connections, all essential for successful adaptation and integration into society. Emotional and social signals are frequently conveyed through nonverbal visual cues, and understanding the foundational role vision plays in shaping everyday affective experiences is fundamental. Here, we aim to summarize existing research on social cognition in individuals with blindness. By doing so, we strive to offer a comprehensive overview of social processing in sensory deprivation while pinpointing areas that are still largely unexplored. By identifying gaps in current knowledge, this review paves the way for future investigations to reveal how visual experience shapes the development of emotional and social cognition in the mind and the brain.

Keywords: Blindness, Social cognition, Theory of mind, Emotion, Facial expressions, Well-being, Visual impairment.

1. Introduction

1.1 The crucial role of sight in the social world

Humans are, by nature, social animals and spend most of their lives within highly dynamic and complex social environments (e.g., Fiske and Taylor, 2013).

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Recognizing and correctly interpreting social stimuli from the surrounding world enables individuals to navigate intricate social landscapes, fostering meaningful connections and relationships and ensuring optimal functioning in daily life (Dolan, 2002). In particular, individuals predominantly rely on discernible cues, such as gaze direction, facial expression, and bodily posture, to infer the mental states of others and adjust their behavior accordingly (Atkinson et al., 2004; De Gelder et al., 2015; Todorov et al., 2015). Moreover, these social signals convey fundamental information about the pleasantness and intensity of current experiences (Tracy et al., 2015), and offer insights into potential environmental opportunities and threats (Kandel, 2020). All these psychological processes that allow individuals to interpret, comprehend, and respond to social information fall under the umbrella term of *social cognition* (Frith and Frith, 2007).

Notably, a great deal of social information gleaned from the surrounding environment predominantly relies on vision. For instance, we may observe an individual with an irate face, hands resting on hips, and upper body leaning forward, readily understanding that they are angry before they even say something (Dael et al., 2012). In this case, quickly perceiving and recognizing another's emotional state could lead us to keep our distance from them to avoid a possible danger (e.g., verbal and physical aggression). Sight, therefore, plays a pivotal role in social interactions, enhancing our ability to interpret stimuli and respond effectively.

Curiously, the eyes, often considered the mirror of the soul, also emerge as highly informative in social interactions (Adams and Nelson, 2016). In particular, they appear as a very discriminative feature in identifying faces (Schyns et al., 2002), and the inability to adequately use information from the eye region of the face leads to a failure in fear recognition (Adolphs et al., 2005). Furthermore, the gaze is integral to mentalizing processes (Baron-Cohen and Cross, 1992), as well as joint attention mechanisms (Langton et al., 2000), and the construction of triadic representations (Tomasello, 2014) that allow individuals to share attention with others on the same external stimuli (Emery, 2000; Mundy and Newell, 2007). Importantly, we also know that people predominantly rely on visual cues when performing specific inferences on social information, for instance discriminating emotional expressions (Collignon et al., 2008; Falagiarda and Collignon, 2019).

The importance of visual experience in the social context is also reflected in language through visual metaphors describing emotional states (e.g., eyes shine for joy) or to express affective bodily sensations (e.g., eye

daggers for anger). Direct reference to visual sensory experience to talk about feelings highlights the close connection between sight and emotions, suggesting that vision might contribute to constructing emotional concepts (Giraud et al., 2023). The dominant role of visual information in affective processing is also testified by recent neuroimaging studies, showing that activity in the early visual cortex can classify distinct categories of emotion (Kragel et al., 2019), and that the mapping mechanisms of affect in transmodal cortices is similar to that of sensory information in primary areas (Lettieri et al., 2019, 2022).

The converging evidence from behavioral, linguistic, and neuroimaging research on the prominent function of sight should encourage us to consider a unique perspective often neglected: the outlook of individuals who navigate the social context without relying on the visual system. People with visual impairment or blindness explore the world mainly through other senses, such as hearing, smell, and touch, often showing an enhancement of these sensory systems due to crossmodal plasticity mechanisms (Collignon et al., 2009; Collignon and Volder, 2009; Frasnelli et al., 2011; Hasson et al., 2016; Kupers and Ptito, 2011; Pascual-Leone et al., 2005; Ricciardi et al., 2014). These findings prompt intriguing questions about the impact of time spent without visual inputs on this plasticity reorganization in the social and emotional context. Additionally, it is crucial to understand the effectiveness of alternative sensory information for blind individuals in navigating their social and emotional surroundings. Exploring how those without sight perceive affective experiences and interact with others is crucial for comprehending the complex relationship between sensory inputs and social skills.

The current review will thoroughly examine the existing research on the development of social cognition in the absence of vision and its implications. Given the multifaceted nature of social cognition, we will meticulously explore findings related to the Theory of Mind, perception and recognition of emotions, and recent studies on interoception and the bodily representation of affective states among individuals with blindness. The work aims to summarize research conducted until September 2024 to enhance our understanding of how lack of vision shapes how people can explore and adequately move in the social environment. By identifying gaps in the current knowledge, we aim to pave the way for future research directions that can contribute to a more nuanced comprehension of social cognition in the absence of vision.

