

**EMOTIONAL PROCESSING IN ALEXITHYMIA:
BEHAVIORAL EVIDENCE**

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Abstract

Social cognition plays a crucial role in primate survival. A key facet of social cognition is the recognition of others' emotions, which facilitates social interactions by providing insights into others' mental states and enabling us to adjust our behaviors accordingly.

This dissertation focuses on understanding emotional processing deficits associated with alexithymia - a personality trait characterized by difficulties identifying and describing emotions - in a neurotypical population. To achieve this goal, we designed two experiments to investigate whether the emotional processing deficits associated with alexithymia extend to neutral expressions (Experiment I) and to explore their possible connection to altered holistic processing (Experiment II). In both experiments, perceptual difficulty was increased by adding visual noise, known to exacerbate alexithymia-related deficits. Alexithymia traits were independently measured using the Toronto Alexithymia Scale (TAS-20).

In the first experiment, 35 university students were presented with 30 images of fearful faces, neutral faces, and objects, which they were asked to categorize. Results showed lower accuracy across all categories associated with increasing alexithymia scores. In the second experiment, 90 upright and inverted faces (displaying fear, happiness, and neutral expressions) were presented to 49 university students in a similar design to Experiment I. Participants with higher alexithymia scores performed worse when holistic processing was disrupted by image inversion, compared to upright presentation.

Our analysis suggests that individuals with higher levels of alexithymia exhibit a general impairment in perceptual categorization, contrasting with the anticipated emotion-specific deficits (Experiment I) and rely on holistic processing (Experiment II).

Keywords: Emotional facial expressions, Emotional processing, Alexithymia, Neutral faces, Holistic processing.

Resumo

A cognição social é essencial para todos os primatas. Uma dimensão essencial da cognição social é o reconhecimento das expressões faciais de emoção. Esta característica permite aceder indiretamente aos estados mentais de outros indivíduos, permitindo ajustar o nosso comportamento em conformidade.

Este estudo analisou o processamento emocional associados à alexitimia, condição caracterizada pela dificuldade em identificar e descrever emoções – numa população neurotípica. Foram desenhadas duas experiências para averiguar se possíveis défices associados a traços de alexitimia se estendem ao processamento de faces neutras (Experiência I) e se este efeito está associado a alterações no processamento holístico (Experiência II). Em ambas as experiências, os estímulos foram apresentados sob condições percetuais taxativas que acentuam os défices presentes na alexitimia. Os traços da alexitimia foram medidos através do questionário *Toronto Alexithymia Scale* (TAS-20).

Na primeira experiência apresentámos, 30 faces neutras, 30 faces de medo e 30 objetos a 35 estudantes universitários para estes as categorizarem. Os resultados demonstraram um decréscimo na capacidade de categorização com o aumento do nível de alexitimia. Na segunda experiência foram apresentadas a 49 estudantes universitários, 90 faces direitas e invertidas (medo, felicidade e neutras) em condições semelhantes à Experiência I. Foi verificada uma pior performance na capacidade de categorização quando comprometemos o processamento holístico associado a mais traços de alexitimia.

A nossa análise sugere que indivíduos com mais traços associados à alexitimia exibem alterações percetivas generalizadas, ao invés dos esperados déficits em emoções específicas (Experiência I) e que dependem do processamento holístico para o processamento emocional (Experiência II).

Palavras-chave: Expressões emocionais faciais, Processamento emocional, Alexitimia, Faces neutras, Processamento holístico

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1. Introduction

Faces have a distinct biological and social significance, allowing for the extraction of a wealth of information about someone else, ranging from their identity to an inference of their traits. An important aspect of face processing is the recognition of others' emotions, as this allows to indirectly tap into another's state of mind (Palermo & Rhodes, 2007).

The importance of understanding others' emotions from their facial expression is apparent from its processing speed, only taking 33 ms for a decision to be made regarding the recognition of a particular emotion (Prkachin, 2003a). In line with this, emotional facial expressions are known to increase attention engagement comparatively with neutral faces (Vuilleumier & Schwartz, 2001). Highlighting the importance of studying emotional processing, deficits in emotion recognition are considered altered or a potential risk for various psychiatric and neurological conditions, including depression (Honkalampi, Hintikka, et al., 2001a), anxiety disorders (Oathes et al., 2008), eating disorders (Nowakowski et al., 2013), schizophrenia (Kohler et al., 2000), parkinson (Gray & Tickle-Degnen, 2010), and autism (Yeung, 2022).

This thesis will focus on understanding the mechanisms that underpin the deficits in emotional processing found in alexithymia, a disorder characterized by impaired emotional processing, particularly, negative emotional signals (Prkachin et al., 2009). Alexithymia is associated with a stimulus-bound, externally oriented cognitive style revealing difficulties in identifying feelings, distinguishing between feelings and bodily sensations of emotional arousal, describing feelings to others, and constrictive imaginative processes (Goerlich, 2018). At a neural level it has been associated with reduced neural responses to emotional stimuli from the external environment, as well as with reduced neural activity during imagery in the limbic and paralimbic areas; i.e., amygdala (Kugel et al., 2008), insula (Bird et al., 2010a) both anterior (Heinzel et al., 2010) and posterior (Mantani et al., 2005), and cingulate cortex (Kano & Fukudo, 2013).

Here we will investigate if deficits in emotion recognition present in alexithymia extend to the absence of emotion (neutral faces). Furthermore, we will investigate if a potential alteration in the holistic processing of emotion can underpin the deficits observed in alexithymia. This question arises from the well-known reliance on holistic/configural processes for face processing (Yin, 1969).

With these two goals in mind, we designed two categorization experiments in which visual stimuli were presented under different levels of ambiguity by adding visual noise using the RISE technique. This algorithm allows for the creation of varying levels of taxing perceptual conditions in the images by adding visual noise while maintaining important factors for face perception, such as contrast, luminosity, and spatial frequency (Sadr & Sinha, 2004). Increasing taxing perceptual conditions is known to exacerbate deficits in emotion recognition seen in alexithymia, which will allow us to experimentally mimic a disruption of social stimuli that can occur in environmental conditions in a more ecological setting.

In the first study, we will analyse emotional processing deficits of the absence of emotion (neutral face), reported as being disrupted (Peasley-Miklus et al., 2016). To our knowledge, the specificity of these effects has not been investigated using non-human stimuli as a control condition. We included a high arousal negative valence emotion (fear face) known to be impaired in alexithymia (Rosenberg et al., 2020) across five levels of perceptual difficulty. For the control variable, we included an object condition (e.g. flowers, fruits, leaves, or mushrooms), to ascertain if any perceptual deficits observed in alexithymia are emotion specific or generalisable to any visual stimuli. We expect individuals with higher levels of alexithymia to be increasingly impaired in the categorization of emotion and the absence of it, particularly with increasingly taxing visual conditions.

In the second study, we will behaviorally assess how the holistic processing of emotional facial expressions is modulated by higher levels of alexithymia. We will use face inversion as an experimental manipulation thought to disrupt holistic processing (Yin, 1969). In this experiment we build from the first study, removing the object control condition and adding an emotion, happiness. The inclusion of happy facial expressions allows us to probe if a potential role of holistic processing in alexithymia occurs both for positive and negative valence emotions. In line with previous research, the effect of alexithymia is expected to be greater for negative emotions (fear) relative to positive (happiness; Prkachin et al., 2009). Participants will be presented with upright or inverted images of fearful, neutral, and happy emotional faces, across three levels of increasing visual perceptual difficulty. As before, participants with higher alexithymia are expected to show an increased impairment in emotion recognition, particularly for conditions of increased perceptual difficulty. These effects are expected to be more pronounced for inverted faces, which would reveal the importance of the holistic processing of emotional facial expressions.

The following literature review will cover the basic concepts of emotional communication and its evolution, as well as its importance and impairments. It will further

cover the neural pathways for emotional processing, with a particular emphasis on alexithymia development and particular impairments regarding emotional facial processing.

1.1. Emotional Communication

For communication to occur, information must be produced by an organism (a sender) that causes a change in another organism (an observer/receiver; Dezechache et al., 2013; Scott-Phillips, 2008). Social information can be considered a signal if results from natural selection, and the information is designed for the receiver, therefore benefiting the sender (Laidre & Johnstone, 2013). On the other hand, information is considered a cue if it is not the result of natural selection. This information still influences the receivers' behaviour without necessarily benefiting the sender. In this case, information is captured by bystanders rather than being directed to a specific observer. Communication is modulated by the observer's individual history and characteristics, such as how they perceive the properties of the information e.g. valence and arousal intrinsic to the information content (Cohen et al., 2011; Lichtenstein-Vidne et al., 2012; Okon-Singer et al., 2007; Pessoa, 2005; Wiens et al., 2011).

Emotional communication plays an important role in conspecific interactions such as finding mates, protection, or escaping predators (Tooby & Cosmides, 1990). This type of stimuli modulates the alertness system of attention. This system, associated with the transition from rest to a vigilant state, is attuned to the presentation of an alerting emotional cue such as emotions of fear or anger (Dennis et al., 2008; Dennis & Chen, 2007; Fan et al., 2002).

Emotional states can be expressed and perceived through various sensory modalities, including visual (González-Garrido et al., 2009), auditory (Koelsch et al., 2018), olfactory (Soudry et al., 2011), and tactile (Ravaja et al., 2017). The need to understand others' emotions helped, through evolution to organize physiological, motivational, and cognitive systems, facilitating adaptive responses for the organism's survival (Parr et al., 2005).

Individuals living in complex social groups require efficient communication about the environment and internal events. Signals must be easy to recognize and discriminate from environmental noise, reflecting the general motivation or intent of the organism. Otherwise, the information value will be lost (Parr et al., 2005). Conversely, individuals' emotional processing skills must be sufficiently developed to interpret the variety of meanings associated with similar displays used in different contexts (Ferretti & Papaleo, 2019). Emotional signals did not emerge with humans, as evidenced by the neural circuit in different species, namely rats (Panksepp & Burgdorf, 2003) and chimpanzees (Matsusaka, 2004).

In primates, prosimians primarily utilize olfactory cues in social signalling while anthropoid primates rely primarily on visual cues such as facial expressions. The use of visual information in anthropoid primates in the diurnal niche (such as humans), may be a reflection of their enhanced visual acuity associated with structural modifications of the face, such as convergent and fronted orbits alongside alterations in the nervous system of visual function, including higher cone density in the central retina, and a magnified representations of the central visual field within the brain (Ross, 2000). This enhanced visual acuity has allowed some primates, including humans, to process visual information from faces in a specialised way, being able to use the information to accurately identify age, sex, identity, and emotional intent (Parr et al., 2006; Schmidt & Cohn, 2001). Compared to verbal communication, musculature-based emotional signals have the advantage of being faster and more effective at clarifying ambiguous information in constrained environments. These benefits may have played a pivotal role in enhancing species survival and fitness (Dezecache et al., 2013).

The musculature necessary for facial expressions is derived from the second hyoid pharyngeal arch and is innervated by the seventh cranial nerve (Noden & Francis-West, 2006). Of particular importance is the orofacial region, this anatomical region is the point of intersection of respiratory, sensory, feeding, and communication behaviors, therefore is responsible for coordinating the facial muscles to produce vocalization, facial expressions, or mastication (Sherwood et al., 2005). They are controlled by two anatomical routes, the first goes through the facial nucleus in the pons, allowing for the regulation of spontaneous and emotional movement. The second is dedicated to voluntary movements and is controlled by the activity the facial representation area in the motor cortex (Parr et al., 2005).

The diverse repertoire of emotional facial expressions varies among primates, with differences emerging from the combinatory influence of sensory ecology, phylogenetic history, social organization, and cognitive abilities (Preuschoft & van Hooff, 1995). Primates such as chimpanzees have been described to display the same emotion with different intensities, and the same facial muscles seem to be used across different expression categories (Parr et al., 2005). Comparing emotional displays between different primates, such as apes, chimpanzees, bonobos, and humans reveals that while the fear facial expression is demonstrated by both humans and apes through the opening of the mouth, on the other hand, chimpanzees and bonobos predominantly display fear through bared teeth. Notably, humans possess distinctive features for displaying fear such as raised eyebrows and widened eyes, features that are in turn particularly used for fear recognition by the observer (Kret et al., 2020).

1.2. Neural Underpinnings of Face and Emotional Processing

The tendency to orient gaze toward faces is already apparent in humans as early as the third trimester (Reid et al., 2017). Throughout our development, we acquire expertise in processing the face's static and changeable aspects. The static features include identity, gender, and age and the changeable include gaze direction and emotional expressions (Bruce & Young, 1986; Haxby et al., 2000).

