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Communicative intentions processing in Autism Spectrum Disorder: Behavioral and Neural Correlates.

[Behawioralne i neuronalne korelaty rozpoznawania intencji komunikacyjnych u osób z zaburzeniami ze spektrum autyzmu.]

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Contributions

The analyses presented in the thesis were based on the data collected in the following projects:

Project 1: From biological motion processing to theory of mind - neural and behavioural correlates of social cognitive deficits in individuals with autism spectrum disorders. [2018/31/N/HS6/03757, P.I. Małgorzata Krawczyk]

Project 2: The role of brain networks in social information processing in schizophrenia - an investigation with multimodal brain imaging (EEG/fMRI) and neuromodulation (tDCS/EEG) methods. [2016/23/D/HS6/02947, P.I: dr hab. Łukasz Okruszek, prof. IP PAN]

Małgorzata Krawczyk - Conceptualization, Methodology, Formal Analysis, Investigation - Behavioral and Neuroimaging Assessment (individuals with ASD and TD participants, part of the group of patients with schizophrenia), Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization, Project Administration (Project 1), Funding Acquisition (Project 1).

Łukasz Okruszek - Conceptualization, Methodology, Software, Formal Analysis, Data Curation, Writing - Review & Editing, Supervision, Project Administration (Project 2), Funding Acquisition (Project 2).

Michał Jarkiewicz - Investigation - Clinical Assessment

Karolina Golec-Staśkiewicz - Investigation - Clinical Assessment

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Streszczenie

Zaburzenia poznania społecznego uznawane są za kluczowy element fenotypu nie tylko w przypadku autyzmu, ale także w odniesieniu do innych zaburzeń neurorozwojowych, w tym schizofrenii. Mimo udowodnionych podobieństw w trudnościach w zakresie przetwarzania informacji społecznych w obu grupach klinicznych, rozpoznawanie intencji na podstawie obserwacji ruchu biologicznego nie zostało dotychczas w tym kontekście dogłębnie zbadane. Poniższy projekt badawczy miał na celu analizę behawioralnych i neuronalnych korelatów rozpoznawania intencji komunikacyjnych u osób ze spektrum autyzmu, w zakresie ich behawioralnych i neuronalnych korelatów oraz specyficzności na tle zaburzeń obserwowanych w innej grupie klinicznej. W celu zaadresowania postawionych pytań badawczych, do analizy włączono dane pochodzące z dwóch projektów dotyczących poznania społecznego w autyzmie [2018/31/N/HS6/03757] i schizofrenii [2016/23/D/HS6/02947]. Analiza danych behawioralnych obejmowała 29 osób ze spektrum autyzmu (ASD), 29 typowo rozwijających się osób (TD) oraz 53 osoby z diagnozą schizofrenii (SCZ). Analiza neuroobrazowa obejmowała dane strukturalne (sMRI) i funkcjonalne (fMRI) pochodzące od 42 dopasowanych demograficznie uczestników (21 ASD oraz 21 TD). Zastosowano paradygmaty mierzące rozpoznawanie intencji komunikacyjnych w oparciu o gesty wykonywane przez jedną lub dwie osoby, prezentowane przy użyciu ruchu punktów świetlnych. Dodatkowo włączono dwie baterie testów mierzących funkcjonowanie poznawcze oraz społeczno-poznawcze.

Rozdziały od 1. do 3. zawierają wprowadzenie teoretyczne oraz uzasadnienie dla prezentowanego programu badawczego. Omówiono kluczowe aspekty poznania społecznego i rozpoznawania intencji komunikacyjnych **(Rozdział 1.)**, oraz trudności w tym zakresie obserwowane u osób z autyzmem **(Rozdział 2.)**, a także specyficzność tych

mechanizmów w odniesieniu do osób ze schizofrenią **(Rozdział 3.)**. **Rozdział 4.** przedstawia główne cele projektu badawczego i pytania badawcze wraz z hipotezami. W dalszej części rozdziału omówiono kluczowe aspekty zastosowanej metodologii i schematu badawczego. W **Rozdziale 5.** porównano rozpoznawanie intencji komunikacyjnych w grupach ASD i TD. U osób z autyzmem w porównaniu do osób typowo rozwijających się zaobserwowano trudności w zakresie przetwarzania intencji komunikacyjnych na podstawie ruchu biologicznego, którym nie towarzyszyły różnice międzygrupowe w zakresie funkcjonowania poznawczego i społeczno poznawczego. W **Rozdziale 6.** porównano zniekształcenia społeczno poznawcze u osób z grupy ASD i TD. W porównaniu do grupy kontrolnej, osoby z autyzmem prezentowały wyższy poziom zniekształceń w metodach samoopisowych, ale nie w miarach wykonaniowych. **Rozdział 7.** omawia wyniki analizy danych sMRI i fMRI. Nie zaobserwowano różnic między osobami ASD i TD w zakresie budowy anatomicznej oraz aktywności sieci percepcji społecznej, przetwarzania emocjonalnego oraz teorii umysłu podczas przetwarzania intencji komunikacyjnych. W **Rozdziale 8.** porównano rozpoznawanie intencji komunikacyjnych w grupach ASD i SCZ. Podobnie jak osoby z autyzmem, osoby ze schizofrenią wykazywały trudności w rozpoznawaniu gestów komunikacyjnych, którym dodatkowo towarzyszyło obniżone funkcjonowanie społeczno-poznawcze. Omówienie i dyskusję otrzymanych wyników zaprezentowano w **Rozdziale 9.**

Podsumowując, otrzymane wyniki wskazywać mogą na trudności w rozpoznawaniu intencji komunikacyjnych zarówno u osób z autyzmem, jak i u osób ze schizofrenią, co może stanowić jeden z czynników prowadzących do obniżonego funkcjonowania społecznego. Dalsze badania w tym zakresie mogą pozwolić na dogłębną analizę mechanizmów prowadzących do zaobserwowanych trudności

Abstract

Social cognition (SC) has been extensively studied with regard to both non-clinical and psychiatric populations. It was repeatedly presented that overlapping SC difficulties are part of the phenotype in autism, but also other neurodevelopmental disorders, including schizophrenia. However, less is known about difficulties in recognition of intentional communicative cues from the biological motion in the neurodevelopmental conditions, which is considered as a crucial prerequisite for other SC abilities, including theory of mind.

Hence, the presented research project was focused on investigating behavioral and neural correlates of intentional cues recognition from biological motion (BM) in people with autism and, in the broader context, of the neurodiversity spectrum. To address this issue, we used data from two projects on social cognitive functioning in autism [2018/31/N/HS6/03757] and schizophrenia [2016/23/D/HS6/02947]. Behavioral analysis included 29 participants with autism (ASD), 29 typically developing participants (TD), and 53 participants with schizophrenia (SCZ). Analysis of data from structural (sMRI) and functional (fMRI) magnetic resonance imaging included data from 42 matched head-to-head participants (21 ASD and 21 TD).

To investigate differences in communicative intention recognition, single-agent and dyadic point-light display paradigms were used along with two batteries of social cognitive and neurocognitive tasks. In **Chapters 1. to 3.,** a theoretical introduction into the main concepts discussed in the study and a rationale for the research programme were presented. **Chapter 1.** reviews general aspects of social cognition and communicative intention processing on the behavioral, and on the neural level. **In Chapter 2.,** a review of behavioral and neural aspects of social cognition and communicative intention recognition in autism is presented. The specificity of these difficulties is discussed in **Chapter 3.**, which compares

social cognitive abilities in autism and schizophrenia, with a main focus on communicative intention recognition. **Chapter 4.** includes an overview of main research goals and questions, along with hypotheses and a general overview of the research design and methodology. Analysis of the differences in communicative intention recognition from BM is presented in **Chapter 5.** Decreased performance on the point light walker (PLW) measures was observed in people with ASD, despite no differences in the social and neurocognition. **Chapter 6.** included the analysis of social cognitive bias in autism. Compared to the TD group, individuals with ASD presented a heightened level of social cognitive bias on self-report, but not vignette-based and performance-based measures. **Chapter 7.** presents the analysis of sMRI and fMRI data. No differences between ASD and TD groups were observed within the neural circuits engaged in social perception, emotional processing and mentalizing, with regard to communicative intention processing. Differences in communicative intention recognition between individuals with ASD and SCZ were analyzed in **Chapter 8**. Both groups presented a decreased performance in BM measures of intention recognition, although only SCZ individuals presented a lower level of overall social cognitive and neurocognitive functioning compared to the ASD group. Overview of the obtained results followed by a general discussion is included in **Chapter 9**.

With all things considered, our results point toward possible difficulties in communicative intention recognition in both autism and schizophrenia. Thus, while abnormalities of intention processing might be an important feature leading to social functioning difficulties across the neurodiversity spectrum, more research is needed to disentangle specific underlying mechanisms.

Chapter 1. Social Cognition

To successfully navigate a complex social environment, humans had to develop a unique set of predispositions that allowed us to detect, evaluate and adjust our behavior based on a constant stream of social information, commonly referred to as "social cognition" (SC; Adolphs, 2009). Within a social neuroscience scope, social cognitive abilities are organized hierarchically, from basic social perception to high-level, computationally demanding operations, including processes like simple detection of agency from moving objects, emotion recognition and theory of mind (Ochsner, 2008; Schurz et al., 2021). Crucially, all these abilities require "understanding conspecifics as being like themselves, who have intentional and mental lives like their own" (Adolphs, 2009) and this realization is sometimes regarded as an initial step of social information processing.

Importantly, neural circuits dedicated for social cognitive abilities are partially separable from the ones associated with neurocognitive abilities, which are nonspecific to the social realm (e.g. attention, memory, executive function). For instance, the default mode network (DMN) has been shown to deactivate when the complex non-social task has to be completed as its activity disrupts the processing of non-social information (Menon, 2023). At the same time, DMN has been closely related to the mentalizing and introspection processes (Nair et al., 2020). For this reason, social cognition is usually considered as partially separate from neurocognition, although these two domains are not completely disjointed and some social cognitive processes rely upon domain-general skills, including attentional modulation, or information encoding, storage and retrieval (Green et al., 2015). Similarly, studies with neuropsychiatric populations confirm the partial independence of social and neurocognition. For instance, focal brain injuries might result in social cognitive deficits irrespective of neurocognitive impairments (Spikman et al., 2011). Accordingly,

research on schizophrenia confirmed that social cognitive and neurocognitive abilities should be modelled as two distinctive factors that explain different aspects of a functional outcome (Allen et al., 2007). Moreover, double dissociation between social and nonsocial cognition has been described in research comparing different neurodevelopmental syndromes - while some people with autism and high level of cognitive resources can still experience major social cognitive difficulties, individuals with William's syndrome present normal, or even heightened level of social cognitive skills ("hypersociability" phenomenon) despite intellectual impairment (Tager-Flusberg et al., 2006). It can then be concluded that information of social character, because of their fundamental value, are processed differently than other types of information, with the engagement of specialized mechanisms (Ochsner & Lieberman, 2001).