To achieve these goals, we conducted a literature search across three electronic databases (Google Scholar, PubMed, and SCOPUS), using a

combination of the following search terms among others: "social cognition" or "Theory of Mind", "emotion", "interoception" AND "blind", "blindness" or "visual impairment". After duplicate removal, an independent screening of the study titles and abstracts was carried out by the first and the last authors of this review to identify studies most pertinent to our objectives. Additionally, the reference lists of all potentially relevant articles within the field were scrutinized to ensure the inclusion of any study overlooked during the electronic database search. To perform an exhaustive overview, we included studies conducted in blind populations and set no age limits. Only articles not written in the English language, not conducted on humans, and not focused on the abilities related to social cognition were excluded. Overall, a total of 82 studies were reviewed for the purpose of qualitative synthesis. More specifically, we have identified 36 studies related to the Theory of Mind, 24 concerning the facial expression of emotions, and 22 on emotion perception and recognition, including the bodily representation of emotional states.

Discussion of the included articles will provide a comprehensive picture of the current state of the art on social cognition in the blind population, highlighting critical issues in the literature and the efforts still to be made for better inclusion and quality of life improvement for blind individuals.

2. The development of social cognition

During the initial four years of life, children undergo critical development stages, acquiring the awareness that people possess a mind of their own and an increasing interest in the intentions, thoughts, and feelings behind others' behavior (Wellman et al., 2001). Central to this developmental journey is the acquisition of the Theory of Mind, the ability to attribute mental states to oneself and others (Premack and Woodruff, 1978). Theory of mind is essential for comprehending the social landscape, making inferences about others' psychological states and future behaviors, and adjusting one's behavior accordingly (Brüne and Brüne-Cohrs, 2006; Frith and Frith, 2003).

Most social cues on which people rely to enact mentalizing processes are accessible through vision that, as previously discussed, represents the primary sensory modality to perceive and recognize relevant social information. Individuals with blindness or visual impairment face challenges in accessing these visual cues, potentially hindering their ability to attribute

mental states to others (Pring et al., 1998). Previous research has indicated that children with visual impairments often delay acquiring Theory of Mind abilities (Green et al., 2004; McAlpine and Moore, 1995; Minter et al., 1998; Peterson et al., 2000). For instance, McAlpine and Moore (1995) suggested, albeit with a limited sample size, that blindness may restrict children's access to the information that facilitates the development of the Theory of Mind, though they might not inherently lack comprehension of false belief scenarios. Similarly, Minter et al. (1998) found that blind children struggled with understanding and applying certain mental state concepts, while two other studies revealed Theory of Mind deficits up to the age of 12 (Green et al., 2004; Peterson et al., 2000). These studies report lateness ranging between four and seven years in the correct execution of false belief tasks in congenitally blind compared to sighted children, and authors concur that the absence of information provided by the mutual gaze and the joint attention may contribute to this delay (Green et al., 2004; McAlpine and Moore, 1995; Minter et al., 1998). Roch-Levecq (2006) suggested that the delay in developing the Theory of Mind in blind children was related to their difficulty being involved in a feedback loop of affect mirroring with their parents. Researchers, therefore, converge on the idea that the absence of sight, by influencing the primitive forms of intersubjectivity, negatively affects the development of social cognition abilities. In this regard, some evidence has shown that the limited joint attention experiences in early childhood (Alfaro et al., 2018; Baron-Cohen, 1997) likely reflect on social interaction and communication (Korkmaz, 2011; Preisler, 1991; Tröster and Brambring, 1992), with consequences on the Theory of Mind but also the development of language abilities (McConachie and Moore, 1994; Morales et al., 1998; Tàdic et al., 2010). On this point, some researchers evidence a significant correlation between verbal mental age and understanding false beliefs, showing better performance at higher verbal age (Green et al., 2004; Minter et al., 1998). These findings suggest that language abilities may provide blind children with an alternative nonvisual strategy for understanding other people's minds (Landau and Gleitman, 1985; Pérez-Pereira and Conti-Ramsden, 1999). However, the development of these capabilities may be impaired due to the limited access to communication and social experiences in early life (see Sonksen and Dale, 2002 for a more comprehensive discussion). Of note, it remains uncertain whether the development of mentalizing abilities lags behind language acquisition and language-mediated skills (Dyck et al., 2004).