Classical models of face processing consider a hierarchical network comprising both a core and an extended system. In the core system of visual analysis, there is an interaction between the inferior occipital gyri, the superior temporal sulcus (STS), and the lateral fusiform gyrus (FFA). The input is received by the occipital gyri, responsible for the early perception of facial features, coding low-level aspects (Fox et al., 2009). These regions, communicate with the STS which processes changeable features, such as gaze and emotional expressions, and with the FFA which processes the invariant aspect of face input, such as identity and gender (Haxby et al., 2002).

Some studies demonstrated that the FFA also communicates with the STS to retrieve personal identity information, such as name and biography. Both areas are responsive to changes in identity and expression, demonstrating a possible overlap of function (Fox et al., 2009; Ganel et al., 2005). The FFA also seems to play an important role in coding facial expressions (Harry et al., 2013; Wegrzyn et al., 2015), demonstrating sensitivity to informational expressions (Fox et al., 2009; Ganel et al., 2005; Kawasaki et al., 2012);

The areas of the extended system contribute to further codify the stimuli, by further processing the input. The STS interacts with the intraparietal sulcus, the auditory cortex, the amygdala, the insula, and the limbic system with the later structures imprinting the emotional connotation.

1.3. Holistic Processing of Faces and Emotions

For humans, faces are a unique category, which drive attention even before birth (Reid et al., 2017). Faces are holistically processed, meaning that it is processed as a whole and not only as the sum of its parts (Craig et al., 2022). This reliance on holistic processing, is especially evident when comparing face and non-face stimuli, such as objects or houses. Among these, faces are most affected by paradigms that disrupt holistic processing (Farah et al., 1998). The importance of holistic processing for expert face understanding is particularly clear when considering that individuals with prosopagnosia, a deficit that impairs the ability to recognize

faces, do not show increased deficits under paradigms that disrupt holistic processing (Avidan et al., 2011). This is suggestive that these deficits might be derived from an inability to process faces holistically in these individuals.

There are different paradigms to assess holistic face processing, such as tasks studying the composite effect, part-whole effects, and the inversion effect. The composite effect occurs when a face is created by combining the upper half of one individual's face with the lower half of another's. This blending typically impairs the ability to discriminate or recognize the individuals represented in each half. However, this effect is diminished or eliminated when the two halves are misaligned (Young et al., 2013). In the part-whole task, the face is shown to the participant either as isolated parts (e.g. eyes and mouth; leading to featural processing) or as a whole face (Tanaka & Farah, 1993a). For the inversion effect the face is presented with a rotation of 180°. This presentation disproportionately impairs recognition of faces compared with non-face stimuli (Tanaka & Farah, 1993b; Yin, 1969), an impairment that is resistant to training (Robbins & McKone, 2003) and that compromises the identification of own-face, familiar, and unfamiliar faces (Lee et al., 2022).

Fewer studies have tried to clarify the impact of holistic processes in the categorization of emotional facial expressions. Some studies have suggested that the inversion effect is reduced for neutral faces (Veres-Injac & Schwaninger, 2009), while on the contrary, the emotional expressions of happiness, sad, fear, disgust, and anger seem more impaired (Derntl et al., 2009). It has also been stated that emotions that are harder to identify in an upright orientation are the most impaired under the inversion paradigm (Prkachin, 2003b).

1.4. Impaired processing of expressions of emotion: Alexithymia

Alexithymia was initially described during clinical observations of patients with psychosomatic disorders, commonly regarded as unsuitable for dynamic therapeutic approaches (Sifneos, 1973). They were characterized by having a deficit in emotional function, evident by a struggle from the individual to articulate their emotions adequately as well as a poverty of fantasy life.

Three years later at the 11th European Conference on Psychosomatic Research (1976), where alexithymia was the main theme, individuals with this profile were further characterized by having difficulties identifying feelings (DIF), difficulties in distinguishing between feelings and bodily sensations of emotional arousal; difficulty describing feelings (DDF) to others;

constricted imaginal processes, as evidenced by a few fantasy descriptions; and a stimulus-bound, externally oriented cognitive style (Goerlich, 2018; Krystal, 1979).

Alexithymia constraints appear associated with deficits in automatic (Vermeulen et al., 2006) and emotional processing (Wang et al., 2022a), evident in both behavioral (Luminet et al., 2021) and neurobiological levels (Ihme et al., 2014a). These alterations seem associated with a lack of interoceptive awareness (Brewer et al., 2016; Donges & Suslow, 2017).

These types of impairments are presented through all sensory modalities, for instance, in the auditory modality, atypical processing has been observed for music and speech (Goerlich et al., 2011), as well as for vocalizations (Bayot et al., 2014; Heaton et al., 2012). Alexithymia has also been associated with general deficits in olfactory processing (Özsoy-ünübol et al., 2020), as well as in the identification of pleasantness in olfactory stimuli (Cecchetto et al., 2017). Gustatory ability is also impaired in alexithymia (Özsoy-ünübol et al., 2020), with deficits in identifying food preferences (Özsoy-ünübol et al., 2020; Robino et al., 2016). Finally, temperature sensitivity (Borhani et al., 2017) and texture identification are also altered (Borhani et al., 2017; Iosifyan & Korolkova, 2019). Alexithymia has been recognized as a potential risk to various psychiatric and neurological conditions, including depression (Honkalampi, Hintikka, et al., 2001b), anxiety disorders (Fietz et al., 2018), and eating disorders (Nowakowski et al., 2013; Speranza et al., 2007).

1.5. Etiology of Alexithymia

In its etiology, alexithymia has been associated with both genetic and environmental factors. Serotonin (5-HT) is a neurotransmitter that has been linked to the regulation of pain and emotional aversion processing (Cools et al., 2008), and in humans, there are different configurations of its transporter (5-HT transporter-linked promoter region, 5-HTTLPR) that differentially influence serotonin levels. The variations associated with 5-HTTLPR are the short (S) and long (L) polymorphism, creating the genotypes S/S, S/L, or L/L. Individuals who scored higher in an alexithymia scale tend to have the L/L genotype leading to higher concentrations of serotonin levels in the synaptic cleft compared to individuals with the L/S or S/S genotype (Kano et al., 2012).

From a development perspective, it has been suggested that childhood trauma would be an important factor when assessing a patient's history (Krystal, 1979), and when evaluating their attachment style, both forms of insecure attachment (anxious and avoidant) are more common in individuals who have higher scores in alexithymia (Wearden et al., 2003).

Regarding neuronal activity, individuals with high alexithymia scores exhibit reduced brain activity in response to emotional stimuli in regions responsible for appraisal and encoding of affective responses, namely the amygdala, occipitotemporal areas (fusiform gyrus), and insula (Bird et al., 2010b; Donges & Suslow, 2017; Moriguchi & Komaki, 2013; Reker et al., 2010).

Although contentious, research increasingly converges towards acknowledging alexithymia as a personality trait prevalent across the general population (Salminen et al., 2006). In a further attempt to understand its distribution in the general population, (Honkalampi, Koivumaa-Honkanen, et al., 2001) study the Finnish population which had an alexithymia prevalence of approximately 10%. In a Danish twin study, it was estimated heritability of 30%-33% (Jørgensen et al., 2007).

1.6. Deficits in facial emotional processing in alexithymia

Although there is a generalized agreement that individuals with higher alexithymia scores have deficits in emotion recognition, the literature still conveys mixed results regarding which expressions are mostly impaired (Montebarocci et al., 2011).

Individuals with high alexithymia show a significantly diminished sensibility for emotional negative expressions, such as anger, sadness, and in particular fear. Despite the diminishing display of sensitivity to this signal, they attribute higher intensity to the facial expression of fear (Prkachin et al., 2009). Fear and anger facial expressions have been reported to be the two emotions most difficult to recognize, when compared to happy and neutral expression (Ihme et al., 2014b; but see Pandey & Mandal, 1997 for no effect of alexithymia on emotion processing).

Regarding intrinsic factors of alexithymia, Difficulty in Identifying Feelings (DDF) significantly correlates with poorer performance in labelling all emotions (Ihme et al., 2014b; Prkachin et al., 2009).

1.7. Present study

The evolutionary trajectory of primates highlights social cognition as essential for individual survival. Primates share specific neural structures, muscular systems, and brain organization that support the expression and recognition of emotions. Deficits in emotional recognition are recognized as risk factors for various psychiatric and neurological disorders, underscoring the need to study these impairments closely. However, there is still a gap in the

literature on the nuances of alexithymia. On one hand it is not fully clear the specificity of alexithymia's deficits for emotion processing, or if these deficits extend to the ability to detect the absence of emotion. On the other hand, it is not clear how individuals with this condition utilize holistic processing for emotion categorization. This work aims to address these gaps across two separate experiments.

2. Experiment I

Although alexithymia is mainly associated with a deficit in emotion recognition, particularly negative valence emotions (Wang et al., 2022b), several studies have also reported deficits in recognising the absence of emotion (neutral face; Peasley-Miklus et al., 2016). Therefore, in this experiment, to further explore the later effect we will use fearful and neutral faces, as well as an object category as a control condition, which to our present knowledge has not been done before. We expect individuals with higher scores of alexithymia to present increased deficits in categorizing human emotion or lack of it (neutral faces) and an absence of similar effects for the control condition. We also expect the potential deficits to increase under taxing visual conditions as observed in previous literature (Cook et al., 2013; Suslow et al., 2024). Contrary to previous studies we used the RISE technique to increase the perceptual difficulty, in alternative to morph faces (Bird & Cook, 2013), covered faces (Reker et al., 2010) or high and low pass filtering (Kätsyri et al., 2008). This allowed us to control important factors for face perception, such as contrast, luminosity, and spatial frequency.

2.1. Method

2.1.1. Participants.

Sample size was determined with the use of G-power 3.1, considering a correlation of $\rho = .58$, based on the study of Kätsyri and colleagues (2008), leading to an estimated sample size of 20 participants ($1-\beta = .80$, $\alpha = .05$).

We recruited 40 university students from ISPA – Instituto Universitário. The inclusion criteria were, an age over 18 years, biologically male or female, with normal or corrected to normal vision. Five participants were excluded for not completing the full experiment. The final sample was comprised of thirty-five participants, aged 19-31 ($M = 20.5 \pm 2.34$; 30 female and 5 male). This experiment was approved by the ethical committee of ISPA- Instituto Universitario de Ciências Psicológicas, Sociais e da Vida. Written informed consent was obtained from all participants prior to the start of the experiment. Participants were compensated for their time with course credits or a 10€ voucher.

2.2. Material

2.2.1. Stimuli

Six face identities (3 male and 3 female) were selected from the FACES database (Ebner et al. 2010). Models were presented with both neutral and fearful emotional facial expressions. Additionally, six control stimuli were selected OBNIS database (6 exemplars of plant/fungi, hereby described as object category for simplicity, Gomes et al., 2024). These stimuli were selected to provide a control category, to ascertain that any potential findings associated with alexithymia traits are selective for face processing, and not due to general perceptual deficits. This led to a total of 18 unique stimuli. Each image was presented in grayscale, cropped into an oval shape, ensuring they occupy the same visual field area (500 x 348 pixels). Low level visual properties of the stimuli, namely luminosity and effective contrast were equalised using the SHINE toolbox (Willenbockel et al., 2010) powered by MATLAB.

Image visual noise was manipulated using the RISE toolbox (Ales et al., 2012; Sadr & Sinha, 2004). This technique performs an analysis of the frequency spectrum of the source image and then manipulates the spatial structure of the image without altering the original power spectrum. It enables the generation of image sequences from a single image, introducing varying levels of visual noise while keeping the low-level visual properties known to influence affective processing (spatial frequencies, luminance, and contrast). This approach offers an advantage over more traditional scrambling techniques, which cannot maintain these properties intact.

Two pilot experiments, whose data collection was conducted within the scope of this thesis, were ran to obtain levels of visual noise corresponding to a categorization accuracy of 0%, 25%, 50%, 75%, and 100% per stimuli. In the first pilot study participants (N = 79) were asked to categorise images as emotional faces, neutral faces, and objects in a similar paradigm as the current experiment (see procedure section below). In this study we used 21 visual noise levels, ranging from 100 to 0% in steps of 5%. This first pilot study was not fine grained enough with the presented visual noise levels to obtain the desired behavioural accuracies.

To obtain the desired levels of accuracy, we conducted a second pilot study (N = 60), where we increased the levels of visual noise to 41, ranging from 100 to 5% in steps of 2.5. Based on the results of this second study, we selected the specific levels of image noise per stimuli leading to 5 levels of perceptual difficulty as measured by average accuracy (0%, 25%, 50%, 75%, and 100%).

The final dataset comprised 90 images (18 unique exemplars in 5 levels of perceptual difficulty).