Although the modularity of social cognition is an object of ongoing debate, most of the authors postulate some degree of functional specialization, with neural circuits dedicated for low-level social cues recognition and higher-level mental state inferences (Green, Lee & Ochsner, 2013). According to a National Institute of Mental Health (NIMH) classification, four main domains of social cognition can be distinguished, namely: social perception, emotional processing, theory of mind and social cognitive bias (Green et al., 2008; Pinkham et al., 2018). A further exploration of a factor structure of social cognition in schizophrenia suggested that these skills might be additionally divided into social cognitive skill or capacity (social perception, emotional processing, theory of mind), which refer to objective aspects of social cognition and subjective social cognitive bias (Buck et al., 2016a).

1.1. Biological Motion As a Prerequisite For Social Perception

Social perception may be defined as a process of recognizing and choosing relevant multi-modal cues in order to identify crucial social information (Pelphrey et al., 2004; Rutherford & Kuhleimer, 2013). Although many types of external information might work in a way that grabs our attention, cues signalling animacy and agency in other living beings are among the most effective ones (Rutherford & Kuhleimer, 2013). Essentially, based on some specific characteristics, we must decide that actions of other agents are not random and driven only by external factors, but rather purposeful and intentional - caused by some internal, even the most basic mechanism (Friston, 2010). This mechanism is probably reflexive, adaptive and can be found in all social species, as animated "others" could be "prey, predators or mates" (Schultz et al., 2005). As it was presented in a seminal study by Heider and Simmel (1944), minimal demands have to be met before we proclaim observed actions as intentional and goal-directed, and complex internal states can be assigned to geometrical shapes moving in a coordinated way, even when no contextual information is provided.

The most basic social cue that can reliably turn on our animacy detector is an easily distinguishable pattern of movement. While it is still not clear, what type of information contained in the movement leads us to perceive it as animated, self-propulsion and interactivity are probably among the most reliable cues (Di Giorgio et al., 2017).

Accordingly, it has been postulated that the ability to detect and process social cues from biological motion constitutes our earliest social adaptation (Pavlova, 2012). Biological motion can be defined as an autonomous movement of animate beings (Happé et al., 2017) and is typically studied with some variations of point-light walker paradigms (PLW; Johansson, 1973). A typical PLW paradigm contains an agent presented with the movement

of point-lights located in the area of principal joints in the human body (Rutherford & Kuhleimer, 2013). Importantly, even this seemingly simple ability can be further divided into few stages of processing with increasing levels of complexity, from a basic "life detection" that redirects our attention to a moving, potentially salient object to recognition of a coherent body and its complex dispositions from a pattern of point-light movement (Troje, 2008). It has been shown that adult individuals are proficient in extracting simple perceptual information from the movement of point-light walkers embedded in a noise, or in differentiating a scrambled from untouched biological motion (Rutherford & Kuhleimer, 2013). Moreover, because the preference for simple upright biological motion patterns was observed in 2-days newborns (Simion et al., 2008) and in simpler organisms including newly-hatched chicks (Vallortigara, Regolin & Marconato, 2005), it was proposed that biological motion perception serves as an innate mechanism that makes a ground for social cognitive abilities developing later in life (Pavlova, 2012).

1.2. Emotional Processing

The ability to correctly identify emotional stimuli and use them in an adaptive manner is another pillar of social cognitive functioning (Ochsner, 2008; Palomero-Gallagher & Amunts, 2022). Basic emotion recognition is commonly studied with static photographs or dynamic reproductions presenting different facial affective expressions (Ferretti & Papaleo, 2019). Importantly, typical adult participants are proficient in recognition of basic facial expressions of emotions, including anger, fear, happiness or sadness (Sasson et al., 2010). This ability might be acquired within the first months of our life, and preference for faces compared to other types of stimuli can be observed at birth (review in: Adolphs, 2009). At the same time, information about the affective state might be recognized from the

pattern of movement, which has repeatedly been presented in studies using PLW paradigms (Bachmann et al., 2018; De Gelder & Hortensius, 2014). Typical affective biological motion paradigms cover similar basic emotions that are studied in the context of facial emotion recognition (e.g. Alaerts et al., 2011). It has also been postulated that in some contexts, including observation of distant, degraded stimuli, emotional cues might be better recognized from movement than from faces, and have a stronger influence on our behavioral responses (De Gelder & Hortensius, 2014). Interestingly, the ability to recognize affective states from the PLW stimuli was deemed as culturally universal, even when the recording was based on the movement of an American actor (Parkinson et al., 2017).

1.3. Theory of Mind

Theory of mind (ToM) can be defined as a general ability to represent other people's state of mind, which includes views, beliefs, knowledge and emotions. The sole concept of ToM was derived from a seminal study by Premack & Woodruff "Does the chimpanzee have a theory of mind?" (1978). It has since then been agreed that ToM is not a single ability, but rather constitutes a collection of processes that rely on a coherent brain network (Spunt & Adolphs, 2014). These sub-processes vary with regard to the level of complexity, the engagement of general cognitive resources and modality of cues that are used to make inferences about the mental state. Compared to social perception processes discussed above, theory of mind emerges later in the course of development - while basic, first-order ToM is acquired around third year of life, complex mentalizing abilities that allow us to comprehend ambiguous language use, including jokes or metaphors, develop through adolescence and early adulthood (Yang et al., 2015). In line with this, tasks measuring theory of mind vary considerably with regard to their complexity and the incorporated

stimuli. The false belief paradigm in which participants have to predict a course of actions of a person presented in a story is considered prototypical for mental state reasoning, "because when the belief is false, the action predicted by the belief is different from the action that would be predicted by the true state of affairs" (Saxe and Kanwisher, 2003, p. 1836). Another commonly implemented task is an adapted version of the Heider and Simmel paradigm - in "Frith-Happé" animations participants have to distinguish intentional from non-intentional movement of geometric shapes (Barch et al., 2013). More complex tasks include understanding of hidden clues and verbally expressed intentions (e.g. Hinting Task; Corcoran et al., 1995) or making inferences about hidden attributes of people presented on a photograph ("Why How" paradigm; Spunt & Adolphs, 2014). Crucially, theory of mind abilities is essential for social communication and predicts various aspects of social functioning in both general and psychiatric populations (Braak et al., 2022).

1.4. Processing of Communicative Intentions from Biological Motion

Apart from basic social and affective cues, coherent patterns of motion can also convey more complex information about communicative intentions. While intentions can be broadly defined as internal states directed toward the external world in a form of specific actions, communicative intentions are a specific case of a recursive, mutual interaction between at least two agents, with an objective to communicate a meaning to another person and an essential purpose to be understood (Bara & Ciaramidaro, 2011; Searle, 1980). Importantly, the fact that we can detect communicative intentions despite no clear morphological social cues available, as in case of Heider and Simmer animations, points toward a possible conceptual representation of how animate agents behave, that does not rely exclusively on a raw sensory input (Wheatley et al., 2007). This inner animacy detector

might then serve as an alert that induces a preparational activity to the whole social perception network and biases it toward social, rather than physical processing.

In line with this notion, it has been repeatedly presented that typical adult participants can recognize communicative gestures from PLW and distinguish them from non-communicative gestures with a near-ceiling accuracy (Centelles et al., 2011; Manera et al., 2010). Some authors postulated that actions signaling communicative intentions should be captured and processed preferentially, compared to private and non-social actions (Zillekens et al., 2019), although a reverse pattern was also reported (Centelles et al. 2011). Importantly, the ability to recognize communicative intentions was confirmed both in paradigms with a single point-light walker (PLW) exhibiting a communicative vs non-communicative gesture (Jaywant et al., 2016), as well as in dyadic paradigms in which two PLW agents are either interacting or acting separately (Centelles et al., 2011; Manera et al., 2010). Importantly, the mechanism of recognizing communicative intentions based on single-agent and dyadic stimuli might differ substantially, as in case of dyadic displays the ability to understand individual actions is enhanced by the congruent response from the second agent (Piejka et al., 2022). Moreover, the presence of one agent embedded in a noise is recognized more accurately, if the presented action is of communicative nature (Manera et al., 2011; von der Lühe et al., 2016). These observations, sometimes referred to as a "second agent effect" (Manera et al., 2011) are best explained within the scope of Interpersonal Predictive Coding (IPC), rooted in a wider stance regarding the mechanisms of predictive coding and Bayesian inference and their influence on perceptual processes (Friston, 2002). In a model of predictive social perception Bach and Schenke (2017) described social perception as a process of top-down hypothesis testing, based on the use of contextual information. In the case of recognizing communicative cues from biological motion, if a

presented cue is vague and embedded in a noise, the congruent action of a second agent might be used to leverage a decision-making process.

1.5. Social Cognitive Capacity and Social Cognitive Bias

A concept of social cognitive bias, which may be defined as a systematic pattern or a tendency to make specific and skewed inferences about others' behavior, is gaining increased notion in clinical science (Birch et al., 2025; Buck, 2016b). In the National Institute of Health classification, a differentiation has been made between a social cognitive skill or capacity and social cognitive bias, with the former describing ability to correctly recognize and process social information (Buck, 2016b; Green et al., 2008; Van der Graag, 2013). Previous research with both psychiatric and non-clinical populations supported this distinction.

For instance, social cognitive bias, but not social cognitive capacity, was related to positive and emotional symptoms of schizophrenia measured by PANSS (Buck, 2016b). Similarly, hostile attribution bias was related to subjective loneliness in a healthy population, while no significant association between social cognitive capacity and subjective loneliness was observed (Okruszek et al., 2021). In line with this, it was proposed that social cognitive bias might mediate the relationship between social cognitive capacity and a functional outcome in clinical groups (Birch et al., 2025).

While many types of social cognitive biases have been described in the literature, one of the most important in the clinical research is the negative interpretation bias - a tendency to make negative interpretations of ambiguous or neutral situations (Birch et al., 2025). A subtype of the negative interpretation bias, namely a hostility bias, has been extensively studied especially with regard to psychosis, as an increased tendency to attribute

hostile intentions to other people have been observed both in people with schizophrenia (Buck et al., 2016a) and in ultra-high risk for psychosis individuals (Gawęda et al., 2018). Moreover, meta-analyses confirmed the positive relationship between negativity bias and social anxiety (Chen et al., 2020), as well as between negativity bias and paranoia (Trotta et al., 2021) in both clinical, and sub-clinical populations. In summary, a growing body of literature favors the two-factor model of social cognition, and provides evidence for the vital importance of both social cognitive skill/capacity and social cognitive bias for the functional outcome.