Despite the aforementioned research reporting a delay in the development of social cognition in the blind population, more recent studies seem to nuance these findings. Brambring and Asbrock (2010), using an alternative false belief task based on tactile and auditory experience, found that blind children reached a correct performance of these tasks after 19 months compared to sighted, differently from the 4–7 years delay shown by previous studies (Green et al., 2004; McAlpine and Moore, 1995; Minter et al., 1998; Peterson et al., 2000). Moreover, recent research evidenced no developmental delay in Theory of Mind comprehension in congenitally blind children compared to sighted peers (Bartoli et al., 2019; Pijnacker et al., 2012). Lastly, Richardson and collaborators (2023) observed that blind children's performance on a Theory of Mind task was slightly inferior to that of sighted but did not identify differences in adolescence. All these studies have used more inclusive tools for evaluating social cognition in children with visual impairment or blindness, which may explain at least partly the contrasting findings with previous research. Indeed, the standard false-belief tasks applied in the early studies of the Theory of Mind in blind children (e.g., Green et al., 2004; McAlpine and Moore, 1995; Minter et al., 1998; Peterson et al., 2000), used materials and required procedures that relied primarily on vision, creating a disadvantage in children without sight (Bartoli et al., 2019; Brambring and Asbrock, 2010). In addition, some types of tasks, such as the tactile version of the unexpected content task, seem to be affected by the individual's knowledge and experiential background (Peterson et al., 2000). For instance, in the teapot task used by Minter et al. (1998), children may have had difficulty in predicting the unexpected contents of the teapot despite having correctly recognized the object because their knowledge about it was not based on their tactile experiences but on what others had told them (Brambring and Asbrock, 2010). In other terms, children recognizing the teapot know that it will contain some kind of fluid, but when faced with the unexpected content of sand, they may wonder if their knowledge is incomplete since no one has ever told them before that teapots sometimes contain sand. This hypothesis seems to be supported by new evidence revealing that the cognitive understanding of mental states involved in another's experience may benefit from familiarity with the situation (Landmann et al., 2023). Therefore, difficulties shown by children with a visual deficit may not necessarily reflect impairments in the Theory of Mind but rather a gap in their knowledge and experience.

Regarding the impact of blindness on mentalizing abilities at the neural level, functional magnetic resonance imaging studies have unveiled comparable brain activation patterns in blind and sighted individuals during Theory of Mind tasks (Bedny et al., 2009; Koster-Hale et al., 2014). These patterns encompass activation in cortical regions such as the bilateral temporoparietal junction, medial prefrontal cortex, precuneus, and anterior temporal sulci. Early blindness does not seem to critically impact the development of the social brain (see Arioli et al., 2021 for a comprehensive meta-analysis) and how it constructs emotional experiences (Lettieri et al., 2024a). However, according to a recent study, the functional profile of the Theory of Mind brain regions is qualitatively similar but quantitatively weaker in blind relative to sighted children (Richardson et al., 2023). These areas seem to develop differently in blind children, but this neural delay is resolved during childhood.

In summary, children with blindness face numerous challenges in developing social cognition abilities, which may reflect as a delay rather than a deficit in achieving a functional Theory of Mind in adulthood (Bedny et al., 2009; Koster-Hale et al., 2014; Sak-Wernicka, 2016). The conflicting results in the literature about the delayed development of social cognition skills may be attributed to tasks dependent on visual abilities or different experiential backgrounds. Indeed, recent research employing more comprehensive tools has shown similar performance in the Theory of Mind between blind and sighted children (Bartoli et al., 2019; Brambring and Asbrock, 2010; Pijnacker et al., 2012). These findings emphasize the necessity for comprehensive, unbiased evaluation tools tailored to the unique experiences of blind individuals. Recent studies have focused on developing tasks where vision plays little to no role (Brambring and Asbrock, 2010; Richardson et al., 2023), suggesting that auditory narratives, like the ToM Storybooks, appear more suitable for blind children compared to tactile tasks (Bartoli et al., 2019; Pijnacker et al., 2012). Moreover, scant attention has been dedicated to investigating differences between individuals losing sight later in life and those who never experienced vision. Lastly, it is important to note that the research reported here has focused primarily on studying Theory of Mind. Still, as described above, social cognition encompasses a wide range of abilities, such as empathy, emotional contagion, and perspective-taking. For instance, the study of empathy in the blind population has been negligible, although this is a fundamental skill for resonating with the other person and understanding their point of view (De Vignemont and Singer, 2006). The studies

available in the literature suggest that blind adults exhibit adequate empathic abilities (Fryer and Freeman, 2014; Landmann et al., 2023), but these findings are limited to draw exhaustive conclusions. Therefore, while research on Theory of Mind development in blind individuals has provided valuable insights, further investigation is warranted to fully understand the impact of vision on social cognition abilities in the broadest sense.

2.1 A debate on autistic-like features

The delayed development of the Theory of Mind, combined with lateness in language acquisition and distinctive social interaction patterns, has led researchers to consider blind individuals as having "autistic-like" features (Brown et al., 1997). In particular, parallelisms were drawn with autism spectrum disorder (Tadić et al., 2010), focusing on language skills as potential connecting factors (James and Stojanovik, 2007; Minter et al., 1998; Peterson et al., 2000). Some studies have indicated that both groups of autistic and blind children successfully perform the false belief test when they have significantly higher verbal IQs and verbal mental ages than their peers (Green et al., 2004; Minter et al., 1998). Specifically, while the majority of sighted children typically grasp Theory of Mind concepts at an average verbal mental age of four years, children with visual impairment demonstrate proficiency at the verbal mental age of seven years and eleven months, and children with autism at nine years and seven months (Happé, 1995; Minter et al., 1998). In both cases, the poor outcomes in social cognition abilities obtained by blind and autistic children have been attributed to the lack of visually-driven experiences (e.g., dyadic and triadic joint attention) and visual behaviors (e.g., gaze tracking, direction, and control) in early childhood, which are crucial for the development of social cognition (Hobson, 1993; Hobson and Bishop, 2003; Korkmaz, 2011).