2.2.2. Questionnaires and tests

The Toronto Alexithymia Scale (TAS-20), developed by Michael Bagby and colleagues (1994), was designed to assess individuals' level of Alexithymia traits. In this study, we used a version translated and adapted for the Portuguese population (Praceres et al., 2000). This self-report scale measures alexithymia traits with 20 items divided into a three-factor structure (Bagby et al., 1994) comprising of 1) Difficulty Identifying Feelings (ability to distinguish between feelings and bodily sensations associated with emotional arousal), 2) Difficulties Describing Feelings (ability to describe feelings to others), 3) External-Oriented Thinking (cognitive style reflects in part impoverished inner fantasy life). Items are rated using a Likert Scale with five points 1: Strongly disagree; 2: Disagree; 3: Neither agree nor disagree; 4: Agree; 5: Strongly agree. The total score was calculated by the sum of all items, ranging from 20 to 100. Items 4,5, 10,18, and 19 had inverted scores. In the present study, the scale revealed an appropriate internal consistency (Cronbach's coefficient $\alpha = .81$; data collapsed across all subjects).

Participants also completed the Beck Depression Inventory (BDI-II; Beck et al., 1996; Campos & Gonçalves, 2011), the State-Trait Inventory for Cognitive and Somatic Anxiety (STICSA; Ree et al., 2008), and the Autism-Spectrum Quotient (AQ; Baron-Cohen et al., 2001). These questionnaires measure variables that are not under the scope of this thesis and, therefore the results will not be analysed.

2.3. Procedure

Participants were seated in a quiet room and asked to use a chin rest to maintain a fixed distance from the screen (50 cm). Participants first completed a categorization task where trials started with a fixation cross (displayed for 750 -1200 ms), followed by a screen where the stimulus was presented (e.g. neutral, fearful face or object) for 500 ms. Participants had a 1000 ms window to press the space bar if they were able to identify the stimulus category. If participants did not respond the next trial started, otherwise, a second screen with labels appeared, allowing participants to use the mouse cursor to select the label corresponding to the category they saw. Positions of the labels were counterbalanced between participants. 360 trials

were presented, representing the 6 stimuli per condition (three categories) in 5 levels of perceptual difficulty repeated four times. The task started with a training block with feedback (containing 34 trials) followed by three experimental blocks (splits of 120 trials) to allow for breaks.

Following the experimental task, participants completed all the questionnaires (TAS-20, AQ, BDI, STICSA).

2.3.1. Statistical analysis

All statistical analyses were performed using the GAMLj module (Gallucci, 2019) powered by jamovi (The jamovi project 2022). Generalized Linear Mixed-Effects models were conducted by employing a Binomial Distribution with a Logit Link Function (logistic mixed-effects model). This model predicts the probability of correct categorization of the facial expressions, considering correct categorization as 1 and wrong categorization as 0, in terms of log odds. Multiple comparisons were corrected using the Bonferroni method. This model was applied to address the non-normal distribution of the data and to control for random effects.

2.4. Results

Participants accuracy was measured to test if perceptual deficits observed in alexithymia are specific to processing emotions (fearful faces) or extend to the lack of emotion (neutral faces), assuming an absence of an effect of alexithymia for non-face objects. We further predict that individuals with higher levels of alexithymia will be increasingly impaired in categorizing emotion (and its absence) with increasingly taxing visual conditions (Kätsyri et al., 2008).

A GLMM was ran with stimuli category (i.e., fearful faces, neutral faces, and objects), perceptual difficulty (0%, 25%, 50%, 75%, and 100% of expected accuracy), and TAS-20 score (continuous variable) as predictors in the model. These variables and their interactions were entered as fixed effects. Participants' ID was used as a clustering variable. Random intercepts were included for Participant ID to account for individual differences. Unfortunately, with the number of participants tested, this model did not converge leading to the removal of the easiest and hardest perceptual difficulties, deemed to be less informative (for ease of reading, they will be referred as hard, mid, and easy perceptual difficulty corresponding to 25%, 50%, and 75%

expected accuracy). This simplified model converged showing an R^2_{marginal} of 0.12, and a $R^2_{\text{conditional}}$ of 0.41.

A main effect of the category was observed ($\chi^2(2) = 92.96, p < .001$) characterized by a worse accuracy for fearful faces compared to the object category ($z = -8.28, p < .001$) and neutral faces ($z = -8.49, p < .001$) with no difference between the later categories ($z = 0.229, p > 0.999$). As expected, there was also a main effect of perceptual difficulty ($\chi^2(2) = 578.51, p < .001$), characterized by a decrease in accuracy with increasing perceptual difficulty (meaning from the easy to the hard perceptual difficulty; $z > 11.7, p < .001$; Figure 1 Top Left panel).

There was an interaction between these two variables, category and perceptual difficulty ($\chi^2(4) = 10.67, p = .031$). In the two hardest conditions (Hard [effect of emotion, $\chi^2(2) = 32.1, p < 0.01$]; and Mid [$\chi^2(2) = 59.2, p < 0.01$]) there was a lower accuracy for the fearful face compared with the object category ($z > -4.75, p < .001$), and neutral faces ($z > -5.16, p < .001$), with no difference for neutral faces compared to the object category ($z < 1.22, p > .999$; see right panel on Figure 1). For the easiest condition ($\chi^2(2) = 13.8, p = 0.001$) only the fearful face showed a significant decrease in accuracy compared to the neutral face ($z = 3.62, p = 0.011$), while the remaining conditions did not differ from each other ($z < 2.49, p > 0.452$), Table 1.

Table 1 – Experiment I, estimated means for the interaction of perceptual difficulty and category

Perceptual Difficulty	Category	Prob.	SE	95% Confidence Interval	
				Lower	Upper
Hard	Fearful Face	0.208	0.0374	0.144	0.291
Mid	Fearful Face	0.338	0.0502	0.248	0.443
Easy	Fearful Face	0.615	0.0532	0.507	0.712
Hard	Neutral Face	0.324	0.0492	0.236	0.427
Mid	Neutral Face	0.499	0.0559	0.391	0.607
Easy	Neutral Face	0.708	0.0467	0.609	0.790
Hard	Object	0.314	0.0484	0.228	0.416
Mid	Object	0.532	0.0557	0.423	0.638
Easy	Object	0.680	0.0490	0.577	0.767

Note. Estimated means are estimated keeping constant other effects in the model to the mean

There was a marginal effect of TAS-20 ($\chi^2(1) = 3.32, p = .068$), suggestive of a general decrease in accuracy with increasing TAS-20 score. Importantly this marginal effect did not interact with stimulus' category ($\chi^2(2) = 0.895, p = .639$; Figure 1 Top Right panel). Nonetheless, there was a marginal interaction between TAS-20 and perceptual difficulty ($\chi^2(2) = 5.18, p = .075$).

Given the relevance of this question for the present works we did an exploratory analysis of this marginal interaction. This interaction was characterized by an effect of TAS-20 in the easiest condition ($\chi^2(1) = 4.81, p = .03$) which progressively disappeared with more taxing perceptual conditions; mid $\chi^2(1) = 2.90, p = .088$; hard, $\chi^2(1) = 2.19, p = .139$; Figure 1 bottom panel).

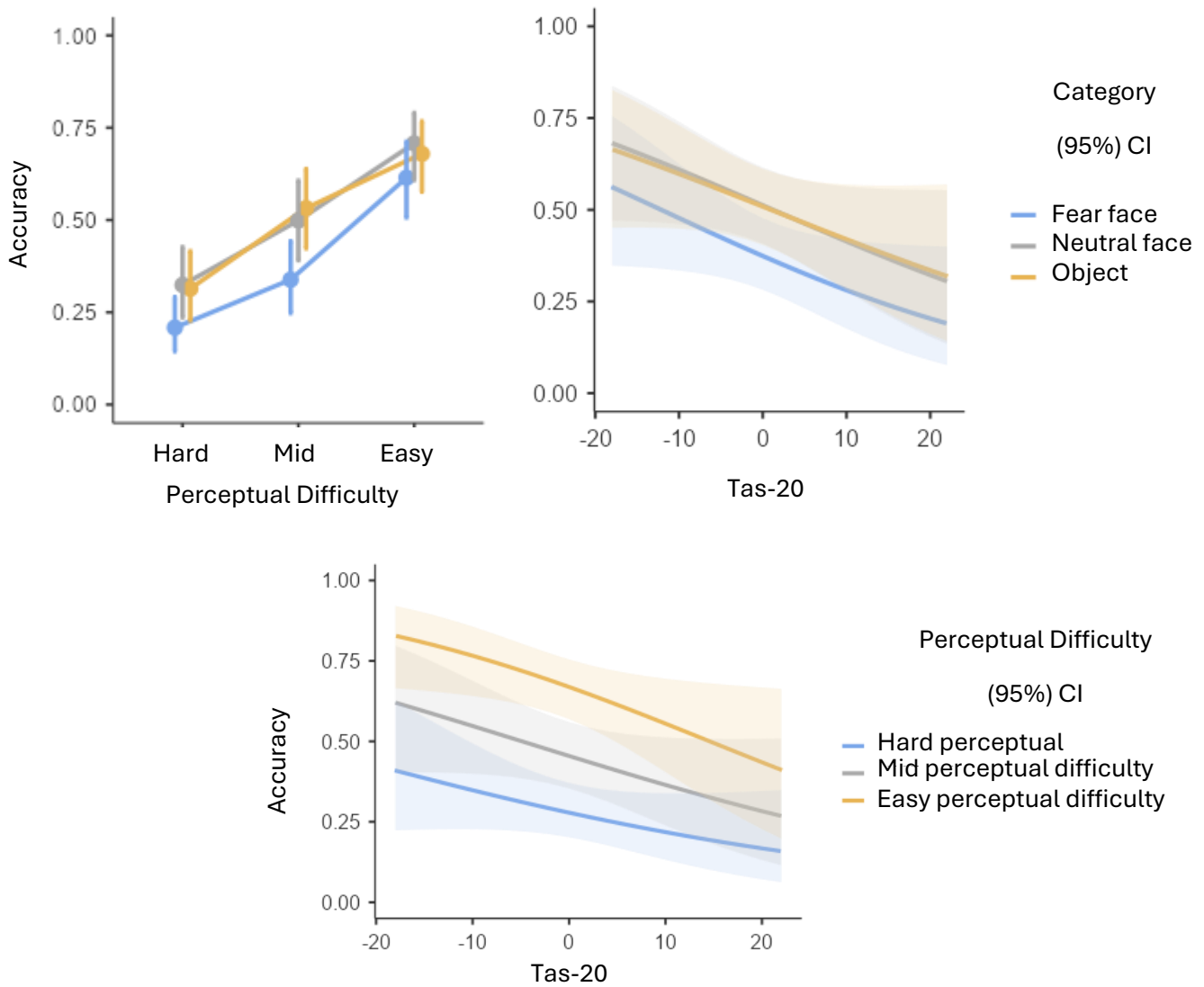


Figure 1 - On the top left panel, accuracy on the task per perceptual difficulty. On the top right panel, accuracy on the task per different TAS-20 scores. At the bottom panel, perceptual accuracy influenced by TAS-20. TAS-20 scores are presented centred.

2.5. Discussion

Although alexithymia is characterized by a deficit in recognizing emotional faces, the literature also suggests a deficit in processing neutral faces (absence of emotional information, Peasley-Miklus et al., 2016). To better grasp this phenomenon, we decided to compare neutral and fearful faces (an emotion that has been shown to be impaired in alexithymia; Prkachin et al., 2009; Rosenberg et al., 2020) to an object category. We hypothesized that individuals with higher alexithymia scores would experience greater impairments in identifying both fear and neutral facial categories compared to those with lower scores, an effect that we thought would be heightened, under increased perceptual difficulty (Reker et al., 2010).

Unexpectedly, alexithymia traits were generally associated with poorer categorization accuracy, as there was no specific category that was more impaired. These findings are suggestive of a more generalised perceptual impairment, not specific to negative valence emotions or their absence (neutral faces). A general impairment of emotion processing has already been suggested in the work of Lane and colleagues (1996), where alexithymic individuals had poorer performances with different types of visual stimuli, including matching emotional faces with the emotional word. Kano and colleagues, (2003) also reported that higher levels of alexithymia modulated neutral, negative, and positive valence emotions. Surprisingly, our results expand previous findings to include a perceptual decrease in performance extended to a non-emotional control condition – an object category.

Our results were also suggestive of an interaction between perceptual difficulty and alexithymia level. Participants who scored higher on the alexithymia scale (TAS-20), had their categorization abilities diminish significantly in the easiest level of perceptual difficulty when compared with other levels of difficulty. It is possible that harder levels of difficulty led to a reduced variability in our population, and thus we do not have the required sensibility to find possible effects of alexithymia. The interpretation of this exploratory analysis must be done with care, given that results were only marginally significant, and it requires further replication.