1.6. Neural Organization of Brain Networks Supporting Social Cognitive Processes

While the nature of which specific networks constitute the core of the, so called, "social brain" is still the topic of the ongoing dispute (Adolphs, 2009; Yang et al., 2015), several key regions supporting the social cognitive processes have been consistently indicated in the literature. Firstly, the face-sensitive region of fusiform gyrus (FFG) has been demonstrated to respond selectively to facial features, including static pictures of faces, but also schematic or cartoon presentations (Kanwisher, 2010) and is responsible especially for the processing of static, morphological aspects of face representations (Haxby et al., 2000; Weiner & Zilles, 2016). Because of its selectivity to invariant rather than dynamic aspects of faces it has been concluded that FFG might be more involved in processing information related to identity, rather than dynamically changing facial expressions (Haxby et al., 2000). Thus, a distributed neural system is responsible for face processing, with dynamic aspects related to face expressions processed within the superior temporal sulcus (STS), rather than FFG (Iidaka, 2013).

Importantly, the superior temporal sulcus (STS) is deemed to be a "central hub" for networks supporting social perception which plays a key role for initial detection of multimodal, socially salient information (Deen et al., 2015; Yang et al., 2015). Importantly, a functional specialization along the anterior-posterior STS was previously demonstrated, with partially separate responsiveness profiles for theory of mind, biological motion, face and voice perception, as well as language comprehension across the various STS sub-regions (Deen et al., 2015). In line with this view, a posterior part of STS (pSTS) is perceived as the main region responsible for perception of biological motion (Basil et al., 2017; Thompson & Parasuraman, 2012), which points toward its role in agency detection (Gao et al., 2012). Importantly, pSTS might be selective not only for action recognition in general, but also for perception of social interactions more specifically, as it reacts more strongly for displays presenting communicative intentions and interaction between two agents, compared to individual actions (Centelles et al., 2011; Isik et al., 2017). Moreover, a region within the posterior STS might also decode the nature of social interaction, including its emotional content or level of cooperation (Isik et al., 2017; Walbrin & Koldewyn, 2019). Furthermore, the role of pSTS in intentional causality detection extends beyond the BM stimuli. For instance, pSTS activity increased linearly with increasing contingency between the movement of two abstract moving objects (Schultz et al., 2005).

In case of social cues conveying affective, including threat-related information, the response is additionally supported by the emotional processing networks, with a central role of amygdala, which coordinates the processing of multimodal affective and social cues (Adolphs, 2009; Gothard, 2020). In line with this, increased activation of the amygdala has been demonstrated in response to negative facial expressions (Hariri et al., 2002). Moreover, impaired recognition of fearful expressions (Adolphs & Spezio, 2006) and decreased

reaction to aversive stimuli (Anderson & Phelps, 2001) following amygdala lesions was previously described.

Processing of basic social information and affective content of the social stimuli might eventually lead to mental state inference processes, which are supported by mentalizing or Theory of Mind brain network (Spunt & Adolphs, 2014). While the engagement of specific regions differs with regard to specific task-related requirements, the role of temporo-parietal junction (TPJ) and medial prefrontal cortex (mPFC) is commonly found across studies on intention attribution (Schurz et al., 2014). Engagement of TPJ was observed across the tasks relying on attribution of intentions to other agents, including attribution of intentionality to animated geometrical shapes (Barch et al, 2013), understanding false beliefs (Saxe & Kanwisher, 2003) or inferring unobservable intentions compared to observable actions (Spunt & Adolphs, 2014).

It was also shown that mPFC might be responsible for the highest-level of mental state representations and processes including self-referential thinking and moral judgments (Amodio & Frith, 2006). Apart from its direct role in theory of mind, mPFC is also engaged in exerting the modulatory control over the lower stages of social information processing, based on the contextual knowledge, previous experiences and incoming stream of sensory information (Hiser & Koenigs, 2018; Isoda, 2021).

Additionally, social cognitive processes are supported by the activity of cerebellum - an accumulating line of evidence points toward its role not only in simple motor and reflexive functions, but also in higher-order cognitive processes (Zhang et al., 2023).

Chapter 2. Social Cognition in Autism Spectrum Disorders

Alterations of social cognitive processes are commonly observed in many psychiatric and neurodevelopmental syndromes, including autism, schizophrenia or mood disorders. However, in case of autism spectrum disorders (ASD; American Psychiatric Association [APA], 2022), alterations of social cognition are considered to constitute a characteristic of the autistic phenotype, and one of the most important factors leading to decreased social communication observed in individuals with ASD (Sasson et al., 2013; Velikonja et al., 2019).

2.1. Autism Characteristics

Autism Spectrum Disorder (ASD) is a highly heterogeneous neurodevelopmental clinical syndrome (previously: a pervasive developmental disorder) that encompasses a varying range of clinical presentations and etiological pathways (Geschwind, 2009; Lord et al., 2020) and affects 1-2% population (American Psychiatric Association [APA], 2022).

Autism is currently recognized based on a presence of two groups of symptoms: persistent deficits in social communication and restrictive, repetitive patterns of behavior (APA, 2022; World Health Organization [WHO], 2002), which replaced the “autistic triad” that included abnormalities in reciprocal social interactions, abnormal patterns of communication and restrictive patterns of behavior, that constituted a basis for autism diagnosis according to ICD-10 (WHO, 2019).

Social and communication difficulties are present across a variety of contexts, including difficulties in initiating and responding to contact, poor understanding and use of non-verbal communication and establishing, as well as maintaining social relationships. Similarly, restricted and repetitive patterns of behavior must be manifested in at least two

areas, including stereotyped motor movements, insistence on sameness and restricted interests.

Additional diagnostic specifiers in current ICD-11 and DSM-5 classifications specifiers include the presence of accompanying intellectual impairment, the amount of support needed in everyday functioning and the presence of a known genetic, medical or environmental factor (APA, 2022; WHO, 2022). While both social-communication symptoms and restricted patterns of behavior might manifest in a different way and with varying intensity, their occurrence have to cause a significant impairment in everyday functioning (APA, 2022; WHO, 2022). Symptoms are also present from early developmental stages, although in some cases they might not become apparent as long as the social demands do not exceed the limited abilities (APA, 2022). Crucially, both ICD-10 and DSM-IV included separate neurodevelopmental syndromes, including infantile/childhood autism, atypical autism and Asperger Syndrome, which were replaced by the autism spectrum disorder in the current APA (2022) and WHO (2022) classifications. Importantly, an increasing amount of data points toward a high heterogeneity of autistic population, that is reflected both in the clinical outcome and in etiological pathways (Litman et al., 2025). Full diagnostic criteria of ASD from ICD-10, which has been used as a diagnostic criteria for the sample included in the analyses described in this thesis are included in Table 1.

Table 1
ICD-10 criteria for Childhood autism (F84.0) and Asperger syndrome (F84.5).

F.84.0. Childhood autism

(A) An abnormal or impaired development is evident before the age of 3 years in at least one of the following areas:
  (1) Receptive or expressive language as used in social communication;
  (2) The development of selective social attachment or reciprocal social interaction
  (3) Functional or symbolic play

(B) A total of at least six symptoms from (1), (2), and (3), with at least two from (1) and at least one from each of (2) and (3):
  (1) Qualitative abnormalities in reciprocal social interaction (e.g. failure to adequately use eye-to-eye gaze, facial expression, body posture and gestures; failure to develop peer relationships; lack of socio-emotional reciprocity; lack of spontaneous seeking to share activities with other people).
  (2) Qualitative abnormalities in communication (e.g. delay or a total lack of development of spoken language, failure to initiate or sustain conversations, stereotyped use of language).
  (3) Restricted, repetitive and stereotyped patterns of behaviors and interests (e.g. encompassing preoccupation with one or more stereotyped patterns of interests, compulsive adherence to routine, motor mannerism).

(C) The disorder is not attributable to other varieties of pervasive developmental disorder.

F84.5. Asperger syndrome

Diagnosis is based on the combination of a lack of any clinically significant general delay in language or cognitive development plus, as with autism, the presence of qualitative deficiencies in reciprocal social interaction and restricted, repetitive, stereotyped patterns of behaviour, interests, and activities. There may or may not be problems in communication similar to those associated with autism, but significant language retardation would rule out the diagnosis

Efforts to explain autism etiology gave rise to various influential theories, which proposed specific cognitive mechanisms, including mentalizing, decreased social motivation and weak central coherence, as a "core deficit" in autism (Chevallier et al., 2012; Frith, 2012). Importantly, theories focusing on circumscribed cognitive deficits are currently viewed as overly reductive and not accounting for heterogeneity of ASD population (e.g. Long et al., 2025). At the same time, difficulties in various areas of both neurocognition and social cognition are commonly observed in autism, although with a varying magnitude (Velikonja et al., 2019). Importantly, processes responsible for managing non-social and social information are partially independent, and social cognition might have a mediatory role between neurocognition and decreased social functioning in people with autism (Sasson et al., 2020). Commonly described cognitive difficulties in autism include decreased processing speed and memory in the neurocognitive area, as well as difficulties of emotional processing, theory of mind and basic social perception in the social cognitive domain (Velikonja et al., 2019; Yang et al., 2015).

In the following paragraphs, the most common difficulties related to neurocognitive and social cognitive functioning in autism will be discussed.

2.2. Autism and Neurocognition

Intellectual disability (IQ < 70) can be diagnosed in approximately 30% of people with autism (Shenouda et al., 2023). Importantly, a full IQ score was shown to be related to a total severity score calculated based on the Autism Diagnostic Observation Schedule (Denisova & Lin, 2023). Because of the difference in autism presentation in people with and without intellectual disability, particular neurocognitive deficits should not be generalized to

the whole population (Litman et al., 2025). Thus, only research with ASD participants without co-occurring intellectual disability will be covered in the following overview.

A meta-analysis (Velikonja et al., 2019) pointed toward medium impairments in processing speed (g=-0.61), verbal learning and memory (g=-0.55), and a small magnitude of deficits in attention and vigilance (g=-0.30) and working memory (g=-0.23). Moreover, reduced executive functioning was also reported in people with ASD, with most pronounced difficulties in flexibility and planning, and smaller in inhibition, working memory and fluency (Xie et al., 2020). Crucially, neurocognition in people with ASD is considered as an important determinant of a functional outcome, which might account for 39% of variance in functional skills and 25% variance in social skills (Sasson et al., 2020). In line with these results, a Cognitive Enhancement Therapy led to improvement in both social and non-social functioning in people with autism (Eack et al., 2018), which further underscored a vital role of neurocognition in the presentation of autism symptoms.

2.3. Autism and Social Cognition

Difficulties in recognition of basic social cues were documented in people with autism, including decreased face identification (Morrison et al., 2019; Stantić et al., 2022) and abnormal voice processing (Abrams, 2019). Additionally, abnormal patterns of gaze related to socially salient cues are commonly recognized in autism and might be related to the symptom severity (Frazier et al., 2017; Riddiford et al., 2022).