The delayed development of the Theory of Mind and language, combined with challenges in communication and social interaction (Preisler, 1991; 1993), restricted behaviors (Hobson et al., 1999) and limited symbolic play (Bishop et al., 2005; Rogers and Puchalski, 1984), have led researchers to an occasional conflation of behaviors observed in blind children with symptoms of autism spectrum disorder. As suggested by Brambring (2011), these "autistic-like" features may stem from specific issues related to blindness rather than being indicative of a psychopathological disorder.

For instance, the difficulties faced by blind individuals in reading other people's minds could be influenced by their inability to perceive and

interpret facial expressions, which has been highly correlated with the level of social competence (McAlpine and Moore, 1995; Waiden and Field, 1990). Moreover, their production of facial expressions of emotions was considered substandard, less pronounced and more challenging to interpret due to blindisms (i.e., uncontrollable face movements; Dumas, 1932; Galati et al., 1997, 2001; Rinn, 1991; Webb, 1977). These discrepancies in facial mimicry between blind and sighted may lead researchers to consider the communication of the first group as inadequate, emphasizing similarities with autistic features.

Furthermore, the initial delay in the development of language, along with the semantic and pragmatic difficulties in youths with blindness, may impact social communication and mirror the characteristics observed in children with autism spectrum disorder (Hobson and Bishop, 2003; Tadić et al., 2010). However, language difficulties in blind individuals are typically overcome and resolved by school age (Landau and Gleitman, 1985; Mulford, 1988), unlike most autistic children whose language impairment remains. Moreover, peculiar pragmatic interaction observed in blind children, such as the inappropriate use of questions, the altered gestures, and the frequent use of imitative speech and repetitions (Mulford, 1983; Preisler, 1991; Mamus et al., 2023), could be interpreted as adaptive strategies to acquire information, analyze speech, and avoid isolation (Conti-Ramsden and Perez-Pereira, 1999; Pérez-Pereira, 1994). Lastly, blind children exhibit typical development of structural language (i.e., phonology, morphology, and syntax) and show a keen interest in shared objects, facilitating social engagement and collaborative activities (Molinaro et al., 2020). Indeed, they have often been described as socially responsive, engaged, motivated, and willing to actively participate in social interactions (Peterson et al., 2000). This aspect differs from autism spectrum disorder, in which there is a reduction of interest in shared objects and people, as defined in the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association, 2013).

In conclusion, the similarities between blind and autistic children should be approached cautiously. Several studies have revealed that the delays and challenges faced by visually deprived children across various domains may represent reversible features akin to transient phenomena, distinct from those seen in individuals with autism (Hobson and Lee, 2010). Moreover, the unique characteristics of blind individuals could be related to sensory deprivation and may represent a distinctive approach to navigating the social environment (Molinaro et al., 2020). In light of all

this, it is pivotal to use caution in clinical practice when diagnosing autism spectrum disorder in the sensory-deprived population, the prevalence of which has been estimated to be 30 times higher in blind than sighted individuals (Jure et al., 2016). Researchers can overcome these challenges by using more comprehensive tasks to assess social cognition abilities (e.g., Stevenson and Tedone, 2024; Dale et al., 2024) and improving our understanding of alternative developmental pathways and adaptive-compensatory approaches in children without sight.

3. The facial expressions of emotions

Facial expressions represent a fundamental aspect of nonverbal communication, serving as visible manifestations of underlying emotional states. Through intricate coordination of facial musculature, humans convey a diverse array of emotions, spanning joy, sadness, anger, fear, surprise, and more. These expressions are integral to social interaction, facilitating the rapid transmission of affective information between individuals. Despite the numerous models existing in the literature on the genesis of emotions (e.g., Ekman, 1993; Barrett et al., 2019), the emergence and development of facial expressions still need to be understood, and the role of sight in shaping them remains unclear. In particular, researchers are still debating whether the ability to produce emotional facial expressions is innate, independent of visual learning, or if it develops, at least partially, through exposure to visual cues during early development (Valente et al., 2018). For this reason, facial expressions have garnered substantial attention within the study of blind individuals, so much so that the first studies date back to the 1930s. Notably, Dumas (1932), in an early observational study on blind adults, posited that their limited ability to mimic both intense and subtle emotions suggested a reliance on prior visual observation for voluntary expressions. Subsequent support for this hypothesis was provided by Fulcher (1942), who noted that while blind children exhibited similar voluntary facial expressions as their sighted peers, these proved less nuanced in adulthood, characterized by reduced facial activity and less distinct emotional expressions. Similarly, Webb (1977) observed that facial expressions voluntarily produced by blind adults were often poorly recognized by sighted judges, even though their performance could be improved through training with audio feedback. Regarding genuine emotional expressions, observational studies indicate that blind children have apparent similarities with their sighted peers, albeit with

some differences in their developmental trajectory (Fraiberg, 1975; Freedman, 1964). For example, Thompson (1941) found similar expressions for smiling, laughter, physical discomfort, and anger between blind and sighted children, yet noted a restricted range of facial movements and a diminished tendency to smile with age among blind children compared to their sighted peers. The evidence about similar spontaneous expressions between children with and without sight has led some researchers to propose a potential link between emotional facial expressions and innate cognitive processes (Dumas, 1932; Eibl-Eibesfeldt, 1973; Fulcher, 1942).