There appears to be a generalized impairment in the recognition of fearful emotional expressions compared with objects or neutral faces. Fear is an emotion that signals a possible threat in the environment (Schindler & Bublatzky, 2020) a highly important signal that can directly contribute to individual fitness, it also generates in the observer an alteration in the alertness system (Dennis et al., 2008). Consequently, we were expecting a higher accuracy

compared with neutral facial expressions that lack relevant emotional signalling. Regarding the comparison of fearful faces with the object category, it also came as an unexpected result since humans have particular expertise and dedicated neural structures for faces (Tanaka, 2001) that allows for their faster recognition (Negrini et al., 2017). Although the work of Dennis and colleagues, (2008), suggested that while faces are more salient than other stimuli, emotional expression does not impact stimulus salience (Gray et al., 2013). This is further supported by studies showing that there is no advantage in the identification of fear faces compared to other emotions when presented simultaneously (Juth et al., 2005).

3. Experiment II

In this experiment, we will analyse a potential mechanism that might underpin deficits in emotion processing in alexithymia. Here we will investigate how alexithymia modulates holistic processing of emotions. Since holistic processing of faces is disrupted by inversion (Tanaka & Farah, 1993b), we used this manipulation and presented both upright and inverted faces. Furthermore, the object category was removed, and happy facial expressions were introduced. This allowed us to better understand the impact of alexithymia in the processes of both positive and negative valence emotions. Since in the previous experiment, the levels of perceptual difficulty did not correspond with the levels of accuracy expected, we selected specific levels of image noise to obtain 25%, 50%, and 75% accuracy based on a pilot study. These were 85%, 80%, and 65% of image noise respectively. For ease of readability, we will remain with the nomenclature of hard, mid, and easy perceptual difficulty to describe images with 85%, 80%, and 65% of noise.

3.1. Method

3.1.1. Participants

A total 49 students from ISPA – Instituto Universitário, were recruited using the same inclusion and exclusion criteria as in Experiment 1. This led to the exclusion of three participants who did not complete the experiment. The final sample consisted of forty-six participants aged 18-27, $M=20.3$, $SD \pm 2.29$; 37 female and 9 male. As before, written informed consent was obtained from all participants prior to the start of the experiment. Participants were compensated for their time with course credits or a 10€ voucher.

3.1.1. Materials

3.1.1.1. Stimuli.

To increase the generalisability of results, we increased the number of identities used. Thirty face identities (15 female, 15 male) were selected from the FACES database (Ebner et al. 2010), Chicago Face Database (Ma et al., 2015), and Radboud Faces Database (Langner et

al., 2010). Models were selected with neutral, fearful, and happy emotional facial expressions, leading to a total of 90 unique stimuli.

Low level properties of images were processed as in Experiment 1 (see Materials from Experiment 1). Since the expected accuracy in the previous experiment did not match the participants' actual accuracy, here we opted to use a fixed percentage of visual noise as a metric of perceptual difficulty. A third pilot experiment (N=17) was conducted with the same procedure, in order to obtain the noise levels corresponding to a general accuracy of 25%, 50%, and 75% in line with the data analysed in experiment 1. This led to the inclusion of images with 85%, 80%, and 60% visual noise (hard, mid, and easy perceptual difficulty).

Thus, in this experiment, perceptual difficulty will be defined as a function of visual noise.

3.1.2. Procedure

Here the same procedure was conducted as in Experiment 1 (see Experiment 1 procedure). Participants were shown 540 trials, representing 90 stimuli per condition (happy, fearful, and neutral faces) in 3 levels of perceptual difficulty repeated 2 times. The task started with a training block with feedback (containing 34 trials) followed by three experimental blocks (splits of 180 trials) to allow for breaks.

As in Experiment 1, following the experimental task, participants completed all the questionnaires (TAS-20, AQ, BDI, STICSA).

3.1.3. Statistical analysis

Similar statistical analysis to experiment 1 were conducted. All statistical analyses were performed using the GAMLj module (Gallucci, 2019) powered by jamovi (The jamovi project 2022). Generalized Linear Mixed-Effects models were conducted by employing a Binomial Distribution with a Logit Link Function. The model predicts the log odds of correctly categorizing the facial expression. Multiple comparisons were corrected using the Bonferroni method.

3.2. Results

Participants' accuracy was measured to test if individuals with higher levels of alexithymia would be increasingly impaired in categorizing all emotions when faces are inverted with a more prominent effect for fearful faces. The inclusion of happy facial expressions will allow us to test if perceptual deficits observed in alexithymia are limited to a specific emotional valence (positive or negative).

A GLMM was run with stimuli category (i.e., fearful, neutral, and happy faces), perceptual difficulty (hard, mid, and easy perceptual difficulty), orientation (i.e., upright, and inverted), and TAS-20 score (continuous variable) as predictors in the model. These variables and their interactions were entered as fixed effects. Participants' ID was used as a clustering variable and included as a random effect. This model showed an R^2_{marginal} of .33 and $R^2_{\text{conditional}}$ of .42.

A main effect was found for category ($\chi^2(2) = 30.48, p < .001$) characterized by a generally higher accuracy for happy and fearful faces when compared with neutral faces (happy: $z = 3.78, p < .001$; fear: $z = 5.38, p < .001$) while fearful faces did not significantly differ from happy faces ($z = 1.45, p = .438$, table 2 for descriptive statistics). A main effect was found for perceptual difficulty ($\chi^2(1) = 0.20, p < .001$) characterized by a significant increase in accuracy with easier perceptual difficulty for all pairwise comparisons ($z > -25.9, p < .001$). A main effect was also found for orientation ($\chi^2(1) = 0.20, p < .001$), characterized by a higher performance for stimuli presented upright compared to inverted.

There was a significant interaction between the level of alexithymia and orientation ($\chi^2(1) = 23.09, p < .001$). While the effect of TAS-20 was not significant for upright ($\chi^2(1) = 1.37, p < .24$) or inverted faces ($\chi^2(1) = 0.076, p < .78$), the slope of this variable differed significantly between these two conditions ($z = 4.81, p < .001$, Figure 2). This finding suggests that the performance for upright orientation was significantly improved over the performance for inverted faces with increasing alexithymia traits, supporting a reliance in holistic processing associated with alexithymia.

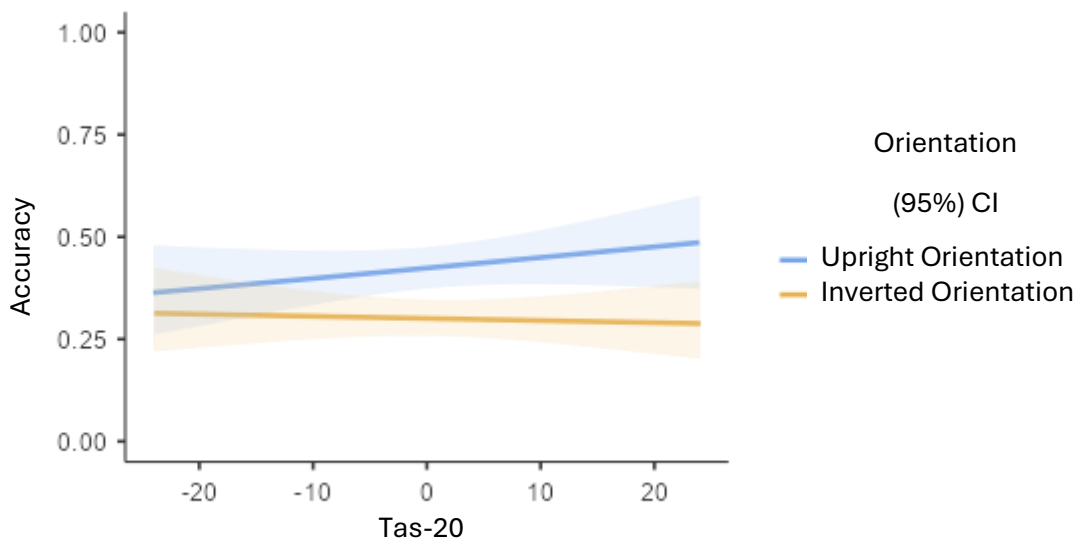


Figure 2 - Accuracy for upright and inverted faces by TAS-20 scores (presented centred).

Table 2 - Estimated means per condition

	Condition	Prob.	SE	95% CI	
				Lower	Upper
Category	Happy	0.367	0.0249	0.320	0.417
	Fear	0.380	0.0252	0.332	0.430
	Neutral	0.333	0.0238	0.289	0.382
Difficulty	Hard	0.126	0.0119	0.104	0.151
	Mid	0.290	0.0219	0.249	0.334
	Easy	0.752	0.0199	0.710	0.788
Orientation	Upright	0.424	0.0258	0.374	0.475
	Inverted	0.301	0.0223	0.259	0.346

Note. Estimated means are estimated averaging across interacting variables

There was a significant interaction between category and orientation ($\chi^2(2) = 12.05, p < .001$), characterized by an advantage in categorization for upright compared to inverted faces for fear and neutral expressions ($z > 11.22, p < .001$). There was no inversion effect for happy faces ($z > 0.56, p = .58$).

There was a significant three-way interaction between category, orientation, and perceptual difficulty ($\chi^2(4) = 12.05, p = .017$). This was characterized by an advantage for upright faces for fear and neutral expression across all levels of perceptual difficulty ($z > 5.62, p < .001$), while a very different pattern was observed for happy faces. In this later case, there was an advantage of inverted faces in the hardest perceptual difficulty ($z = 0.65, p = .519$), an absence of an effect of orientation in the middle level of difficulty, and an advantage of the upright orientation for the easiest level ($z = 2.54, p = .011$), table 3, figure 3.

A three-way interaction with the level of alexithymia, perceptual difficulty, and category was found ($\chi^2(4) = 23.92, p < .001$). This revealed a decreased accuracy for happiness ($z = -2.54, p = .011$) and fear ($z = -2.217, p = .027$) facial expressions with increasing scores of TAS-20, under the hardest level of perceptual difficulty (no effect for neutral faces, $z = 0.956, p = .34$). This negative association between emotional recognition and TAS-20 disappeared for the mid-level perceptual difficulty ($z < .93, p > .354$). Surprisingly for the easiest perceptual difficulty the usually observed deficits in emotional recognition associated with increased TAS-20 were reversed, an effect that was significant for all emotions ($z > 8.29, p < .004$; table 5, Figure 3).

Given that we also had a marginal significance for a four-way interaction of these three variables with orientation ($\chi^2(4) = 8.63, p = .071$), we decided to explore these effects both for upright and inverted faces. While this analysis is fully exploratory, we deemed it important to better compare the findings of Experiment I and Experiment II, given their apparent contradiction for upright faces (common to both experiments).

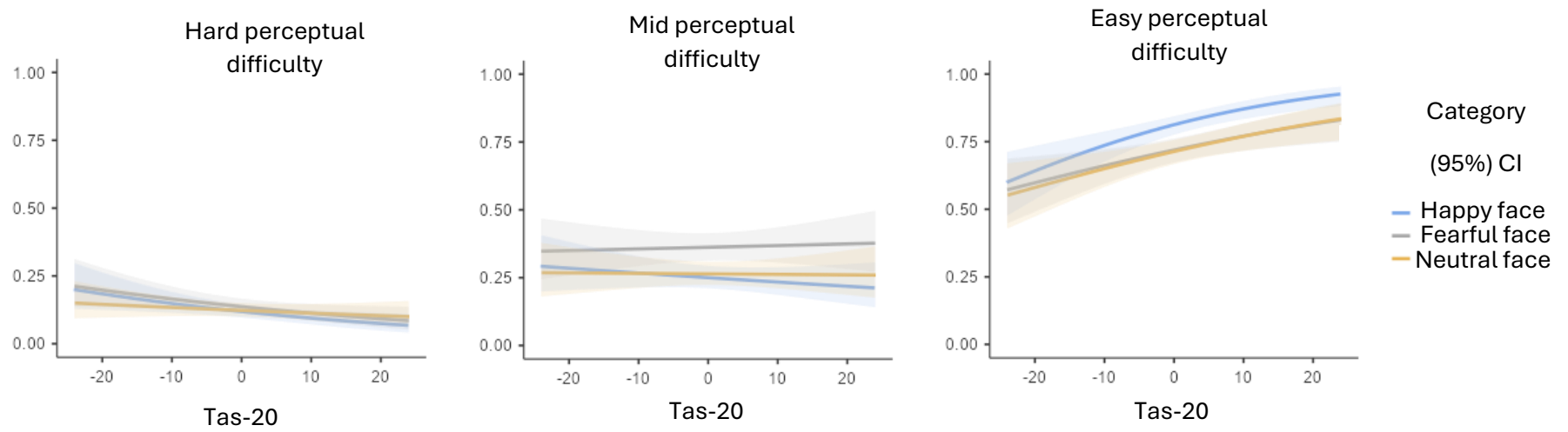


Figure 3 - Left panel, accuracy modulation by scores of Alexithymia on the hardest perceptual difficulty. Middle, accuracy modulation by scores of Alexithymia on the mid perceptual difficulty. Right panel, accuracy modulation by scores of Alexithymia on easiest. TAS-20 scores are presented centered.

Table 3 - Estimated simple effects for the interaction between category, orientation, and perceptual difficulty.