Moreover, worse recognition of basic biological motion in people with ASD compared to the TD population was also reported (Federici et al., 2020; Todorova et al., 2019). Both children and young people with autism presented difficulties in retrieving various aspects of presented PLWs, including preference for biological over non-biological

motion and differentiating biological from scrambled motion, which was related to the level of autism symptoms (Kaiser et al., 2010; Miller & Saygin, 2013).

Difficulties in social cues recognition in autism are also accompanied by emotional processing deficits. Three meta-analyses confirmed decreased overall facial emotion recognition in people with autism compared to typically developing people, and to other clinical populations (Lozier et al., 2014; Uljarevic & Hamilton, 2013; Yeung, 2022). Crucially, some authors hypothesized that these early emerging difficulties in face processing might constitute one of the factors contributing to atypical developmental trajectory and leading to difficulties in social communication (Webb et al., 2017)

While emotion processing in autism is most commonly studied with regard to facial emotion recognition, difficulties in recognition of affective states from biological motion were also reported (Foglia et al., 2021). Crucially, meta-analyses including different aspects of biological motion processing demonstrated more robust differences between people with autism and typically developing participants with regard to the recognition of more complex social cues based on the biological motion stimuli, including tasks assessing the ability to recognize affective states exhibited by point-light agents (Federici et al., 2020; Foglia et al., 2021; Todorova et al., 2019).

In line with a common belief about decreased mental state inference abilities in autism, few meta-analyses confirmed the occurrence of ToM difficulties in individuals with ASD (Fernandes et al., 2018; Ozbek et al., 2023), with a larger effect size compared to other areas of social and non-social cognitive difficulties in autism (Velikonja et al., 2019) Importantly, decreased performance was observed in a wide array of tasks (Ozbek et al., 2023), and large effect sizes were observed in paradigms including both verbal (g=1.05) and visual (g=0.81) stimuli (Chung et al., 2014). As these effects have not been moderated by

factors such as gender, IQ or age, it has been suggested that ToM impairments are homogenous across ASD adults (Chung et al., 2014), although some individuals with ASD might exhibit mentalizing difficulties primarily with regard to the spontaneous, automatic implementation of ToM abilities (Senju, 2009).

Because deficient performance in simple ToM tasks has been perceived as one of the main characteristics accompanying core symptoms of autism (e.g. Hamilton & Marsh, 2013), tasks measuring first-order theory of mind abilities are typically used for autism diagnosis (Byom & Mutlu, 2013). Moreover, differences have also been reported in the most complex mentalizing domains, including faux pas understanding (Garcia-Molina & Clemente-Estevan, 2019) and dynamic social cognition tasks (Murray et al., 2017). Thus, it is important to note that complex mentalizing skills might not be properly acquired even in those individuals with ASD who eventually capture basic, first-level theory of mind abilities (Abell et al., 2000).

However, there is no consensus with regard to the communicative motion processing in individuals with autism. Decreased ability to discriminate communicative signals was observed in a group of autistic children by Centelles and colleagues (2013). In contrast, a preserved ability to detect communicative intentions from biological motion in a group of adults with autism was described by von der Lühe et al. (2016). However, despite no difference in the accuracy between individuals with autism and a typically developing group, decreased ability to use automatic processes facilitating the recognition of communicative interactions was also observed in individuals with ASD (von der Lühe et al., 2016).

Because of a vital importance of recognizing communicative intentions from the coherent movement patterns for acquiring more complex forms of intention understanding,

investigating this ability in people with autism might potentially help disentangle different mechanisms contributing to ToM difficulties in this population.

2.4. Social Cognitive Bias in Autism

Although a lot of effort has been made historically to explain mechanisms of ToM difficulties in autism, less is known about social cognitive bias in people with ASD. Following the widely acknowledged difficulties in mental state inference in autism, the suggestion has been made that a decreased tendency to attribute intentionality, and in consequence – lower social cognitive bias is common in people with ASD (Ciaramidaro et al., 2015; Crespi & Badcock, 2008). Moreover, decreased proneness to cognitive bias in the non-social area and "increased rationality" in people with autism was also repeatedly presented (Rozenkratz et al., 2022). At the same time, no specific pattern has been established with regard to social cognitive bias, as available research in this area has been less conclusive.

When asked to interpret ambiguous social situations, autistic participants did not perform differently from the typically developing group in measures of hostility or intention attribution (Zajenkowska et al., 2021). Similarly, in a visual chasing paradigm focused on the ability to attribute agency and intentions, autism symptoms were not connected to neither hypo- nor hypermentalising tendency, although a greater tendency to anthropomorphize was observed (Lisoy et al., 2022). At the same time, increased hostile attributions might also be related to the functional outcome, with a higher level of social cognitive bias related to lower level of functioning in a group of children with Asperger Syndrome (Meyer et al., 2006).

Inconclusive findings were also reported with regard to negativity biases related to emotion processing. While the negativity bias typical for anxiety disorders was not observed in the autistic population (May et al., 2015), some evidence was found for depressive-like bias, with studies reporting both higher and lower levels of biased thinking (Bergman et al., 2020). Importantly, heterogeneity of social cognitive performance in people with ASD can account for some of the reported discrepancies, and some individuals with ASD might present increased social cognitive bias despite normative social cognitive capacity (Hajdúk et al., 2022). Thus, while mentalizing deficits have been sometimes perceived as equivalent to diminished tendency to make attributions, another perspective should also be considered, namely, that difficulties to appreciate multiple perspectives might make an individual more prone to social cognitive bias (Frith, 2004).

2.5. Neural Correlates of Social Cognitive Difficulties in Autism

Studies on neurobiological underpinnings of autism reported alterations within the key brain circuits related social perception, action observation and mentalizing network (Yang et al, 2015). As a result, Pelphrey, Adolphs and Morris (2004) postulated that neuroanatomical and functional dysfunctions in autism might primarily be related to 3 distinctive regions: the superior temporal sulcus (STS), amygdala (AMY) and the fusiform gyrus (FFG). Additionally, the role of mPFC and TPJ was also discussed in the context of mental state inference difficulties in autism (Murdaugh et al., 2014). Finally, many studies pointed toward a possible cerebellar dysfunction in ASD (Biswas et al., 2024; Kelly et al., 2020), and both patterns of increased and decreased cerebellar volume were reported (Baizer, 2024). Although it is commonly accepted that cerebellum dysfunction might be related to motor and sensory symptoms of autism, its contribution to social communication

symptoms was also postulated, due to the modulatory role in higher-order cognitive processes.

In the following paragraphs, the specific pattern of dysfunctions within the social perception, emotion processing and mentalizing networks in autism will be discussed.

2.5.1. Social Perception Network

Abnormalities within the main hubs of social perception networks were repeatedly observed in autism. It has been postulated that apart from structural abnormalities, FFG and STS in people with autism might be less selective to social information compared to typically developing individuals (Pelphrey et al., 2004; Yang et al., 2015). Accordingly, decreased activity within the pSTS in response to basic social cues, including human voice (Gervais et al., 2004), speech perception (Boddaert et al., 2003) or social touch (Voos, 2013) has been observed in ASD compared to TD individuals. Moreover, both decreased pSTS activity and increased coupling between pSTS and mPFC was observed in people with autism during a simple biological motion task, which was related to autism symptoms level (Isik et al., 2017; Yang et al., 2017). Following these reports, some authors suggested that difficulties in recognizing simple social cues are a consequence of a cascade of abnormal development initiated by early abnormalities within the STS region, which might eventually lead to problems in mental state reasoning (Zilbovicius et al., 2013)

Similarly, decreased FFG activity during more complex face perception tasks was observed in people with ASD compared to TD individuals, including trust-approach judgment, despite no difference related to a simple identity judgment (Pelphrey et al., 2004; Pinkham et al., 2008) Crucially, a model based on structural and functional aspects of FFG

obtained from a merged MRI-EEG data was efficient in differentiating the ASD from non-ASD group (Floris et al., 2025)

2.5.2. Emotion Processing Network

Studies on neural correlates of emotion processing difficulties in autism focus on the role of amygdala. Structural alterations in this region are commonly reported in autism, and might result from the abnormal growth patterns (Donovan & Basson, 2017). Decreased activity of amygdala was also observed in the ASD compared to TD individuals during a range of affective tasks, including basic and complex recognition of emotional cues from faces (Pinkham et al., 2008). Strikingly, a similar magnitude of emotion processing difficulties was observed in people with ASD and in patients with amygdala lesions (e.g. Pelphrey et al., 2004). Importantly, amygdala abnormalities in autism might account not only for deficits in emotion recognition, but also for symptoms like social anhedonia, more severe social anxiety and a secondary aggression (Sweeten et al., 2002). Because of the connections between amygdala and surrounding temporal cortices, it was proposed that early disruption of amygdala might lead to worse differentiation of emotional salience, and in consequence – decreased interest in social stimuli leading to worse expertise in social cognition (Schultz, 2005).

2.5.3. Mentalizing Network

Mental state inference difficulties in the ASD population might be related to TPJ abnormalities (Duvall et al., 2023). Decreased TPJ activity in people with autism compared to typically developing people accompanied both explicit and implicit mentalizing tasks, even when no apparent difference is observed between the ASD and TD group at the

behavioral level (Nijhof et al., 2018). Less robust TPJ response was also observed in the ASD group during intentional causality reasoning, compared to the TD participants (Kana et al., 2014; Murdaugh et al., 2014). Importantly, lower selectivity of TPJ for mentalizing processes that was observed in the ASD individuals might be also related to the level of autism symptoms and the magnitude of social impairment (Ammons et al., 2018; Lombardo et al., 2011). Additionally, a possible mechanism related to ToM difficulties in autism was described, according to which decreased resting state connectivity between right TPJ and left CrusII of the cerebellum might lead to abnormalities in multimodal integration of social cues (Igelström et al., 2016).

At the same time, less is known about the role of mPFC in social cognitive difficulties in autism, despite its vital role in mental state inference. The available results point toward abnormalities within the default mode network in ASD, with a central role of mPFC (Martines-Sanchis, 2014). For instance, increased activity of mPFC was observed in people with autism during an executive function task, in contrast to a decrease of the default mode network including the mPFC activity that is usually observed in typically developing people (Gilbert et al., 2008). At the same time, social cognitive skills training leading to improvement in irony comprehension and gaze processing also resulted in the increase of mPFC activity, which was correlated with the improvement on the social responsiveness score (Ibrahim et al., 2021). It was also suggested that social-communicative symptoms of autism might be related to structural abnormalities within the mPFC, leading to excitatory-inhibitory imbalance in this region (Mediane et al., 2024). Additionally, disrupted patterns of connectivity between mPFC and temporal regions responsible for social perception (Alaerts et al., 2017), as well as abnormal long-range connectivity (Mediane et al., 2024) was also reported. With all things considered, these results might point toward a

possible abnormality in the modulatory role of mPFC, leading to less efficient processing of both social and non-social cues, and in result – difficulties in higher-order mental state inference observed in people with autism.