These studies represent pioneering endeavors in exploring emotional facial expressions in the blind population. However, it is relevant to acknowledge the limitations inherent in these investigations, as these were conducted on small sample sizes and with observational methods, necessitating cautious interpretation of their findings given the subjective nature of researcher assessments. Webb's (1977) study was the first to attempt to overcome this limitation by employing a visual judgment task, in which the adequacy of facial expressions of blind people was determined by recognition rates of naive sighted judges. Nonetheless, this study, conducted solely on five blind participants without a control group, remained constrained. Afterward, other studies have adopted the videotape judgment task to evaluate the facial expressions of emotion in blind participants, involving a group of sighted individuals and further psychometric measures (Roch-Levecq, 2006; Tröster and Brambring, 1992). For instance, Tröster and Brambring (1992), by using the Bielefeld Developmental Test combined with the visual judgment task, observed that congenitally blind children exhibit spontaneous expressions of pleasantness and anger similar to sighted children, albeit with a more restrictive repertoire, consistent with earlier findings (Fraiberg, 1975; Thompson, 1941). Instead, Roch-Levecq, (2006), by asking children with and without sight to reproduce on their face one of the four basic emotions (i.e., fear, happiness, sadness, anger), revealed that voluntary facial expression of blind children did not convey emotions to adult observers as accurately as sighted participants, particularly for fear and happiness. It is important to emphasize that findings derived from visual judgment tasks also face critical challenges, as blind participants' facial expressions may be perceived as inadequate due to blindisms (e.g., eye rotation and eyebrow raising).

To obtain an objective measure of facial expressions, Ekman and Friesen (1978) developed the Facial Action Coding System (FACS), an anatomical analysis system in which each facial movement is deconstructed

into a single unit. Most studies involving the blind community since the 1980s have used the FACS or a similar system (e.g., Max; Izard,1979), in concomitance with visual judgment tasks to investigate facial expressions using a more comprehensive and rigorous approach. Among these researches, Rinn (1991) reported that congenitally blind adults showed a generally poor quality in voluntary facial expressions, yet their spontaneous facial movements closely resembled those of sighted participants. Similarly, Galati and colleagues found significant parallels in genuine facial expressions between blind and sighted children, but only modest differences were observed in voluntary emotional expressions (Galati et al., 1997, 2003). As discussed in a recent review (Valente et al., 2018), several studies support the evidence that blind and sighted individuals engage similar action units and movement patterns during the spontaneous production of specific facial expressions (e.g., Galati et al., 2001, 2003; Kunz et al., 2012; Tracy and Matsumoto, 2008). For instance, in a landmark study, Matsumoto and Willingham (2009), investigating genuine facial expressions of blind and sighted judo athletes, revealed that both produced similar facial configurations when experiencing specific emotions. The only discrepancies were noted in stereotypical behaviors associated with blindisms. These movements, captured in photographs, resulted in atypical static facial features reflected in FACS coding, partially explaining the lower recognition rate of facial expressions in the blind population by sighted judges (Chiesa et al., 2015; Galati et al., 1997, 2001). Furthermore, very recently, Kim and Sutharson (2023b) suggested that the engagement of action units in expressing spontaneous emotion is likely influenced by visual acuity and socio-demographic factors. Concerning voluntary facial expressions, several researches showed challenges in their production and intensity modulation by blind individuals, as well as lower recognition accuracy by sighted judges (Galati et al., 1997; Kunz et al., 2012; Ortega et al., 1983; Roch-Levecq, 2006; Swerts et al., 2012). Additionally, a recent study suggested that visually deprived individuals exhibit the involvement of a specific set of facial muscle movements when expressing different voluntary emotions (i.e., neutrality, anger, fear, disgust, happiness, calmness, and surprise), leading to the production of facial expressions that are similar to each other (Kim, 2023). In conclusion, current literature indicates that individuals with blindness display spontaneous facial expressions similar to sighted people (Galati et al., 2001; Matsumoto and Willingham, 2009; Ortega et al., 1983; Peleg et al., 2006; Thompson, 1941; Tracy and Matsumoto, 2008), although they may encounter challenges in regulating

these expressions (Cole et al., 1989; Galati et al., 2003; Kunz et al., 2012). Nevertheless, studies focusing on blind children have reported a distinct developmental trajectory and a more limited facial expression repertoire compared to their sighted peers (Fraiberg, 1975; Freedman, 1964; Tröster and Brambring, 1992), even though studies relying on modern methodologies are needed to validate these findings. Furthermore, while some studies report difficulties in voluntary facial expressions among blind individuals (Dumas, 1932; Ortega et al., 1983; Rinn, 1991), others indicate only slight differences between blind and sighted (Fulcher, 1942; Galati et al., 1997; Kunz et al., 2012). Overall, researchers agree that voluntary facial expressions of blind people are poorly recognized by sighted judges (Galati et al., 1997; Ortega et al., 1983; Rinn, 1991; Roch-Levecq, 2006; Webb, 1997), partially due to the occurrence of blindisms (Chiesa et al., 2015; Galati et al.,1997) or to the poor ecological validity of the scenarios used to elicit emotional responses (Valente et al., 2018).