Moderator levels		95% Exp(B) CI							
Perceptual difficulty	Category	Contrast	Estimate	SE	exp(B)	Lower	Upper	z	p
Hard	Happy	Inv - Up	0.2354	0.1107	1.265	1.018	1.572	2.125	0.034
	Fear	Inv - Up	-0.6374	0.1071	0.529	0.429	0.652	-5.954	< .001
	Neutral	Inv - Up	-0.6183	0.1100	0.539	0.434	0.669	-5.619	< .001
Mid	Happy	Inv - Up	-0.0554	0.0858	0.946	0.800	1.119	-0.645	0.519
	Fear	Inv - Up	-0.7703	0.0797	0.463	0.396	0.541	-9.663	< .001
	Neutral	Inv - Up	-1.1323	0.0877	0.322	0.271	0.383	-12.909	< .001
Easy	Happy	Inv - Up	-0.2276	0.0897	0.796	0.668	0.950	-2.536	0.011
	Fear	Inv - Up	-0.5710	0.0802	0.565	0.483	0.661	-7.115	< .001
	Neutral	Inv - Up	-1.0542	0.0824	0.348	0.296	0.410	-12.788	< .001

Note. Simple effects are estimated keeping constant other independent variable(s) in the model; Inv corresponds to inverted faces and Up corresponds to upright faces.

Table 4 – Simple effects of alexithymia per perceptual difficulty and category

Moderator levels		95% Exp(B) Confidence Interval						
Perceptual Difficulty	Category	Estimate	SE	exp(B)	Lower	Upper	z	p
Hard	Happy	-0.02567	0.01011	0.975	0.956	0.994	-2.5397	0.011
	Fear	-0.02218	0.01000	0.978	0.959	0.997	-2.2172	0.027
	Neutral	-0.00963	0.01007	0.990	0.971	1.010	-0.9560	0.339
Mid	Happy	-0.00887	0.00956	0.991	0.973	1.010	-0.9276	0.354
	Fear	0.00266	0.00943	1.003	0.984	1.021	0.2819	0.778
	Neutral	-9.47e-4	0.00958	0.999	0.980	1.018	-0.0988	0.921
Easy	Happy	0.04422	0.00959	1.045	1.026	1.065	4.6091	< .001
	Fear	0.02714	0.00943	1.028	1.009	1.047	2.8789	0.004
	Neutral	0.02940	0.00946	1.030	1.011	1.049	3.1071	0.002

Note. Simple effects are estimated keeping constant other independent variable(s) in the model

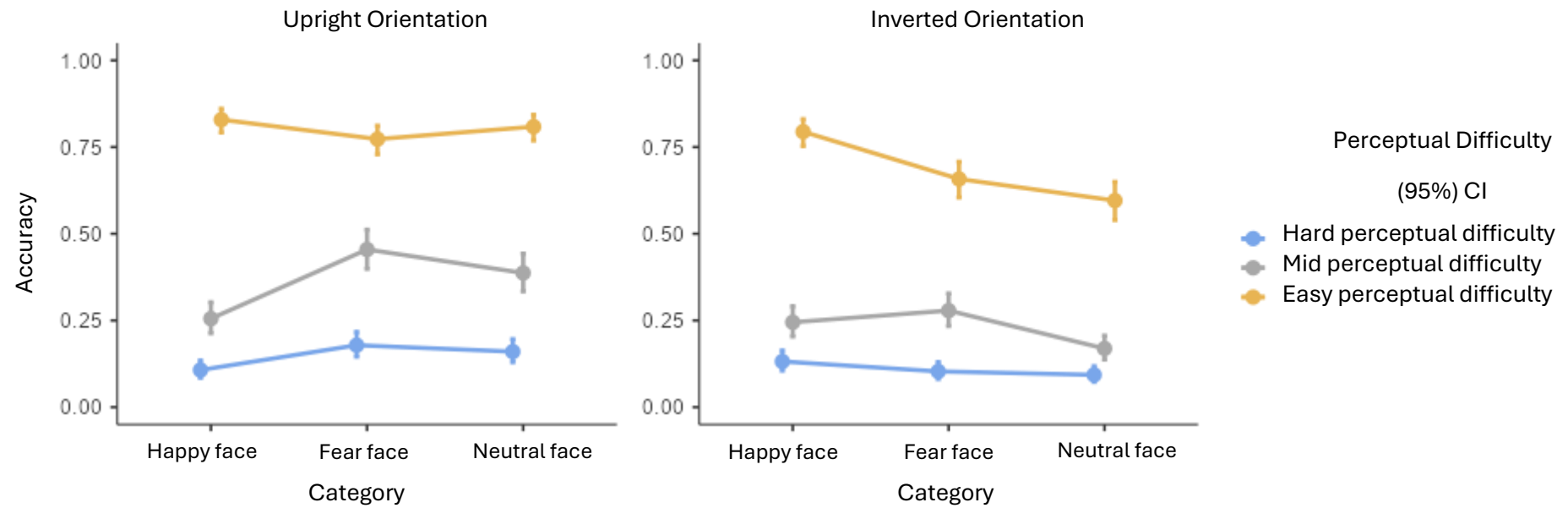


Figure 4 - Left panel, accuracy modulation by category and the three perceptual difficulties in the upright orientation. Right panel, accuracy modulation by category and the three perceptual difficulties in the inverted orientation.

3.2.1.1. Upright Orientation

Here we performed a similar GLMM model only for upright faces, including as fixed factors only stimuli category, perceptual difficulty, and TAS-20 score and their interactions. This model showed an R^2_{marginal} of .34 and $R^2_{\text{conditional}}$ of .44. Here we will focus only on the three-way interaction described above (alexithymia, perceptual difficulty, and category, $\chi^2(4) = 27.49, p < .001$). Under the upright orientation, this effect disappeared ($\chi^2(4) = 4.30, p = 0.368$), with only the interaction between the level of alexithymia and perceptual difficulty $\chi^2(2) = 125.24, p < .001$, showing similar results to the four-way. At the easiest perceptual difficulty there is an increasing accuracy with higher levels of alexithymia ($z = 4.17, p < .001$). In the remaining perceptual difficulties, there was no interaction ($z < -1.29, p > 0.20$).

3.2.1.2. Inverted Orientation

As for the upright condition, we performed a similar GLMM model only for inverted faces ($R^2_{\text{marginal}} = .30$ and $R^2_{\text{conditional}} = .40$). Focusing on the three-way interaction (alexithymia, perceptual difficulty, and category, $\chi^2(4) = 28.00, p < .001$).

Here we observed an effect of TAS-20 where increasing scores were associated with a decrease in emotion recognition for fear ($z = -3.24, p = .001$) and happiness ($z = -2.64, p = .008$) in the hardest level of perceptual difficulty (neutral: $z = -0.76, p = .447$). As before there was no effect of TAS-20 for any of the emotions in the middle level of perceptual difficulty ($z < -1.47, p > .141$, table 5), while in the easiest level of perceptual difficulty TAS-20 was associated with an increased recognition ability for happiness ($z = 4.26, p < .001$) and a marginal effect for fear ($z = 2.64, p = .08$; neutral, $z = 1.64, p = .102$).

Table 5 Interaction Alexithymia, perceptual difficulty and category in an inverted presentation

Moderator levels		95% Exp(B) CI						
Perceptual Difficulty	Category	Estimate	SE	exp(B)	Lower	Upper	z	p
Hard	Happy	-0.02978	0.0113	0.971	0.949	0.992	-2.638	0.008
	Fear	-0.03803	0.0117	0.963	0.941	0.985	-3.241	0.001
	Neutral	-0.00898	0.0118	0.991	0.968	1.014	-0.760	0.447
Mid	Happy	-0.01541	0.0105	0.985	0.965	1.005	-1.472	0.141
	Fear	-0.00337	0.0103	0.997	0.977	1.017	-0.326	0.745
	Neutral	-0.00813	0.0108	0.992	0.971	1.013	-0.751	0.453
Easy	Happy	0.04437	0.0104	1.045	1.024	1.067	4.264	< .001
	Fear	0.01723	0.0101	1.017	0.998	1.038	1.712	0.087
	Neutral	0.01643	0.0100	1.017	0.997	1.037	1.636	0.102

3.3. Discussion

In this experiment, we aimed to identify a possible mechanism, that might modulate alexithymia-related impairments in emotional processing – holistic processing. To this intend we presented inverted stimuli, known to disrupt the holistic processing of emotional faces (Prkachin, 2003a). Furthermore, we introduced only emotional categories to understand if this impairment was associated with a specific emotional valence (Ihme et al., 2014b). We hypothesized that individuals with higher alexithymia scores would experience greater impairments in category identification compared to those with lower scores, particularly under conditions of increased perceptual difficulty and inverted presentation. Regarding the categories, we expected fearful faces to be the most difficult to identify, as individuals with higher alexithymia scores exhibit hypoactivation in brain regions associated with emotional processing, particularly in response to negative-valence stimuli (Ihme et al., 2014b; Van der Velde et al., 2013).

Regarding the interaction of alexithymia level and orientation, our analysis suggests that higher alexithymia traits are associated with an increase in performance for upright stimuli, compared to inverted, suggesting a higher dependence on holistic processes to extract facial

emotional information. As expected, in the hardest perceptual difficulty we saw a decrease in emotion categorization associated with increased alexithymia, for both emotions (happiness and fear) but not for the neutral condition. Surprisingly, we found that individuals with higher alexithymia scores performed better in identifying categories under the easiest perceptual difficulty. Importantly, this result was not just driven by the inverted faces and, instead it was also present for upright faces. While this result is contrary to our hypothesis and the literature, we tentatively suggest that it may be due to these individuals strategically focusing on stimuli that were easier to perceive.

Overall happy emotional faces were the most accurately identified emotion, under the easiest perceptual difficulty. We believe that is due to the mouth being visually salient in this emotional expression compared with the other categories (Calvo et al., 2014).

As in the previous study, these results need to be analysed with caution, as we present a small sample size compared with other studies (Brewer et al., 2016; Montebanocci et al., 2006; Parker et al., 2005), and present contradictory results contrasting with Experiment 1. Further studies must be undertaken to confirm the present findings.

4. General Discussion

In our study, we aimed to analyse alexithymia-related impairments in emotional processing, tackling holistic processing as a potential underpinning mechanism.

In the first experiment, we aimed to determine whether alexithymia driven impairments are specific to the recognition of emotions. To explore this, we presented participants with a negatively valenced emotion, which previous research has suggested may be particularly challenging for individuals with alexithymia to categorize accurately. We also presented stimuli with an absence emotion (neutral faces), given that some studies suggest that the lack of emotion, leads to an activation of the sympathetic system (increased heart rate) and that this arousal may lead to an impaired decision process (Peasley-Miklus et al., 2016). An object category was included to analyse a possible selective impairment of these two categories, which to our knowledge has not been done before. Furthermore, the categories were presented under taxing conditions, since individuals with alexithymia exhibit greater impairments under such conditions (Reker et al., 2010; Sadr & Sinha, 2004).

We were expecting alexithymia related deficits to be specific to emotion processing impacting only the two facial expressions presented. In contrast, our results suggest a general impairment associated with increased alexithymia across all conditions including the control object condition. General impairments in emotion processing including neutral faces, have already been suggested in the work of Lane and colleagues (1996), where alexithymic individuals had poorer performances with different types of visual stimuli, including matching emotional faces with the emotional words. Nonetheless, generalised deficits including for a category with no emotional content, i.e. objects, was not expected.

Furthermore, we expected fearful faces to be easier to categorise since it suggests the presence of a potential threat, benefiting the observer to accurately categorize this signal. Nonetheless, in Experiment I, fearful faces were in general the least accurately categorised in the higher perceptual difficulty. This may be due to the need to view the entire facial expression, not occluded by visual noise, in order to accurately categorize it as a fearful face. Some studies suggest that fear is often confused with disgust, which may further indicate the importance of seeing the full face to interpret the intended emotional signal (Jack et al., 2009).

Meanwhile, in Experiment II, fear and neutral faces had an advantage over the categorization of happy faces in the two hardest levels of perceptual difficulty in the upright orientation. The difference in results between experiments suggests that there might be specific strategies used by participants depending on the content of the task. A tentative explanation for

these findings could relate to the difference in conditions used. In Experiment I participants could be focusing on the categorization of faces vs non-faces due to the presence of an object condition, with the identification of fearful emotions being a secondary decision leading to an associated decreased performance. In Experiment II participants no longer had to make a categorical decision regarding faces vs non-faces leading to different patterns of results in a purer emotion categorization task.

In Experiment 2, we further tested the role of holistic processing in potential deficits associated with alexithymia traits necessary to process emotional faces (Prkachin, 2003a), by taking advantage of the face inversion effect. To our knowledge, this has not been previously tested. The present findings revealed that higher scores of alexithymia were associated with increased accuracy for the upright condition compared with the inverted, suggesting a higher dependence on the holistic process to extract facial emotional information.