Chapter 3. Specificity of Social Cognitive Patterns in Autism and Schizophrenia

In the current diagnostic classifications, schizophrenia (SCZ) and autism spectrum disorders are listed as separate nosological categories (American Psychiatric Association, 2013; World Health Organization, 2022). However, the term "autism" was first introduced by Bleuler to describe symptoms of social withdrawal and isolation that he observed in patients with schizophrenia. The name was then adapted and redefined by Kanner to describe a group of children with severe social deficits (Crespi, 2010). Nevertheless, autism was considered a childhood manifestation of schizophrenia until the introduction of DSM-III, where it was introduced as a separate diagnostic entity (Barlati & Deste, 2016). Although formal criteria for autism and schizophrenia diagnosis are non-overlapping, in some cases specific clinical presentation might hinder a differential diagnosis, including symptoms like social isolation, flat affect and stereotypical movement/gross motor abnormalities (King & Lord, 2010; Mazza et al., 2022). Moreover, some overlap has been suggested with regard to certain risk factors, including genetic predispositions and environmental risk factors (Chisholm et al., 2015). Most importantly, it has been pointed out that abnormalities in basic social information processing, emotion recognition and theory of mind may constitute a significant area of an overlap between the two disorders (Eack et al., 2013; Fernandes et al., 2018). However, opposite presentations of social cognitive deficits were also described in theoretical accounts of autism and schizophrenia – while the pattern of hyper-mentalization (increased attribution of intention) was suggested to underlie some of the positive symptoms in schizophrenia (Frith, 1992/2014), hypo-mentalizing (decreased attribution of intention) is believed to be commonly observed in autism (Bara et al., 2011). At the same time, available meta-analyses reported a comparable magnitude of social

cognitive difficulties in both clinical groups, although people with schizophrenia might present more pronounced neurocognitive problems compared to people with autism with no co-occurring intellectual disability (Ozbek et al., 2023; Pinkham et al., 2020).

In the next sections, main characteristics of neurocognitive and social cognitive features of schizophrenia will be discussed, followed by a thorough comparison of autism and schizophrenia with regard to social cognition.

3.1. Schizophrenia Characteristics

Schizophrenia is currently considered to be one of the most burdensome mental illnesses which affects approximately 1% of the population (APA, 2022). Although onset of schizophrenia typically occurs in the early adolescence, an accumulating line of evidence points toward the neurodevelopmental nature of schizophrenia, with both genetic and environmental factors engaged (Owen et al., 2011).

In the ICD-10 (WHO, 2019) that was recently replaced by ICD-11 (WHO, 2022), schizophrenia was characterized by fundamental distortions of thinking and perception, accompanied by inappropriate or blunted affect. Across the diagnostic classifications, 3 groups of schizophrenia symptoms were distinguished, namely: positive symptoms, negative symptoms and disorganization (Ritsner, 2011).

Positive symptoms reflect an “excess or distortion of normal functions” (APA, 2000) and might be further divided into delusions and hallucinations. Delusions can be defined as inflexible beliefs, spreading across a variety of themes, with persecutory and referential delusions among the most common manifestations of schizophrenia (Ritsner, 2011). Hallucinations are perceptual-sensory disturbances, occurring without immediate external cause. In case of schizophrenia, auditory hallucinations are most common, followed by

olfactory and somatosensory experiences (Waters et al., 2012). Negative symptoms reflect a diminution or loss of normal functions (APA, 2000) and include social withdrawal, flattened affect and substantially decreased sociality. Finally, disorganisation or formal thought disorder is manifested through varying range of symptoms, from loose associations to substantial derailment incoherence or schizophasia ("word salad"; Ritsner, 2011). Crucially, separate subtypes of schizophrenia, such as paranoid or catatonic schizophrenia that were previously listed in the ICD-10 classification are not included in the current classifications. Full ICD-10 for schizophrenia are presented in Table 2.

Table 2
ICD-10 Diagnostic criteria for schizophrenia (F20).

The normal requirement for a diagnosis of schizophrenia is that a minimum of one very clear symptom (and usually two or more if less clear-cut) belonging to any one of the groups listed as (a) to (d) above, or symptoms from at least two of the groups referred to as (e) to (h), should have been clearly present for most of the time during a period of 1 month or more. (...) Symptom (i) in the above list applies only to a diagnosis of simple schizophrenia (F20.6), and a duration of at least one year is required:

(a) Thought echo, thought insertion or withdrawal, and thought broadcasting;

(b) Delusions of control, influence, or passivity, clearly referred to body or limb movements or specific thoughts, actions, or sensations; delusional perception;

(c) Hallucinatory voices giving a running commentary on the patient's behaviour, or discussing the patient among themselves, or other types of hallucinatory voices coming from some part of the body;

(d) Persistent delusions of other kinds that are culturally inappropriate and completely impossible, such as religious or political identity, or superhuman powers and abilities (e.g. being able to control the weather, or being in communication with aliens from another world);

(e) Persistent hallucinations in any modality, when accompanied either by fleeting or half-formed delusions without clear affective content, or by persistent over-valued ideas, or when occurring every day for weeks or months on end;

(f) Breaks or interpolations in the train of thought, resulting in incoherence or irrelevant speech, or neologisms;

(g) Catatonic behaviour, such as excitement, posturing, or waxy flexibility, negativism, mutism, and stupor

(h) "Negative" symptoms such as marked apathy, paucity of speech, and blunting or incongruity of emotional responses, usually resulting in social withdrawal and lowering of social performance; it must be clear that these are not due to depression or to neuroleptic medication;

(i) A significant and consistent change in the overall quality of some aspects of personal behaviour, manifested as loss of interest, aimlessness, idleness, a self-absorbed attitude, and social withdrawal.

ICD-10 Diagnostic criteria for schizophrenia (F20).

The diagnosis of schizophrenia should not be made in the presence of extensive depressive or manic symptoms unless it is clear that schizophrenic symptoms antedate the affective disturbance. (...) Schizophrenia should not be diagnosed in the presence of overt brain disease or during states of drug intoxication or withdrawal.

Although cognitive deficits are not formally recognized as a symptom of schizophrenia, they can be observed in as many as 80% of patients (Harvey et al, 2022), however mounting evidence points toward an existence of subgroups of patients with markedly different levels of cognitive and social functioning (e.g. Vaskinn et al., 2022). Moreover, cognitive deficits along with negative symptoms constitute a substantial portion of schizophrenia morbidity and are one of the strongest predictors of a functional outcome (McCutcheon, 2023). Apart from deficits in various neurocognitive domains, decreased social cognitive functioning is also recognized in people with schizophrenia (Green, 2015; Oliver et al., 2021). Moreover, it has repeatedly been proven that both impairments in neurocognition and social cognition influence different aspects of functional outcome in schizophrenia, and because of that – should be assessed and modeled separately (Green et al., 2019).

3.2. Schizophrenia and Neurocognition

Neurocognitive deficits have been documented in schizophrenia, with differences between SCZ and non-affected participants reaching 2 standard deviations in most pronounced cases (McCutcheon et al., 2023). Impairments in various areas of neurocognition in schizophrenia were confirmed in meta-analyses, with largest effect sizes for processing speed, verbal memory and working memory (e.g. Catalan et al., 2021;

Fatouros-Bergman et al., 2014; Fioravanti et al., 2005). Additionally, a generalized executive dysfunction was also repeatedly observed in patients with SCZ (Thai et al., 2019), and might constitute one of the most important factors predicting the functional outcome (Semkovska et al., 2004). Crucially, cognitive impairments in schizophrenia are also observed in people with ultra-high risk for psychosis and in unaffected family members, which suggests a central role of neurocognitive deficits in the broad psychosis phenotype (Catalan et al., 2021). To facilitate the research on cognitive aspects of schizophrenia, The Measurement and Treatment Research to Improve Cognition in Schizophrenia (MATRICS) initiative identified 7 domains of crucial impairments: Processing speed, Attention, Working memory, Verbal learning and memory, Visual learning and memory, Reasoning and Problem solving, and Social cognition (Green et al., 2004). Based on the selected domains, tasks for the MATRICS Cognitive Battery (MCCB) were selected to provide a standardized tool for assessment of cognitive deficits in schizophrenia for use both in research and in clinical practice. Importantly, neurocognitive deficits in schizophrenia influence the overall functional and clinical outcome, including aspects like independent living and vocational success (Fett et al., 2011; Lepage et al., 2014).

3.3. Schizophrenia and Social Cognition

Social cognitive deficits are common in the schizophrenia population, and might be even stronger predictors of functional outcome than general cognition (Green, 2015). In a 15 year follow up study, 64% of the schizophrenia group reported social disability levels classified as severe or very severe (Bottlender et al., 2010). Increased levels of both objective social isolation (Green et al., 2018) and loneliness (Halverson et al., 2019) are also observed in patients with SCZ compared to healthy individuals. Social cognitive

impairments are also observed throughout the whole course of the illness, including prodromal state, active psychosis and remission (Camparelli et al., 2013), and were found in unaffected family members (Mondragon-Maya et al., 2017). Hence, they are deemed to constitute a stable trait and a factor of genetic vulnerability for schizophrenia. Similarly to the MATRICS initiative, a large-scale Social Cognition Psychometric Evaluation study (SCOPE) evaluated the functioning in domains previously distinguished by NIMH as central for research on social cognition in psychiatry: social perception, emotional processing, theory of mind and social cognitive bias. As a result, a well-validated SCOPE battery was proposed for both research and clinical use in assessment of social cognitive abilities in patients with schizophrenia (Pinkham et al., 2018).

Abnormal recognition of basic social cues in people with schizophrenia was demonstrated with regard to facial recognition (Mewton et al., 2025) and voice perception (Schelinski et al., 2017). Additionally, worse differentiation of basic biological motion was also observed in SCZ individuals (Okruszek & Pilecka, 2017). Importantly, deficits in BM recognition in schizophrenia were related to social competence (Kim et al., 2005) and affective empathy (Matsumoto et al., 2015).

Deficits in emotional processing are also commonly observed in schizophrenia, especially with regard to faces – large effect sizes of decreased facial emotion recognition were confirmed in a meta-analysis, regardless of the specific task incorporated in the study (Kohler et al., 2003). Importantly, difficulties in facial emotion recognition might be larger compared to a simple identity recognition (Mewton et al., 2024). People with schizophrenia might also be less accurate in identification of emotion from biological motion patterns, which was confirmed by one meta-analysis (Okruszek, 2018; Okruszek & Pilecka, 2017).