The research discussed above offers evidence supporting the idea of a non-visually learned and universal origin for facial expressions, particularly for genuine configurations elicited by emotional contexts (Arias et al., 2021; Valente et al., 2018). However, visual feedback could be pivotal for controlling and regulating these facial expressions. Therefore, future studies should investigate whether and how blind individuals adopt compensatory strategies through other sensory modalities to shape their facial emotional expressions.

4. Perception and recognition of emotions

As mentioned above, vision plays an essential role in understanding social cues, particularly in how observing non-verbal signals enables individuals to anticipate others' intentions and emotions (i.e., Theory of Mind), thereby adjusting their behavior accordingly (De Gelder et al., 2015; Perrett and Emery, 1994; Todorov et al., 2015). Nevertheless, there has been questioning regarding the role of other senses, prompting researchers to examine how blind individuals perceive such stimuli and whether the information they gather is adequate for accurately discerning the mental states of others. Indeed, insight into an individual's inner state can also be gained through auditory cues, such as nuances in speech, various tactile sensations (e.g., gentle stroke or a sharp yank), and, to a lesser extent, olfactory signals from body odors (e.g., sweat). Furthermore, by

attending to internal bodily sensations (i.e., interoceptive signals), individuals can recognize and label their own emotional states (Wiens, 2005).

Notably, in the absence of vision, there is a heightened reliance on signals from the remaining senses to extract socially relevant information (Singh et al., 2018). This evidence underscores the importance of understanding how blind individuals navigate social interactions and perceive the world.

Most studies have focused on blind individuals' ability to perceive emotional cues through auditory signals, as hearing serves as their primary mode of social communication (Klinge et al., 2010). While several investigations have explored the ability of blind individuals to process sound and human voice, these mainly focused on auditory perceptual skills (Gougoux et al., 2004; Röder et al., 1999); auditory memory (Amedi et al., 2003; Rokem and Ahissar, 2009; Kattner et al., 2024), language (Bedny et al., 2011; Röder et al., 2000); auditory localization and spatial selective attention (Hughdal et al., 2004; Doucet et al., 2005; Collignon et al., 2006; Battal et al., 2020); and person identification (Fairhall et al., 2017; Hölig et al., 2014). Exploration into the ability of blind people to recognize and perceive emotional expressions or states from non-visual sources remains scarce.

Recent research on emotional perception suggests that blind individuals can discern a broad range of emotions when listening to personal narratives (Kim and Sutharson, 2023a), although in a more intense manner (Ferrari et al., 2024). Moreover, Fryer and Freeman (2014) demonstrated that adding verbal audio descriptions to emotive movie clips for blind individuals can enhance emotional responses, especially when delivered by a human voice rather than text-to-speech. This finding underscores the importance of paralinguistic elements, such as tone of voice, in conveying emotions.

Regarding emotion recognition, the literature on the subject is slightly broader in scope. Previous studies have shown that congenitally blind children tend to have lower abilities in identifying emotional vocalizations compared to their sighted counterparts, and these differences in performance are often attributed to a tendency among blind individuals to prioritize the semantic content of speech over the tone of voice (Dyck et al., 2004; Minter et al., 1991). Similarly, recent research indicates that blindness significantly affects the recognition of emotional intonation in terms of both accuracy and speed (Chen et al., 2022). Following Dyck et al. (2004), Martins and colleagues (2019) found that blind children performed

worse than sighted peers only when the task required evaluating emotional intonation while disregarding semantic content, suggesting that they rely more on it to assess emotions in social situations (Martins et al., 2019). A recent study on vocal emotion discrimination has shown lower performance among blind individuals in identifying angry and fearful expressions compared to sighted controls, though no differences were observed for other emotions (Falagiarda et al., 2024). This finding suggests a potentially influential role of visual experience in perceiving threat-related expressions, highlighting the necessity of multisensory perceptual processes for their recognition. Conversely, Klinge et al. (2010) found that blind subjects exhibited greater competence and speed in discriminating the emotional states of fear and anger. Of note, a recent study reported similar abilities in semantic and prosodic processing of emotional speech between congenitally blind and sighted individuals (Ben-David et al., 2024). Therefore, further research is needed to better clarify the development of auditory emotion recognition abilities in the absence of vision.