In addition, in Experiment II we also tested if there was an emotional valence specific impairment, whereby we substituted the object category for a positive emotional valence stimulus (happy face). As before, we expected a disadvantage in the categorization of negative emotions, in particular fearful faces, associated with increased alexithymia traits since individuals with alexithymia present a hypoactivation in brain regions associated with negative valence stimuli (Ihme et al., 2014b; Van der Velde et al., 2013).

The results suggested that individuals with increasing scores of alexithymia had a lower categorization performance for happy and fearful faces in the hard perceptual difficulty. This effect disappeared for the mid-level perceptual difficulty, and unexpectedly in the easiest perceptual difficulty, individuals with higher scores of alexithymia had higher accuracy across all categories, compared with individuals with lower scores, a result that contrasted with experiment I.

To further clarify the difference in results between experiments for upright faces, in Experiment 2, we further examined the marginal effects between alexithymia, perceptual difficulty, category, and orientation by analyzing the effects separately for upright and inverted orientations. For upright faces, contrary to Experiment I, there was an increased accuracy with alexithymia in the easiest perceptual difficulty, mimicking the overall results for Experiment II. In the inverted orientation, the results suggest a decreased recognition for fear and happy faces in the hardest perceptual difficulty, whereas on the easiest one higher levels of alexithymia had better performance in the categorization of all emotion, with marginal significance for fear and neutral faces.

This result is contradictory not only to our Experiment 1, which shows a decrease in accuracy with higher scores of alexithymia but also is incongruent with the literature (Grynberg et al., 2012; Suslow & Kersting, 2021). Further studies are needed to clarify these results, which should be analysed with caution, as the present study had a small population of primarily university students. The limited number of participants due to time constraints, led to a more restricted analysis only using the participants' ID as random effect (which could increase the chance of false positives).

Further studies must be undertaken to confirm the present findings, with a higher number of participants, we also suggest the use of physiological measurements such as Heart Rate Variability, and Electroencephaphy (EEG). Regarding assessing the level of alexithymia we suggest the use of the Toronto Structured Interview for Alexithymia (TSIA), allowing for a more in depth analysis of the level of alexithymia traits in our participants.

5. Conclusion

In this study, we observed the importance of some perceptual mechanisms that allow for the retrieval of emotional content for individuals with higher scores for alexithymia. One of these was the importance of holistic processing in the retrieval of emotional information from faces. Regarding specific emotional information, a higher score for alexithymia seemed to be associated with general effects (impairment in experiment I and both impairment and improvement in experiment II), with deficits generalizable to non-face objects.

Emotion specific advantages were highly variable depending on task demands, which shows that participants can develop task specific strategies, which can be different across experiments. Generally, recognition of fearful emotional faces was poorer when the task required a non-face categorization (Experiment I), a pattern inverted under mid levels of perceptual difficulty (Experiment II), and not present in the other perceptual difficulties.

To our knowledge, this was the first study that tried to understand the holistic processing of emotions in alexithymia and that contrasted emotional faces with non-human stimuli. Further studies should be performed with a higher number of participants and physiological measurements to better comprehend the effects of the disruption of holistic processing and possible generalised perceptual deficits.

6. Bibliography

- Ales, J. M., Farzin, F., Rossion, B., & Norcia, A. M. (2012). An objective method for measuring face detection thresholds using the sweep steady-state visual evoked response. *Journal of Vision, 12*(10). <https://doi.org/10.1167/12.10.18>
- Avidan, G., Tanzer, M., & Behrmann, M. (2011). Impaired holistic processing in congenital prosopagnosia. *Neuropsychologia, 49*(9), 2541–2552. <https://doi.org/10.1016/j.neuropsychologia.2011.05.002>
- Bagby, R. M., Parker, J. D. A., & Taylor, G. J. (1994). The twenty-item Toronto Alexithymia scale—I. Item selection and cross-validation of the factor structure. *Journal of Psychosomatic Research, 38*(1), 23–32. [https://doi.org/10.1016/0022-3999\(94\)90005-1](https://doi.org/10.1016/0022-3999(94)90005-1)
- Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The Autism-Spectrum Quotient (AQ): Evidence from Asperger Syndrome/High-Functioning Autism, Males and Females, Scientists and Mathematicians. In *Journal of Autism and Developmental Disorders* (Vol. 31, Issue 1). <https://doi.org/10.1023/A:1005653411471>
- Bayot, M., Pleyers, G., Kotsou, I., Lefèvre, N., Sauter, D. A., & Vermeulen, N. (2014). Joint effect of alexithymia and mood on the categorization of nonverbal emotional vocalizations. *Psychiatry Research, 216*(2), 242–247. <https://doi.org/10.1016/j.psychres.2013.12.007>
- Beck, A. T., Steer, R. A., Ball, R., & Ranieri, W. F. (1996). Comparison of Beck depression inventories -IA and -II in psychiatric outpatients. *Journal of Personality Assessment, 67*(3), 588–597. https://doi.org/10.1207/s15327752jpa6703_13
- Bird, G., & Cook, R. (2013). Mixed emotions: The contribution of alexithymia to the emotional symptoms of autism. In *Translational Psychiatry* (Vol. 3). <https://doi.org/10.1038/tp.2013.61>
- Bird, G., Silani, G., Brindley, R., White, S., Frith, U., & Singer, T. (2010a). Empathic brain responses in insula are modulated by levels of alexithymia but not autism. *Brain, 133*(5), 1515–1525. <https://doi.org/10.1093/brain/awq060>
- Bird, G., Silani, G., Brindley, R., White, S., Frith, U., & Singer, T. (2010b). Empathic brain responses in insula are modulated by levels of alexithymia but not autism. *Brain, 133*(5), 1515–1525. <https://doi.org/10.1093/brain/awq060>
- Borhani, K., Lådavas, E., Fotopoulou, A., & Haggard, P. (2017). “Lacking warmth”: Alexithymia trait is related to warm-specific thermal somatosensory processing. *Biological Psychology, 128*, 132–140. <https://doi.org/10.1016/j.biopsycho.2017.07.012>
- Brewer, R., Cook, R., & Bird, G. (2016). Alexithymia: A general deficit of interoception. *Royal Society Open Science, 3*(10). <https://doi.org/10.1098/rsos.150664>
- Bruce, V., & Young, A. (1986). Understanding face recognition. *British Journal of Psychology, 77*(3), 305–327. <https://doi.org/10.1111/j.2044-8295.1986.tb02199.x>

- Calvo, M. G., Beltrán, D., & Fernández-Martín, A. (2014). Processing of facial expressions in peripheral vision: Neurophysiological evidence. *Biological Psychology*, *100*(1), 60–70. <https://doi.org/10.1016/j.biopsycho.2014.05.007>
- Campos, R. C., & Gonçalves, B. (2011). The portuguese version of the beck depression inventory-II (BDI-II) preliminary psychometric data with two nonclinical samples. *European Journal of Psychological Assessment*, *27*(4), 258–264. <https://doi.org/10.1027/1015-5759/a000072>
- Cecchetto, C., Rumiati, R. I., & Aiello, M. (2017). Alexithymia and emotional reactions to odors. *Scientific Reports*, *7*(1). <https://doi.org/10.1038/s41598-017-14404-x>
- Cohen, N., Henik, A., & Mor, N. (2011). Can emotion modulate attention? Evidence for reciprocal links in the attentional network test. *Experimental Psychology*, *58*(3), 171–179. <https://doi.org/10.1027/1618-3169/a000083>
- Cook, R., Brewer, R., Shah, P., & Bird, G. (2013). Alexithymia, Not Autism, Predicts Poor Recognition of Emotional Facial Expressions. *Psychological Science*, *24*(5), 723–732. <https://doi.org/10.1177/0956797612463582>
- Cools, R., Roberts, A. C., & Robbins, T. W. (2008). Serotonergic regulation of emotional and behavioural control processes. In *Trends in Cognitive Sciences* (Vol. 12, Issue 1, pp. 31–40). <https://doi.org/10.1016/j.tics.2007.10.011>
- Craig, B. M., Chen, N. T. M., & Lipp, O. V. (2022). Featural vs. Holistic processing and visual sampling in the influence of social category cues on emotion recognition. *Cognition and Emotion*. <https://doi.org/10.1080/02699931.2022.2057442>
- Dennis, T. A., & Chen, C. C. (2007). Neurophysiological mechanisms in the emotional modulation of attention: The interplay between threat sensitivity and attentional control. *Biological Psychology*, *76*(1–2), 1–10. <https://doi.org/10.1016/j.biopsycho.2007.05.001>
- Dennis, T. A., Chen, C. C., & McCandliss, B. D. (2008). Threat-related attentional biases: an analysis of three attention systems. *Depression and Anxiety*, *25*(6). <https://doi.org/10.1002/da.20308>
- Derntl, B., Seidel, E. M., Kainz, E., & Carbon, C. C. (2009). Recognition of emotional expressions is affected by inversion and presentation time. *Perception*, *38*(12), 1849–1862. <https://doi.org/10.1068/p6448>
- Dezecache, G., Mercier, H., & Scott-Phillips, T. C. (2013). An evolutionary approach to emotional communication. *Journal of Pragmatics*, *59*, 221–233. <https://doi.org/10.1016/j.pragma.2013.06.007>
- Donges, U. S., & Suslow, T. (2017). Alexithymia and automatic processing of emotional stimuli: A systematic review. *Reviews in the Neurosciences*, *28*(3), 247–264. <https://doi.org/10.1515/revneuro-2016-0049>
- Fan, J., McCandliss, B. D., Sommer, T., Raz, A., & Posner, M. I. (2002). Testing the Efficiency and Independence of Attentional Networks. *Journal of Cognitive Neuroscience*, *14*(3), 340–347. <https://doi.org/10.1162/089892902317361886>

- Farah, M. J., Wilson, K. D., Drain, M., & Tanaka, J. N. (1998). What is “special” about face perception? *Psychological Review*, *105*(3), 482–498. <https://doi.org/10.1037/0033-295X.105.3.482>
- Ferretti, V., & Papaleo, F. (2019). Understanding others: Emotion recognition in humans and other animals. In *Genes, Brain and Behavior* (Vol. 18, Issue 1). Blackwell Publishing Ltd. <https://doi.org/10.1111/gbb.12544>
- Fietz, J., Valencia, N., & Silani, G. (2018). Alexithymia and autistic traits as possible predictors for traits related to depression, anxiety, and stress: A multivariate statistical approach. *Journal of Evaluation in Clinical Practice*, *24*(4), 901–908. <https://doi.org/10.1111/jep.12961>
- Fox, C. J., Moon, S. Y., Iaria, G., & Barton, J. J. S. (2009). The correlates of subjective perception of identity and expression in the face network: An fMRI adaptation study. *NeuroImage*, *44*(2), 569–580. <https://doi.org/10.1016/j.neuroimage.2008.09.011>
- Gallucci, M. (2019). *GAMLj: General analyses for linear models*. <https://gamlj.github.io>
- Ganel, T., Valyear, K. F., Goshen-Gottstein, Y., & Goodale, M. A. (2005). The involvement of the “fusiform face area” in processing facial expression. *Neuropsychologia*, *43*(11), 1645–1654. <https://doi.org/10.1016/j.neuropsychologia.2005.01.012>
- Goerlich, K. S. (2018). The multifaceted nature of alexithymia - A neuroscientific perspective. *Frontiers in Psychology*, *9*(AUG). <https://doi.org/10.3389/fpsyg.2018.01614>
- Goerlich, K. S., Wittman, J., Aleman, A., & Martens, S. (2011). Hearing feelings: Affective categorization of music and speech in Alexithymia, an ERP study. *PLoS ONE*, *6*(5). <https://doi.org/10.1371/journal.pone.0019501>
- Gomes, N., Benrós, M. F., & Semin, G. R. (2024). Validation of the open biological negative image set for a Portuguese population: Comparing Japanese and Portuguese samples and an exploration of low-order visual properties of the stimuli. *Behavior Research Methods*, *56*(2), 860–880. <https://doi.org/10.3758/s13428-023-02090-9>
- González-Garrido, A. A., Ramos-Loyo, J., López-Franco, A. L., & Gómez-Velázquez, F. R. (2009). Visual processing in a facial emotional context: An ERP study. *International Journal of Psychophysiology*, *71*(1), 25–30. <https://doi.org/10.1016/j.ijpsycho.2008.07.017>
- Gray, H. M., & Tickle-Degnen, L. (2010). A meta-analysis of performance on emotion recognition tasks in Parkinson’s disease. *Neuropsychology*, *24*(2), 176–191. <https://doi.org/10.1037/a0018104>
- Gray, K. L. H., Adams, W. J., Hedger, N., Newton, K. E., & Garner, M. (2013). Faces and awareness: Low-level, not emotional factors determine perceptual dominance. *Emotion*, *13*(3), 537–544. <https://doi.org/10.1037/a0031403>
- Grynberg, D., Chang, B., Corneille, O., Maurage, P., Vermeulen, N., Berthoz, S., & Luminet, O. (2012). Alexithymia and the processing of emotional facial expressions (EFEs): Systematic review, unanswered questions and further perspectives. *PLoS ONE*, *7*(8). <https://doi.org/10.1371/journal.pone.0042429>