Decreased mental state inference abilities in people with schizophrenia compared to typically developing individuals were also confirmed by meta-analyses and conceptual reviews (Bora et al., 2009; Kronbichler et al., 2017). Theory of mind deficits in schizophrenia have been documented using a wide range of tasks tapping into distinct ToM-related abilities (Bora et al., 2009). Moreover, potential relationship between these deficits and clinical presentation of schizophrenia was also proposed, with increased, but inaccurate ToM related to positive symptoms, and decreased ToM related to negative symptomatology (Frith, 1992/2014). Mentalizing difficulties were also related to the functional outcome, including decreased social functioning of patients with schizophrenia (Phalen et al., 2017). While it is a matter of ongoing debate how much variance in mentalizing deficits can be attributed to neurocognitive functioning, factors like IQ level cannot fully explain ToM difficulties in people with schizophrenia (Brune, 2005; Harrington et al., 2005).

Decreased recognition of communicative intentions from biological motion stimuli was also observed in schizophrenia. In studies using dyadic point-light paradigms, individuals with schizophrenia presented lower sensitivity to communicative cues compared to typically developing participants (Okruszek et al., 2015; Okruszek et al., 2018a). Interestingly, despite lower accuracy of communicative cues recognition, people with schizophrenia presented preserved interpersonal predictive coding ability, with a typical improvement of performance in congruent communicative compared to non-communicative conditions (Okruszek et al., 2018b).

3.4. Social Cognition in Autism and Schizophrenia - Comparison

Social cognitive (SC) difficulties accompanied by abnormal patterns of "social brain" activity are commonly observed both in autism and schizophrenia (Eack et al., 2013; Fernandes et al., 2018). However, because of the well-documented multifaceted, hierarchical nature of social cognition (Happé et al, 2017; Schurz et al., 2021), alterations in this domain are also not uniform and might affect specific processes to varying degrees (Lemmers-Jansen et al., 2023). Thus, social cognitive assessment in both schizophrenia and autism usually includes tasks tapping various lower- and higher-order processes, including social cues perception and mental state inference (Morrison et al., 2019; Pinkham et al., 2018). While both groups show diminished performance in tasks measuring social perception, emotion recognition and mental state attribution, it remains an ongoing debate whether specific profiles of these deficits are comparable in autism and schizophrenia (Pinkham et al., 2020). Although both clinical groups share difficulties in basic emotion recognition, these difficulties might be more pronounced in autism compared to schizophrenia (Fernandes et al., 2018), with differences related to the activation of specific brain circuits, including the superior temporal cortex and temporo-parietal junction, also reported (Sugranyes et al., 2011). Similarly, while autism is sometimes considered as "a disorder of mentalization" (Abell et al, 2000), difficulties in monitoring intentions of other people are also regarded as one of the main cognitive correlates of psychotic symptoms (Frith, 1992/2014), and large, similar effect sizes of ToM deficits have been found in both clinical groups (Chung et al., 2014). Despite the heterogeneity of the available findings, a recent meta-analysis confirmed a shared pattern of theory of mind and emotion recognition difficulties in autism and schizophrenia (Oliver et al., 2021).

Despite evidence that both people with schizophrenia and autism might struggle with some aspects of intention recognition from BM stimuli (Centelles et al., 2013; Okruszek, 2018), no study to date has directly compared their performance in this area. At the same time, two studies reported contradictory patterns of interpersonal predictive coding and biological motion sensitivity in autism and schizophrenia. While the decreased effect of interpersonal predictive coding might be observed in people with autism who did not differ from healthy controls with regard to the accuracy of communicative intention recognition (von der Lühe et al., 2016), the opposite effect was found in patients with schizophrenia who presented preserved interpersonal predictive coding effect despite decreased ability to process communicative interactions in explicit categorization task (Okruszek et al., 2018). Arguably, while some difficulties in communicative intention recognition might be observed across the neurodiversity spectrum, specific mechanisms and manifestation might differ in autism and schizophrenia. Nevertheless, comparative analysis is necessary to assess shared and distinct pathways leading to social cognitive difficulties and decreased social functioning in different neurodevelopmental conditions (Sasson et al., 2011).

Chapter 4. Overview of the Research Programme

4.1. Research Goals and Hypotheses

The main research goal of a presented work was to analyze behavioral and neural aspects of intention processing in autism. Furthermore, we examined the specificity of the findings in the ASD population by comparing it with the pattern of behavioral results observed in patients with schizophrenia. The following hypotheses (H) stated with regard to the main research questions (Q) were verified throughout the research programme:

Q1: Is autism related to decreased recognition of information about intentions and affective states from biological motion?

H1.1: Compared to TD participants, ASD participants will present worse recognition of information about intentions and affective states from biological motion, particularly:

H1.1a: Compared to TD participants, ASD participants will present a decreased recognition of communicative gestures presented by a single PLW.

H1.1b: Compared to TD participants, ASD participants will present a decreased recognition of communicative interactions presented by dyadic PLWs.

H1.1c: Compared to TD participants, ASD participants will present a decreased recognition of affective states presented by a single PLW.

H1.2: Ability to recognize communicative cues from biological motion will be related to mental state inference abilities in both ASD and TD participants.

H1.3: In the ASD group, decreased ability to recognize communicative intentions from biological motion will be linked to higher levels of autism symptoms.

H1.4: Decreased neurocognitive functioning will be observed in the ASD, compared to the TD group.

H1.5: Decreased social cognitive abilities will be observed in ASD compared to the TD group, such as:

H1.5a: Decreased ToM abilities will be observed in the ASD group compared to the TD group.

H1.5b: Decreased emotion recognition abilities will be observed in the ASD group compared to the TD group.

H1.6: Social cognitive and neurocognitive functioning will be related to autism symptoms in the ASD group, such as:

H1.6a: Autism symptoms will be correlated with an overall neurocognitive score.

H1.6b: Autism symptoms will be correlated with an overall social cognitive score.

H1.7: In the ASD group, an indirect relationship between communicative intention recognition and autism symptoms will be observed, such as the relationship between the accuracy in PLD tasks and autism symptoms will be mediated by the social cognitive composite score.

Q2: Is social cognitive bias decreased in autism compared to the typically developing population?

H2.1: Participants with ASD will present a lower level of social cognitive bias compared to TD individuals, such as:

H2.1a: Compared to TD participants, participants with ASD will present a lower level of social cognitive bias in self-report measures.

H2.1b: Compared to TD participants, participants with ASD will present a lower level of social cognitive bias in vignette-based measures.

H2.1c: Compared to TD participants, participants with ASD will present a lower level of negativity bias in facial emotion recognition.

H2.1d: Compared to TD participants, participants with ASD will present a lower bias in communicative intention recognition, i.e. decreased tendency to recognize non-communicative actions as communicative.

H2.2.: In both ASD and TD groups, a relationship between self-report, vignette-based and performance-based measures of social cognitive bias will be observed.

H2.3.: In people with ASD, the lower level of social cognitive bias will be related to the higher level of autism symptoms.

Q3: What are the neural underpinnings of difficulties in intention recognition in people with autism?

H3.1: Structural alterations within the "social brain" areas will be observed in ASD compared to the TD group, particularly:

H3.1a: The decreased thickness of cortical regions within the mentalizing and emotional processing networks (STS, TPJ, mPFC) will be observed in people with ASD compared to the TD group.

H3.1b: The decreased volume of subcortical structures (AMY) within the emotional processing network will be observed in people with ASD compared to the TD group.

H3.2: Alterations in the engagement of social brain networks related to communicative and affective cues perception will be observed in autism, such as:

H3.2a: Observation of communicative interaction between two point-light agents will elicit lower activation of the mentalizing network, including TPJ, mPFC and

subregion of the pSTS specialized for the intentionality recognition in people with ASD compared to TD participants.

H3.2b: Observation of affective exchange between two point-light agents will elicit lower activation of the amygdala (emotional processing network) in people with ASD compared to TD participants.

H3.2c: Observation of non-communicative actions of two point light agents will elicit smaller activation of the pSTS region (social perception network) in people with ASD compared to TD participants.

Q4: Can cognitive difficulties observed in individuals with ASD be differentiated from the ones observed in patients with schizophrenia?

H4.1: Social cognitive deficits are non-specific for autism, such as:

H4.1a: Compared to TD, participants with SCZ will present decreased emotion recognition abilities

H4.1b: Compared to TD, participants with SCZ will present decreased theory of mind abilities.

H4.2: Individuals with SCZ will present a higher level of neurocognitive deficits than the ASD group, such as:

H4.2a: Compared to TD participants, SCZ participants will present a decreased level of neurocognitive functioning.

H4.2b: Compared to ASD participants, SCZ participants will present a decreased level of neurocognitive functioning.

H4.3: Decreased ability to recognize communicative intentions and affective state from biological motion will be observed in autism compared to schizophrenia, such as:

H4.3a: Decreased recognition of communicative gestures presented by a single PLW agent will be observed in ASD compared to SCZ participants.

H4.3b: Decreased recognition of communicative actions presented by dyadic PLWs will be observed in ASD compared to SCZ participants.

H4.3c: Decreased recognition of affective states presented by a single PLW agent will be observed in ASD compared to SCZ participants.

4.2. General Outline of the Research Methodology

The analyses which allowed to respond to research questions Q1, Q2 and Q3 were part of the research project titled "From biological motion processing to theory of mind - neural and behavioral correlates of social cognitive deficits in individuals with autism spectrum disorders." [NCN signature: 2018/31/N/HS6/03757, P.I. Małgorzata Krawczyk]. In the course of the project, we compared two groups of adult participants: people with a diagnosis of autism spectrum disorders (ASD group) and typically developing participants (TD group). The study included a behavioral assessment of social cognitive and neurocognitive functioning, that was followed by a neuroimaging assessment, in which neural underpinnings of social cognitive processes were evaluated using a magnetic resonance imaging (MRI) technique. Additionally, people in the ASD group took part in a clinical interview prior to their inclusion in the study. The behavioral and clinical assessment were conducted at the Institute of Psychology, Polish Academy of Sciences, while the neuroimaging assessment was conducted at the Laboratory of Brain Imaging at the Nencki Institute of Experimental Biology, Polish Academy of Sciences. Behavioral and MRI parts of the study were conducted by the PhD candidate. The clinical interviews were

conducted interchangeably by two licensed psychologists and coordinated by the PhD candidate.

To address the question about the specificity of the SC difficulties in the autistic population (Q4), we used behavioral data gathered during a project on social cognition in schizophrenia [NCN signature: 2016/23/D/HS6/02947, PI dr hab. Łukasz Okruszek, prof. IP PAN] in which the PhD candidate was part of the team conducting the behavioral assessment. Similarly to the first project, the study investigated social cognitive impairments in people with schizophrenia (SCZ group) compared typically to developing participants (TD group).