Importantly, prosody is not the only feature of the human voice that allows individuals to make inferences about the mental state of their interlocutor. In this regard, a recent study on emotional vocalization demonstrated that congenitally blind individuals can recognize speakers who are smiling based solely on the sound of their voices (Arias et al., 2021). By listening to different sentences altered in their frequencies due to the smile or unsmile gesture, blind individuals showed a smile-detection accuracy comparable with sighted controls, as well as similar facial muscle activity. Additionally, it has been demonstrated that blind individuals were as accurate as sighted controls in detecting vocalization valence and authenticity (Sarzedas et al., 2024), albeit with slower response times (Gamond et al., 2017). Studies involving music tracks have found no significant differences between blind and sighted individuals in their ability to detect emotions (Park and Chong, 2017).

Taken together, mixed findings have been found in the ability of visually deprived individuals to perceive and identify emotions from auditory sources, although the role of prosody in this process remains contentious. Furthermore, most of the studies reported above were conducted on blind children and adolescents (e.g., Chen et al., 2022; Dyck et al., 2004; Martins et al., 2019; Minter et al., 1991), but the difficulties reported may be affected by a broader delay in the development of language-mediated skills and communication. Therefore, the challenges in emotional vocal recognition may partially resolve in adulthood, though

further investigation is warranted. Lastly, given that prosody represents just one feature of the human voice through which emotional cues can be inferred, additional studies could employ more ecologically valid tasks (e.g., real social interactions or emotional movies) to comprehensively understand the emotion recognition abilities of blind individuals.

In addition to hearing, smell is another sensory channel that has received some attention for detecting emotional states. Although the olfactory system plays a less prominent role in human behavior compared to vision and hearing (Hummel and Nordin, 2005), previous research indicates that natural body odors influence social interactions and decision-making processes (de Groot et al., 2012; Gottfried and Dolan, 2003; Haegler et al., 2010). In particular, different chemosignals can induce positive and negative emotions and influence performance at facial expression recognition tasks (for a review, see Calvi et al., 2020). For blind individuals, the sense of smell might represent an alternative strategy to perceive social cues, especially considering the adaptive neuroplastic changes in their olfactory system (Huart et al., 2013; Kupers et al., 2011). Moreover, visually deprived individuals exhibit a lower odor detection threshold, greater awareness of their olfactory environment, and outperform sighted in the identification of odors (Beaulieu-Lefebvre et al., 2011; Cuevas et al., 2009; for a review see Sorokowska et al., 2019). Despite these findings, only one study has investigated the sense of smell concerning social and affective communication in the visually deprived population, demonstrating that congenitally blind individuals have a higher ability to identify fear from samples of male body odor compared to sighted people (Iversen et al., 2015). This early evidence suggests that smell could serve as a compensatory strategy for blind individuals to detect and recognize specific social cues, although further research is needed to confirm these findings.

Another significant sensory modality that enables individuals to navigate their surroundings is touch. Through the sense of touch, people can detect and discriminate external stimuli, including perceiving form, shape, and texture, identifying the direction of stimuli moving over their bodies, and recognizing objects (McGlone et al., 2014). In the social context, touch represents the unique method to construct a mental representation of others' faces and bodies for blind individuals, providing an alternative strategy to detect emotional facial expressions beyond the voice. Studies on emotion recognition through haptic exploration of facial expressions revealed that both blind and sighted adults demonstrate similar levels of accuracy in this

type of task (Kitada et al., 2013; Picard et al., 2010), with faster processing by blind individuals Picard et al. (2010). A recent investigation conducted in visually-deprived children also found no significant differences in accuracy between blind and sighted (Chennaz et al., 2024).

However, research focus on the discriminative functions of touch has often overshadowed another crucial aspect: its pleasantness. Researchers have increasingly recognized the importance of affective touch in recent years, referring to its social and emotional role (Morrison et al., 2010). Affective tactile experiences during childhood play a crucial role in attachment style (Krahé et al., 2018; Suvilehto et al., 2015), and the development of the social brain (Cascio et al., 2019). Given that blind individuals appear to possess enhanced discriminative tactile acuity compared to sighted people (Alary et al., 2009; Goldreich and Kanics, 2006), their affective haptic experience may also differ. A recent study demonstrated that blind individuals perceive relatively greater pleasantness on the palms of their hands, while sighted people report more pleasant tactile stimulation on the forearm (Radziun et al., 2023a). The preference for the palm over other body parts observed in individuals without sight might arise from the fact that palms represent the primary source for exploring and learning about the surrounding environment, including social and emotional aspects.

Additionally, affective touch is closely intertwined with interoceptive signals. Through touch, individuals can perceive pleasant and painful stimuli on their skin, which provide homeostatic input about the status of their own body and its needs, contributing to a broader interoceptive system (Crucianelli and Ehrsson, 2023). In this regard, a recent investigation on cardiac interoception revealed a higher accuracy in heartbeat perception in blind individuals (Radziun et al., 2023b). These findings may have implications for bodily awareness and the processing of subjective emotional experiences (Garfinkel et al., 2014; Critchley and Garfinkel, 2017; Wiens, 2005), potentially influencing the bodily representation of emotions in the absence of vision. Recently, we developed a naturalistic haptic task in which blind and sighted individuals indicated in which parts of their body they perceived changes during positive and negative emotions. We found that, in the experience of affect, blind people focus more on the mouth and the hand areas, while sighted individuals focus on visceral sensations, suggesting that sensory deprivation impacts the bodily representation of emotions (Lettieri et al., 2024b). Together with this, through semi-structured interviews, a recent investigation observed that language plays a relevant role in pairing bodily reactions with emotions (Giraud et al., 2023).