- Harry, B., Williams, M. A., Davis, C., & Kim, J. (2013). Emotional expressions evoke a differential response in the fusiform face area. *Frontiers in Human Neuroscience, OCT*. <https://doi.org/10.3389/fnhum.2013.00692>
- Haxby, J. V., Hoffman, E. A., & Gobbini, M. I. (2000). The distributed human neural system for face perception. *Trends in Cognitive Sciences, 4*(6), 223–233. [https://doi.org/10.1016/S1364-6613\(00\)01482-0](https://doi.org/10.1016/S1364-6613(00)01482-0)
- Haxby, J. V., Hoffman, E. A., & Gobbini, M. I. (2002). Human Neural Systems for Face Recognition and Social Communication. In *Biol Psychiatry* (Vol. 51).
- Heaton, P., Reichenbacher, L., Sauter, D., Allen, R., Scott, S., & Hill, E. (2012). Measuring the effects of alexithymia on perception of emotional vocalizations in autistic spectrum disorder and typical development. *Psychological Medicine, 42*(11), 2453–2459. <https://doi.org/10.1017/S0033291712000621>
- Heinzel, A., Schäfer, R., Müller, H. W., Schieffer, A., Ingenhag, A., Eickhoff, S. B., Northoff, G., Franz, M., & Hautzel, H. (2010). Increased activation of the supragenual anterior cingulate cortex during visual emotional processing in male subjects with high degrees of alexithymia: An event-related fMRI study. *Psychotherapy and Psychosomatics, 79*(6), 363–370. <https://doi.org/10.1159/000320121>
- Honkalampi, K., Hintikka, J., Laukkanen, E., & Viinamäki, J. L. H. (2001a). Alexithymia and depression: A prospective study of patients with major depressive disorder. *Psychosomatics, 42*(3), 229–234. <https://doi.org/10.1176/APPI.PSY.42.3.229>
- Honkalampi, K., Hintikka, J., Laukkanen, E., & Viinamäki, J. L. H. (2001b). Alexithymia and depression: A prospective study of patients with major depressive disorder. *Psychosomatics, 42*(3), 229–234. <https://doi.org/10.1176/appi.psy.42.3.229>
- Honkalampi, K., Koivumaa-Honkanen, H., Tanskanen, A., Hintikka, J., Lehtonen, J., & Viinamäki, H. (2001). Why Do Alexithymic Features Appear to Be Stable? A 12-Month Follow-Up Study of a General Population. In *Regular Article Psychother Psychosom* (Vol. 70).
- Ihme, K., Sacher, J., Lichev, V., Rosenberg, N., Kugel, H., Rufer, M., Grabe, H. J., Pampel, A., Lepsien, J., Kersting, A., Villringer, A., Lane, R. D., & Suslow, T. (2014a). Alexithymic features and the labeling of brief emotional facial expressions - An fMRI study. *Neuropsychologia, 64*, 289–299. <https://doi.org/10.1016/j.neuropsychologia.2014.09.044>
- Ihme, K., Sacher, J., Lichev, V., Rosenberg, N., Kugel, H., Rufer, M., Grabe, H. J., Pampel, A., Lepsien, J., Kersting, A., Villringer, A., Lane, R. D., & Suslow, T. (2014b). Alexithymic features and the labeling of brief emotional facial expressions - An fMRI study. *Neuropsychologia, 64*, 289–299. <https://doi.org/10.1016/j.neuropsychologia.2014.09.044>
- Iosifyan, M., & Korolkova, O. (2019). Emotions associated with different textures during touch. *Consciousness and Cognition, 71*, 79–85. <https://doi.org/10.1016/j.concog.2019.03.012>

- Jack, R. E., Blais, C., Scheepers, C., Schyns, P. G., & Caldara, R. (2009). Cultural Confusions Show that Facial Expressions Are Not Universal. *Current Biology*, *19*(18), 1543–1548. <https://doi.org/10.1016/j.cub.2009.07.051>
- Jørgensen, M. M., Zachariae, R., Skytthe, A., & Kyvik, K. (2007). Genetic and environmental factors in alexithymia: A population-based study of 8,785 Danish twin pairs. *Psychotherapy and Psychosomatics*, *76*(6), 369–375. <https://doi.org/10.1159/000107565>
- Juth, P., Lundqvist, D., Karlsson, A., & Öhman, A. (2005). Looking for foes and friends: Perceptual and emotional factors when finding a face in the crowd. *Emotion*, *5*(4), 379–395. <https://doi.org/10.1037/1528-3542.5.4.379>
- Kano, M., & Fukudo, S. (2013). The alexithymic brain: The neural pathways linking alexithymia to physical disorders. In *BioPsychoSocial Medicine* (Vol. 7, Issue 1). <https://doi.org/10.1186/1751-0759-7-1>
- Kano, M., Fukudo, S., Gyoba, J., Kamachi, M., Tagawa, M., Mochizuki, H., Itoh, M., Hongo, M., & Yanai, K. (2003). Specific brain processing of facial expressions in people with alexithymia: An H215O-PET study. *Brain*, *126*(6), 1474–1484. <https://doi.org/10.1093/brain/awg131>
- Kano, M., Mizuno, T., Kawano, Y., Aoki, M., Kanazawa, M., & Fukudo, S. (2012). Serotonin transporter gene promoter polymorphism and alexithymia. *Neuropsychobiology*, *65*(2), 76–82. <https://doi.org/10.1159/000329554>
- Kätsyri, J., Saalasti, S., Tiippana, K., von Wendt, L., & Sams, M. (2008). Impaired recognition of facial emotions from low-spatial frequencies in Asperger syndrome. *Neuropsychologia*, *46*(7), 1888–1897. <https://doi.org/10.1016/j.neuropsychologia.2008.01.005>
- Kawasaki, H., Tsuchiya, N., Kovach, C. K., Nourski, K. V., Oya, H., Howard, M. A., & Adolphs, R. (2012). Processing of Facial Emotion in the Human Fusiform Gyrus. *Journal of Cognitive Neuroscience*, *24*(6), 1358–1370. https://doi.org/10.1162/jocn_a_00175
- Koelsch, S., Skouras, S., & Lohmann, G. (2018). The auditory cortex hosts network nodes influential for emotion processing: An fMRI study on music-evoked fear and joy. *PLoS ONE*, *13*(1). <https://doi.org/10.1371/journal.pone.0190057>
- Kohler, C. G., Bilker, W., Hagendoorn, M., Gur, R. E., & Gur, R. C. (2000). Emotion Recognition Deficit in Schizophrenia: Association with Symptomatology and Cognition. In *Biol Psychiatry* (Vol. 48).
- Kret, M. E., Prochazkova, E., Sterck, E. H. M., & Clay, Z. (2020). Emotional expressions in human and non-human great apes. In *Neuroscience and Biobehavioral Reviews* (Vol. 115, pp. 378–395). Elsevier Ltd. <https://doi.org/10.1016/j.neubiorev.2020.01.027>
- Krystal, H. (1979). Alexithymia and Psychotherapy. *American Journal of Psychotherapy*, *33*(1), 17–31. <https://doi.org/10.1176/appi.psychotherapy.1979.33.1.17>
- Kugel, H., Eichmann, M., Dannlowski, U., Ohrmann, P., Bauer, J., Arolt, V., Heindel, W., & Suslow, T. (2008). Alexithymic features and automatic amygdala reactivity to facial

- emotion. *Neuroscience Letters*, 435(1), 40–44.
<https://doi.org/10.1016/j.neulet.2008.02.005>
- Laidre, M. E., & Johnstone, R. A. (2013). Animal signals. *Current Biology*, 23(18), R829–R833. <https://doi.org/10.1016/j.cub.2013.07.070>
- Lane, R. D., Lee, S., Reidel, R., Weldon, V., Kaszniak, A., & Schwartz, G. E. (1996). Impaired Verbal and Nonverbal Emotion Recognition in Alexithymia. *Psychosomatic Medicine*, 58(3), 203–210. <https://doi.org/10.1097/00006842-199605000-00002>
- Langner, O., Dotsch, R., Bijlstra, G., Wigboldus, D. H. J., Hawk, S. T., & van Knippenberg, A. (2010). Presentation and validation of the radboud faces database. *Cognition and Emotion*, 24(8), 1377–1388. <https://doi.org/10.1080/02699930903485076>
- Lee, J. K. W., Janssen, S. M. J., & Estudillo, A. J. (2022). A featural account for own-face processing? Looking for support from face inversion, composite face, and part-whole tasks. *I-Perception*, 13(4). <https://doi.org/10.1177/20416695221111409>
- Luminet, O., Nielson, K. A., & Ridout, N. (2021). Having no words for feelings: alexithymia as a fundamental personality dimension at the interface of cognition and emotion. In *Cognition and Emotion* (Vol. 35, Issue 3, pp. 435–448). Routledge.
<https://doi.org/10.1080/02699931.2021.1916442>
- Ma, D. S., Correll, J., & Wittenbrink, B. (2015). The Chicago face database: A free stimulus set of faces and norming data. *Behavior Research Methods*, 47(4), 1122–1135.
<https://doi.org/10.3758/s13428-014-0532-5>
- Mantani, T., Okamoto, Y., Shirao, N., Okada, G., & Yamawaki, S. (2005). Reduced activation of posterior cingulate cortex during imagery in subjects with high degrees of alexithymia: A functional magnetic resonance imaging study. *Biological Psychiatry*, 57(9), 982–990. <https://doi.org/10.1016/j.biopsych.2005.01.047>
- Matsusaka, T. (2004). When does play panting occur during social play in wild chimpanzees? *Primates*, 45(4), 221–229. <https://doi.org/10.1007/s10329-004-0090-z>
- Michael Bagby, R., Taylor, G. J., & Parkers, J. D. A. (1994). *THE TWENTY-ITEM TORONTO ALEXITHYMIA SCALE-II. CONVERGENT, DISCRIMINANT, AND CONCURRENT VALIDITY* (Vol. 38, Issue 1).
- Montebarocci, O., Montebarocci, O., Codispoti, M., Surcinelli, P., Franzoni, E., Baldaro, B., & Rossi, N. (2006). *Alexithymia in female patients with eating disorders* (Vol. 11).
- Montebarocci, O., Surcinelli, P., Rossi, N., & Baldaro, B. (2011). Alexithymia, verbal ability and emotion recognition. *Psychiatric Quarterly*, 82(3), 245–252.
<https://doi.org/10.1007/s11126-010-9166-7>
- Moriguchi, Y., & Komaki, G. (2013). Neuroimaging studies of alexithymia: Physical, affective, and social perspectives. In *BioPsychoSocial Medicine* (Vol. 7, Issue 1).
<https://doi.org/10.1186/1751-0759-7-8>
- Negrini, M., Brkic, D., Pizzamiglio, S., Premoli, I., & Rivolta, D. (2017). Neurophysiological correlates of featural and spacing processing for face and non-face stimuli. *Frontiers in Psychology*, 8(MAR). <https://doi.org/10.3389/fpsyg.2017.00333>

- Noden, D. M., & Francis-West, P. (2006). The differentiation and morphogenesis of craniofacial muscles. In *Developmental Dynamics* (Vol. 235, Issue 5, pp. 1194–1218). <https://doi.org/10.1002/dvdy.20697>
- Nowakowski, M. E., McFarlane, T., & Cassin, S. (2013). Alexithymia and eating disorders: a critical review of the literature. *Journal of Eating Disorders, 1*(1), 21. <https://doi.org/10.1186/2050-2974-1-21>
- Oathes, D. J., Ray, W. J., Yamasaki, A. S., Borkovec, T. D., Castonguay, L. G., Newman, M. G., & Nitschke, J. (2008). Worry, generalized anxiety disorder, and emotion: Evidence from the EEG gamma band. *Biological Psychology, 79*(2), 165–170. <https://doi.org/10.1016/j.biopsycho.2008.04.005>
- Özsoy-ünübol, T., Kullakçı, H., İlhan, İ., & Yilmaz, F. (2020). Evaluation of olfactory and gustatory functions in patients with fibromyalgia syndrome: Its relationship with anxiety, depression, and alexithymia. *Archives of Rheumatology, 35*(4), 584–591. <https://doi.org/10.46497/ArchRheumatol.2020.7833>
- Palermo, R., & Rhodes, G. (2007). Are you always on my mind? A review of how face perception and attention interact. *Neuropsychologia, 45*(1), 75–92. <https://doi.org/10.1016/j.neuropsychologia.2006.04.025>
- Pandey, R., & Mandal, M. K. (1997). Processing of facial expressions of emotion and alexithymia. *British Journal of Clinical Psychology, 36*(4), 631–633. <https://doi.org/10.1111/j.2044-8260.1997.tb01269.x>
- Panksepp, J., & Burgdorf, J. (2003). “Laughing” rats and the evolutionary antecedents of human joy? *Physiology and Behavior, 79*(3), 533–547. [https://doi.org/10.1016/S0031-9384\(03\)00159-8](https://doi.org/10.1016/S0031-9384(03)00159-8)
- Parker, P. D., Prkachin, K. M., & Prkachin, G. C. (2005). Processing of facial expressions of negative emotion in alexithymia: The influence of temporal constraint. *Journal of Personality, 73*(4), 1087–1107. <https://doi.org/10.1111/j.1467-6494.2005.00339.x>
- Parr, L. A., Heintz, M., & Akamagwuna, U. (2006). Three studies on configural face processing by chimpanzees. *Brain and Cognition, 62*(1), 30–42. <https://doi.org/10.1016/j.bandc.2006.03.006>
- Parr, L. A., Waller, B. M., & Fugate, J. (2005). Emotional communication in primates: Implications for neurobiology. In *Current Opinion in Neurobiology* (Vol. 15, Issue 6, pp. 716–720). <https://doi.org/10.1016/j.conb.2005.10.017>
- Peasley-Miklus, C. E., Panayiotou, G., & Vrana, S. R. (2016). Alexithymia predicts arousal-based processing deficits and discordance between emotion response systems during emotional imagery. *Emotion, 16*(2), 164–174. <https://doi.org/10.1037/emo0000086>
- Praceres, N., Parker -J, -D A, Taylor, J., Resumo, G., & Chave, P. (2000). *Adaptação Portuguesa da Escala de Alexitimia de* (Vol. 9).