In both studies, participants in the control groups were healthy adults without known history of psychiatric or neurodevelopmental diagnoses, recruited via social media platforms. The ASD group consisted of adult participants with no co-occurring intellectual impairment, recruited from local therapy centers and social media self-help groups. SCZ participants were recruited from outpatients treated at the Institute of Psychiatry and Neurology in Warsaw and online advertisements. Participants in the clinical groups provided a formal confirmation of their autism or schizophrenia diagnosis. The diagnosis was further corroborated during a clinical interview using the Polish version of the Autism Diagnosis Observation Schedule, Second Edition (ADOS-2; Chojnicka & Pisula, 2017) in the ASD group or Positive and Negative Syndrome Scale (PANSS; Kay et al., 1987) in the SCZ group. Mean ADOS and PANSS scores are presented in Table 3 (ASD) and Table 4 (SCZ), respectively.Table 3 was reproduced from Krawczyk et al., 2025.

Table 3

ADOS scores of the individuals in the ASD group.

ADOS Scale	min	max	mean	SD
ADOS - SA	2	19	8.69	3.97
ADOS - RRSB	0	5	2.21	1.52
ADOS - total	3	22	10.9	4.97
AQ	17	44	35.00	7.10

Note: Table reproduced from: Krawczyk, M., Pinkham, A., Golec-Staśkiewicz, K., Wysocka, J., & Okruszek, Ł. (2025). Recognizing communicative intentions from single-and dyadic point light displays in autistic adults. *Social Neuroscience*, 1-13.

Table 4

Positive and Negative Syndrome Scale scores in the SCZ group presented according to a five-factor model.

Factor	min	max	mean	SD
Positive symptoms	5	29	14.77	6.21
Negative symptoms	8	39	16.39	6.09
Disorganization	10	32	19.04	5.55
Excitation	8	24	12.96	3.83
Affective symptoms	8	28	17.37	5.67

Both projects used an overlapping set of social cognitive and neurocognitive measures, which allowed for the direct comparison of the data.

Behavioral testing was completed in a fixed order during one session which lasted approximately 1.5-2h, depending on the pace at which the participant went through the assessment. Behavioral assessment included a validated battery of neurocognitive (MATRICS Consensus Cognitive Battery; Jędrasik-Styła et al., 2015) and social cognitive

measures (Social Cognitive Psychometric Evaluation Study; Pinkham et al., 2018), along with the paradigms assessing the recognition of intention and affective state from biological motion. Additionally, a set of self-administered measures related to social cognitive bias were handed to the participants at the end of the behavioral session.

Neuroimaging assessment lasted approximately 1.5h, and was divided in two scanning sessions with a short break in between. The scanning protocol included an anatomical T1-weighted scan, a paradigm tapping the ability to recognize intentional and affective cues from biological motion (Social Perception and Interaction Database; Okruszek & Chrustowicz, 2020), and a set of localizer tasks for basic social perception (BioLoc, Deen et al., 2015), emotional processing (HCP-EMO, Barch et al., 2013) and theory of mind (HCP-SOC, Barch et al., 2013; Why How, Spunt & Adolphs, 2014).

All participants signed an informed written consent and were reimbursed for their participation in the study (100 PLN for each meeting, excluding the clinical assessment). Data in both projects were gathered in compliance with the Helsinki Declaration and approved by the Ethics Committee at The Institute of Psychology, Polish Academy of Sciences [document numbers: 17/10/2019, 11/12/2016].

Data gathered during both projects was analyzed to address the outlined research problems.

Q1: To address the issue of potential difficulties in the recognition of communicative intentions in the autistic population, we compared the performance of ASD and TD participants on a set of neurocognitive and social cognitive measures, including measures of emotion and communicative intention recognition from biological motion. The analysis is described in detail in Chapter 5.

Q2: In order to investigate the social cognitive bias in individuals with autism in the context of communicative intention recognition, we further analyzed the difference between ASD and TD participants on a set of self-report and vignette-based measures of social cognitive bias as well as secondary scores derived from performance-based measures. The analysis is described in Chapter 6.

Q3: To investigate neural correlates of social information processing in individuals with ASD, we analyzed the pattern of structural differences and functional activations related to processing of communicative intentions between well-matched groups of ASD and TD participants. The neuroimaging analysis is described thoroughly in Chapter 7.

Q4: To address the problem of the specificity of SC difficulties in people with autism, we compared the performance of the ASD and SCZ groups on the set of measures of social perception, emotion recognition, theory of mind and recognition of communicative intentions from biological motion. The analysis is presented in Chapter 8.

Chapter 5. Social Cognition and Communicative Intention Inference in Autism

Q1: Is autism related to decreased recognition of communicative intentions from biological motion?

The following chapter was based on the previously published article: Krawczyk, M., Pinkham, A., Golec-Staśkiewicz, K., Wysocka, J., & Okruszek, Ł. (2025). Recognizing communicative intentions from single- and dyadic point light displays in autistic adults. *Social Neuroscience*, 1–13. https://doi.org/10.1080/17470919.2025.2491676

Methodology (5.2) and Results (5.3) were included with minimal edits and adjustments. Moreover, Discussion (5.4) includes an overview of the main findings that was based on the Discussion section in the quoted article.

5.1. Introduction

As discussed in Chapter 2., social cognitive deficits constitute a central part of autism phenotype (Morrison et al., 2021; Sasson et al., 2013). However, the extent and uniformity of these deficits are still a matter of an ongoing discussion. Moreover, most of the available studies focus on facial emotion recognition and theory of mind abilities. At the same time, less is known about the ability to recognize communicative cues from the biological motion, which is considered a prerequisite for more complex forms of mental state inference (Pavlova, 2012). Although meta-analyses confirmed that recognizing specific social information, including affective state, from the whole-body motion might be particularly affected in people with autism (Federici et al., 2020), the mechanisms of potentially aberrant processing of communicative intention recognition are less known. Moreover, despite a postulated hierarchical nature of social cognition (Schurz et al., 2021), a

thorough understanding of specific pathways leading from disrupted detection of communicative cues and mentalizing difficulties in autism is also lacking.

To address this gap in the literature, we implemented a novel methodology focused on the ability to recognize communicative and affective cues from dyadic and single-agent biological motion stimuli. We hypothesized that people with autism will present a decreased recognition of communicative gestures presented by a single PLW agent (H1.1a), and by dyadic PLWs (H1.1b), as well as a decreased recognition of affective states from a single PLW agent (H1.1c). Moreover, we predicted that decreased ability to recognize communicative intentions from biological motion will be linked to difficulties in mental state inference in both ASD and TD participants (H1.2.). Additionally, we expected that in the ASD group decreased ability to recognize communicative intentions will be linked to higher levels of autism symptoms (H1.3.). Furthermore, we predicted a lower level of neurocognitive abilities (H1.4.) and social cognitive abilities, including theory of mind (H1.5a) and emotion recognition (H1.5b) in people with ASD compared to TD participants. Additionally, we expected that autism symptoms in the ASD group would be related to both neurocognitive (H1.6a) and social cognitive (H1.6b) functioning. Finally, we also hypothesized that communicative intention recognition will be related to autism symptoms indirectly, with social cognitive composite as a mediating variable (H1.7.).

5.2. Methodology

5.2.1. Participants

The analysis was conducted on data gathered from 58 participants who completed the full behavioral assessment.

The ASD group included 29 individuals (17F, 11M, 1NB; mean age 30.35, SD = 6.54, range: 19 - 42) with a clinical diagnosis of autism spectrum disorders without co-occurring intellectual disability (according to ICD-10 valid at the time of diagnosis: 26 with Asperger's Syndrome, 2 with infantile autism, 1 with pervasive developmental disorder). The ADOS-2 (Chojnicka & Pisula, 2017) assessment was completed by a certified diagnostician (mean ADOS-2 score = 10.90, SD = 4.97). In compliance with ADOS guidelines, in 5 cases in which assessment was already performed in adulthood, the examination was not repeated and the score was obtained from the diagnostic center with a written consent given by the participant. Out of 29 individuals, 25 reported having completed some kind of psychological intervention (details are presented in Supplementary materials in Supplementary Table 1). Moreover, 27 out of 29 autistic participants were either employed (part- or full-time) or still pursuing an educational degree; 2 people were unemployed and did not engage in any educational activity.

The control group consisted of 29 typically developing (TD) participants (17 F, 12M; mean age 28.41, SD = 6.54, range: 20 - 42), without a diagnosis of ASD and other developmental disorders, also among close family members, and without known history of psychiatric diagnoses. Only healthy individuals with AQ <= 23 were included in the control group. Groups were matched with regard to age ($t(56) = 1.17$; $p = .25$) and gender distribution ($X^2 = 1.44$; $p = .49$). Both autistic and non-autistic groups presented a high level of cognitive functioning, corroborated by their educational level, vocational engagement and neuropsychological tests discussed below.

5.2.2. Procedure

The procedure included a set of neurocognitive and social cognitive measures. To examine participants' neurocognitive capacity, The Polish version of the MATRICS Consensus Cognitive Battery (Jędrasik-Styła et al., 2015) was utilized. In line with our previous research (Okruszek et al., 2021), social cognitive capacity was assessed in participants using four tasks from the Social Cognitive Psychometric Evaluation Study (SCOPE; Morrison et al., 2019; Pinkham et al., 2018) available in Polish. Finally, to evaluate the participants' ability to adequately process complex information from point-light stimuli, three experimental tasks (Gestures from Biological Motion task; Jaywant et al., 2016; Communicative Interaction Database 5-AFC; Manera et al., 2015; Emotion from Biological Motion; Heberlein et al., 2004) were utilized. All tasks are described in detail below.