In conclusion, blind individuals appear to hold a greater compensatory strategy to explore the social environment and detect emotions through non-visual sensory channels. However, specific sensory modalities, such as smell and touch, remain poorly investigated, and further research is needed to corroborate existing findings. Moreover, the unclear picture regarding auditory emotion recognition suggests the need for future studies to consider the ecological validity of the task employed. Understanding how vision impacts the perception and recognition of emotions is essential for elucidating the mechanisms underlying affective processing, shedding light on the broader implications for emotional development and the acquisition of social skills.

5. The impact of blindness on social life and psychological consequences

Blindness and visual impairment profoundly impact various aspects of daily life, reverberating into the realms of social interaction and psychological well-being. According to the 2020 Vision Loss Expert Group findings, 43,3 million people worldwide are blind, and 295 million suffer from moderate to severe vision impairment (Bourne et al., 2021).

These individuals encounter multifaceted challenges, potentially leading to adverse psychological consequences, as studies highlighted a close correlation between blindness and adverse emotional experiences (Pinquart and Pfeiffer, 2011). Research indicates that individuals with visual impairment are more prone to perceive negative emotions such as distress, depression, loneliness, and anxiety (Choi et al., 2018; Nyman et al., 2012). Notably, approximately 5% of adults with visual impairment experience major depressive disorder, while 7% grapple with an anxiety disorder, and one in three exhibit subthreshold symptoms of either (Binder et al., 2020; van der Aa et al., 2015), significantly surpassing the prevalence in the general population.

This vulnerability transcends age demographics, affecting blind adolescents at a disproportionate rate compared to their sighted peers (Koenes and Karshmer, 2000). Therefore, it seems that blindness and visual impairment can influence the quality of life and psychological well-being, necessitating psychological adjustments (Ishtiaq et al., 2016; Renaud and Bédard, 2013), in a different manner across age groups. Indeed, the higher incidence of depression among blind adolescents is often attributed to

challenges such as academic difficulties, social isolation, heightened stress, and altered self-esteem (Koenes and Karshmer, 2000). Instead, in adults with visual impairment, reduced psychological well-being can be attributed partly to challenges in the labor market and difficulties in mastering age-specific developmental milestones, such as building a family (Pinquart and Pfeiffer, 2011). Older adults with visual disabilities face elevated depression rates linked to poor functioning, reduced mobility, and limited participation in social activities (Desrosiers et al., 2009; Kempen et al., 2012).

Beyond the challenges faced by blind individuals in daily life, the absence of visual experiences may hinder the development of emotion regulation abilities, a crucial component of mental health maintenance (Chennaz et al., 2022). Specifically, blind individuals seem to make less use of cognitive reappraisal strategy and exhibit difficulties in emotion suppression (Salimi et al., 2016). Given the pivotal role of emotion regulation in the genesis and maintenance of mental disorders, such as depression and anxiety (Gross and Jazaieri, 2014), addressing these difficulties becomes imperative in promoting psychological adjustment and well-being among the blind population.

In conclusion, the impact of blindness on social life and psychological well-being is profound and multifaceted, necessitating comprehensive interventions that address both the practical challenges of daily living and the intricacies of emotional regulation.

6. Conclusions

Our review highlights the importance of delving into the intricacies of social cognition abilities in individuals with blindness. Indeed, while significant strides have been made in scientific inquiry, the social and emotional life in the absence of vision has often been overshadowed. Yet, social cognition abilities are the core of interactions, enabling individuals to interpret social cues, empathize with others, regulate emotions, and cultivate meaningful relationships, all crucial components for successful adaptation and integration into society. Despite some progress, a significant gap persists in our comprehension of how individuals with blindness navigate the emotional landscapes of life. Of note, with studies exploring blindness and social cognition abilities far from being comprehensive, research on the distinction between congenital and acquired blindness is at an even more early stage. Future research efforts should focus on advancing

knowledge in this area, as it would shed new light on the mechanisms underlying visual experience and elucidate how losing access to a previously available sense influences social and emotional behavior.

Through an exhaustive examination of a diverse array of studies, we were able to highlight critical shadow zones in the scientific literature, particularly in understanding the emotional experiences and compensatory strategies of individuals with blindness. Importantly, the study of blind individuals provides profound insights into the fundamental role of visual sensory experience in shaping the development of social and emotional abilities. Indeed, only by examining how people without sight navigate and interpret their affective experiences we can understand the intricate interplay between sensory inputs and social development.

Furthermore, by directing attention toward the emotional lives of individuals with blindness and visual impairment, we can promote their well-being and facilitate meaningful participation within society. Addressing these gaps in our understanding establishes the foundations for a more inclusive and empathetic society that values the diverse experiences and perspectives of all its members, regardless of visual ability.

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