- Preuschoft, S., & van Hooff, J. A. R. A. M. (1995). Homologizing Primate Facial Displays: A Critical Review of Methods. *Folia Primatologica*, *65*(3), 121–137. <https://doi.org/10.1159/000156878>
- Prkachin, G. C. (2003a). The effects of orientation on detection and identification of facial expressions of emotion. *British Journal of Psychology*, *94*(1), 45–62. <https://doi.org/10.1348/000712603762842093>
- Prkachin, G. C. (2003b). The effects of orientation on detection and identification of facial expressions of emotion. *British Journal of Psychology*, *94*(1), 45–62. <https://doi.org/10.1348/000712603762842093>
- Prkachin, G. C., Casey, C., & Prkachin, K. M. (2009). Alexithymia and perception of facial expressions of emotion. *Personality and Individual Differences*, *46*(4), 412–417. <https://doi.org/10.1016/j.paid.2008.11.010>
- Ravaja, N., Harjunen, V., Ahmed, I., Jacucci, G., & Spapé, M. M. (2017). Feeling Touched: Emotional Modulation of Somatosensory Potentials to Interpersonal Touch. *Scientific Reports*, *7*. <https://doi.org/10.1038/srep40504>
- Ree, M. J., French, D., MacLeod, C., & Locke, V. (2008). Distinguishing cognitive and somatic dimensions of state and trait anxiety: Development and validation of the State-Trait Inventory for Cognitive and Somatic Anxiety (STICSA). *Behavioural and Cognitive Psychotherapy*, *36*(3), 313–332. <https://doi.org/10.1017/S1352465808004232>
- Reid, V. M., Dunn, K., Young, R. J., Amu, J., Donovan, T., & Reissland, N. (2017). The Human Fetus Preferentially Engages with Face-like Visual Stimuli. *Current Biology*, *27*(12), 1825–1828.e3. <https://doi.org/10.1016/j.cub.2017.05.044>
- Reker, M., Ohrmann, P., Rauch, A. V., Kugel, H., Bauer, J., Dannlowski, U., Arolt, V., Heindel, W., & Suslow, T. (2010). Individual differences in alexithymia and brain response to masked emotion faces. *Cortex*, *46*(5), 658–667. <https://doi.org/10.1016/j.cortex.2009.05.008>
- Robbins, R., & McKone, E. (2003). Can holistic processing be learned for inverted faces? *Cognition*, *88*(1), 79–107. [https://doi.org/10.1016/S0010-0277\(03\)00020-9](https://doi.org/10.1016/S0010-0277(03)00020-9)
- Robino, A., Mezzavilla, M., Pirastu, N., La Bianca, M., Gasparini, P., Carlino, D., & Tepper, B. J. (2016). Understanding the role of personality and alexithymia in food preferences and PROP taste perception. *Physiology and Behavior*, *157*, 72–78. <https://doi.org/10.1016/j.physbeh.2016.01.022>
- Rosenberg, N., Ihme, K., Lichev, V., Sacher, J., Rufer, M., Grabe, H. J., Kugel, H., Pampel, A., Lepsien, J., Kersting, A., Villringer, A., & Suslow, T. (2020). Alexithymia and automatic processing of facial emotions: Behavioral and neural findings. *BMC Neuroscience*, *21*(1). <https://doi.org/10.1186/s12868-020-00572-6>
- Ross, C. F. (2000). Into the Light: The Origin of Anthropeida. *Annual Review of Anthropology*, *29*(1), 147–194. <https://doi.org/10.1146/annurev.anthro.29.1.147>
- Sadr, J., & Sinha, P. (2004). Object recognition and Random Image Structure Evolution. *Cognitive Science*, *28*(2), 259–287. <https://doi.org/10.1016/j.cogsci.2003.09.003>

- Salminen, J. K., Saarijärvi, S., Toikka, T., Kauhanen, J., & Äärelä, E. (2006). Alexithymia behaves as a personality trait over a 5-year period in Finnish general population. *Journal of Psychosomatic Research*, *61*(2), 275–278. <https://doi.org/10.1016/j.jpsychores.2006.01.014>
- Schindler, S., & Bublatzky, F. (2020). Attention and emotion: An integrative review of emotional face processing as a function of attention. In *Cortex* (Vol. 130, pp. 362–386). Masson SpA. <https://doi.org/10.1016/j.cortex.2020.06.010>
- Schmidt, K. L., & Cohn, J. F. (2001). Human facial expressions as adaptations: Evolutionary questions in facial expression research. *Yearbook of Physical Anthropology*, *44*, 3–24. <https://doi.org/10.1002/ajpa.20001>
- Scott-Phillips, T. C. (2008). Defining biological communication. In *Journal of Evolutionary Biology* (Vol. 21, Issue 2, pp. 387–395). <https://doi.org/10.1111/j.1420-9101.2007.01497.x>
- Sherwood, C. C., Hof, P. R., Holloway, R. L., Samendeferi, K., Gannon, P. J., Frahm, H. D., & Zilles, K. (2005). Evolution of the brainstem orofacial motor system in primates: A comparative study of trigeminal, facial, and hypoglossal nuclei. *Journal of Human Evolution*, *48*(1), 45–84. <https://doi.org/10.1016/j.jhevol.2004.10.003>
- Sifneos, P. E. (1973). The Prevalence of ‘Alexithymic’ Characteristics in Psychosomatic Patients. *Psychotherapy and Psychosomatics*, *22*(2–6), 255–262. <https://doi.org/10.1159/000286529>
- Soudry, Y., Lemogne, C., Malinvaud, D., Consoli, S. M., & Bonfils, P. (2011). Olfactory system and emotion: Common substrates. In *European Annals of Otorhinolaryngology, Head and Neck Diseases* (Vol. 128, Issue 1, pp. 18–23). Elsevier Masson SAS. <https://doi.org/10.1016/j.anorl.2010.09.007>
- Speranza, M., Loas, G., Wallier, J., & Corcos, M. (2007). Predictive value of alexithymia in patients with eating disorders: A 3-year prospective study. *Journal of Psychosomatic Research*, *63*(4), 365–371. <https://doi.org/10.1016/j.jpsychores.2007.03.008>
- Suslow, T., & Kersting, A. (2021). Beyond Face and Voice: A Review of Alexithymia and Emotion Perception in Music, Odor, Taste, and Touch. In *Frontiers in Psychology* (Vol. 12). Frontiers Media S.A. <https://doi.org/10.3389/fpsyg.2021.707599>
- Suslow, T., Kersting, A., & Bodenschatz, C. M. (2024). Dimensions of Alexithymia and Identification of Emotions in Masked and Unmasked Faces. *Behavioral Sciences*, *14*(8). <https://doi.org/10.3390/bs14080692>
- Tanaka, J. W. (2001). The entry point of face recognition: Evidence for face expertise. *Journal of Experimental Psychology: General*, *130*(3), 534–543. <https://doi.org/10.1037/0096-3445.130.3.534>
- Tanaka, J. W., & Farah, M. J. (1993a). Parts and Wholes in Face Recognition. *The Quarterly Journal of Experimental Psychology Section A*, *46*(2), 225–245. <https://doi.org/10.1080/14640749308401045>

- Tanaka, J. W., & Farah, M. J. (1993b). Parts and Wholes in Face Recognition. *The Quarterly Journal of Experimental Psychology Section A*, *46*(2), 225–245. <https://doi.org/10.1080/14640749308401045>
- The Jamovi project. (2019). *jamovi* (version 1.0). <https://www.jamovi.org>
- Tooby, J., & Cosmides, L. (1990). The past explains the present. *Ethology and Sociobiology*, *11*(4–5), 375–424. [https://doi.org/10.1016/0162-3095\(90\)90017-Z](https://doi.org/10.1016/0162-3095(90)90017-Z)
- Van der Velde, J., Servaas, M. N., Goerlich, K. S., Bruggeman, R., Horton, P., Costafreda, S. G., & Aleman, A. (2013). Neural correlates of alexithymia: A meta-analysis of emotion processing studies. In *Neuroscience and Biobehavioral Reviews* (Vol. 37, Issue 8, pp. 1774–1785). <https://doi.org/10.1016/j.neubiorev.2013.07.008>
- Veres-Injac, B., & Schwaninger, A. (2009). The time course of processing external and internal features of unfamiliar faces. *Psychological Research*, *73*(1), 43–53. <https://doi.org/10.1007/s00426-008-0147-5>
- Vermeulen, N., Luminet, O., & Corneille, O. (2006). Alexithymia and the automatic processing of affective information: Evidence from the affective priming paradigm. *Cognition and Emotion*, *20*(1), 64–91. <https://doi.org/10.1080/02699930500304654>
- Vuilleumier, P., & Schwartz, S. (2001). Emotional facial expressions capture attention. *Neurology*, *56*(2), 153–158. <https://doi.org/10.1212/WNL.56.2.153>
- Wang, Z., Goerlich, K. S., Luo, Y. J., Xu, P., & Aleman, A. (2022a). Social-specific impairment of negative emotion perception in alexithymia. *Social Cognitive and Affective Neuroscience*, *17*(4), 387–397. <https://doi.org/10.1093/scan/nsab099>
- Wang, Z., Goerlich, K. S., Luo, Y. J., Xu, P., & Aleman, A. (2022b). Social-specific impairment of negative emotion perception in alexithymia. *Social Cognitive and Affective Neuroscience*, *17*(4), 387–397. <https://doi.org/10.1093/scan/nsab099>
- Wearden, A., Cook, L., & Vaughan-Jones, J. (2003). Adult attachment, alexithymia, symptom reporting, and health-related coping. *Journal of Psychosomatic Research*, *55*(4), 341–347. [https://doi.org/10.1016/S0022-3999\(02\)00635-9](https://doi.org/10.1016/S0022-3999(02)00635-9)
- Wegrzyn, M., Riehle, M., Labudda, K., Woermann, F., Baumgartner, F., Pollmann, S., Bien, C. G., & Kissler, J. (2015). Investigating the brain basis of facial expression perception using multi-voxel pattern analysis. *Cortex*, *69*, 131–140. <https://doi.org/10.1016/j.cortex.2015.05.003>
- Willenbockel, V., Sadr, J., Fiset, D., Horne, G. O., Gosselin, F., & Tanaka, J. W. (2010). Controlling low-level image properties: The SHINE toolbox. *Behavior Research Methods*, *42*(3), 671–684. <https://doi.org/10.3758/BRM.42.3.671>
- Yeung, M. K. (2022). A systematic review and meta-analysis of facial emotion recognition in autism spectrum disorder: The specificity of deficits and the role of task characteristics. *Neuroscience & Biobehavioral Reviews*, *133*, 104518. <https://doi.org/10.1016/J.NEUBIOREV.2021.104518>
- Yin, R. K. (1969). Looking at upside-down faces. *Journal of Experimental Psychology*, *81*(1), 141–145. <https://doi.org/10.1037/H0027474>

Young, A. W., Hellawell, D., & Hay, D. C. (2013). Configurational Information in Face Perception. *Perception*, 42(11), 1166–1178. <https://doi.org/10.1068/p160747n>