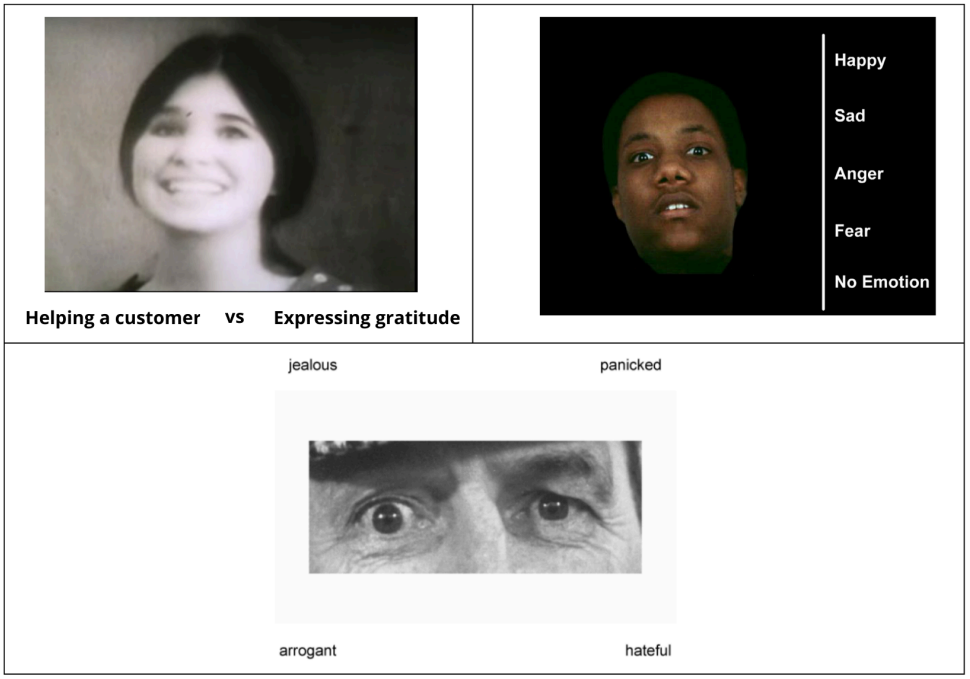
MATRICS Consensus Cognitive Battery (MCCB; Green et al., 2004). MCCB includes 10 tasks tapping into seven cognitive domains, including working memory (Wechsler Memory Scale-III Spatial; Letter-Number Span), processing speed (Trail Making Task - part A, Brief Assessment of Cognition in Schizophrenia - Symbol Coding, Animal Fluency), attention/vigilance (Continuous Performance Test-Identical Pairs; CPT), verbal learning and memory (Hopkins Verbal Learning Test-Revised; HVLT-R), visual learning and memory (Brief Visuospatial Memory Test-Revised; BVMT) and reasoning and problem solving (Neuropsychological Assessment Battery Mazes Task), and social cognition (Mayer-Salovey-Caruso Emotional Intelligence Test-Managing Emotions Branch; MSCEIT). The Polish version of the MCCB battery has been shown to have good psychometric properties (Jędrasik-Styła et al., 2015). While MCCB is primarily used in patients with schizophrenia, it has also been successfully applied in ASD participants (Eack

et al., 2013). Considering its multifaceted nature covering main cognitive domains, the battery is also well suited to comparisons between different clinical and non-clinical populations. While traditionally IQ measure is used as an indicator of cognitive functioning, we decided to use a battery of tasks more sensitive for selective difficulties in particular neurocognitive and social cognitive areas. As MCCB was incorporated in our study as a neurocognitive measure, the MSCEIT Social Cognition task has not been included in the current analyses. MCCB testing lasts around 60 minutes and is completed in a fixed order.

SCOPE measures (Pinkham, Harvey and Penn, 2018). Four SCOPE measures were included in the current study to examine participants' abilities with regard to Social Perception (Mini Profile of Non-Verbal Sensitivity; Bänziger et al., 2011), Emotion Recognition (ER-40; Kohler et al., 2003) and Theory of Mind abilities (Reading Mind in the Eyes, Baron-Cohen 2001; Hinting Task, Corcoran & Frith, 1995). All listed measures were shown to effectively distinguish people with autism from typically developing individuals, although with a substantial heterogeneity of performance (Morrison et al., 2019). We have effectively utilized this version of the SCOPE battery in our previous studies with patients with schizophrenia (Okruszek et al., 2023) and healthy individuals (Okruszek et al., 2021). Examples of the stimuli included in the SCOPE battery are presented on Figure 1.

Figure 1

Examples of the stimuli from MiniProfile of Non-Verbal Sensitivity (MiniPONS, top left), Emotion Recognition-40 (ER-40, top right) and Reading Mind in the Eyes (RMET, bottom).

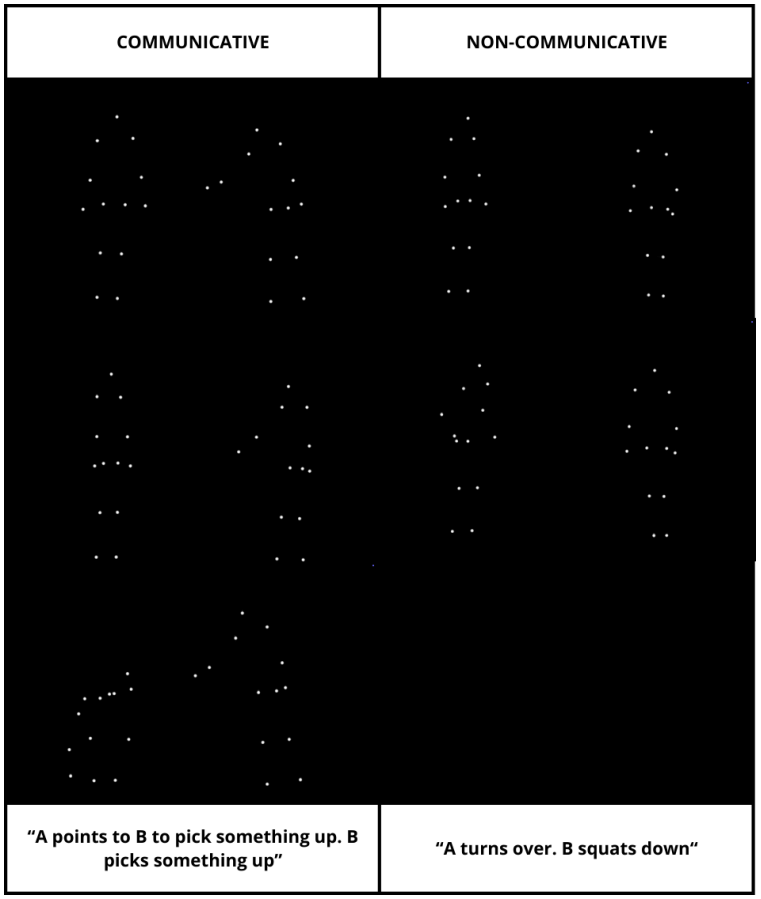


Communicative Interaction Database 5-AFC (CID-5; Manera et al., 2015). The original CID-5 task consists of 21 short videos (2.5-8s.) depicting two agents either engaging in a communicative interaction (COM) or performing individual actions (IND). Each person presented in CID-5 is depicted by 13 point-lights corresponding to the head, shoulders, elbows, wrists, hips, knees, and feet. The videos are presented twice, with a fixation cross between presentations. After viewing the videos, participants are required to (1) classify the stimuli as either communicative or non-communicative, and then (2) to select the most accurate description of the presented actions out of five options. Both questions are forced choice, and participants have to give an answer to proceed to the next question or the next item. To avoid potentially biasing participants by using an uneven

number of animations from each category (14 COM and 7 IND), a shortened version of the CID-5 was used in this study with 6 COM and 6 IND animations. The shortened version has been effectively utilized in our previous research with clinical populations (Okruszek et al., 2018). Examples of the stimuli are presented on Figure 2. A list of the 12 stimuli used in the present study is included in the Supplementary materials in Supplementary Table 2.

Figure 2

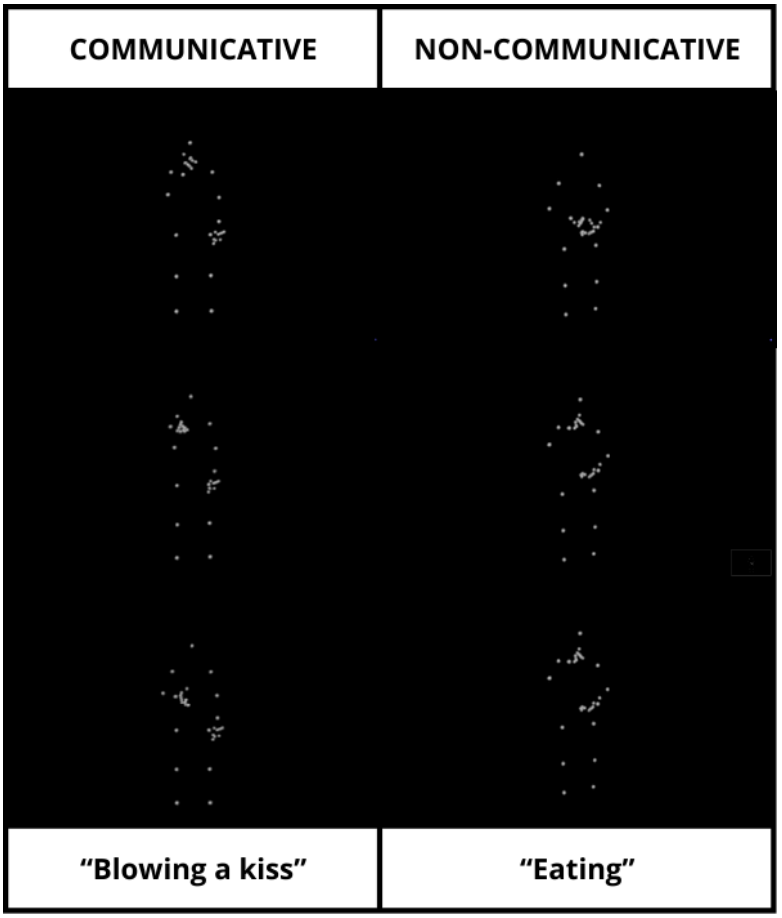
Examples of the communicative and non-communicative stimuli in the CID-5 task.



Gestures from Biological Motion task (Jaywant et al., 2016). The Gestures task utilized stimuli originally published by Zaini et al. (2013) and was originally developed to examine social cognition in patients with Parkinson's disease (Jaywant et al., 2016). Subsequently, the Polish version of the tasks was created for use to supplement the CID-5 assessment by investigating recognition of communicative intentions from a single PLW (Piejka, Piaskowska & Okruszek, 2022). During the task, participants are presented with 26 videos featuring a single PLW performing gestures with (COM) or without (IND) a communicative intention. The videos were created using 23 mapping points, including 13 markers for the head, shoulders, elbows, wrists, hips, knees, and feet, as well as 10 markers for finger joints in both hands. Each stimulus lasts between 2 and 5.5 seconds and was presented twice. Following the video presentation, participants were asked to (1) classify the gesture as either communicative or non-communicative and (2) to provide a verbal description of the gesture to the experimenter. While classification takes the form of a forced-choice task, unlike the CID-5 task, the interpretation of the specific action is done via an open-ended question. Participants were encouraged to produce an interpretation of the action, even if they were uncertain. Participants received 1 point for each correct classification and 1 point for each accurate description. For all participants, the accuracy of descriptions was evaluated by the same rater, who also provided ratings for the original Piejka et al. (2022) study. The full list of stimuli used in the current study is presented in Supplementary Table 3 and examples of the stimuli are presented on Figure 3.

Figure 3

Examples of the communicative and non-communicative stimuli in the Gestures task.



Emotion from Biological Motion (EMO-BM; Heberlein et al., 2004). The tasks consist of 24 videos (1-22 s.) with a single point-light walker moving in a way suggesting one of five emotional states: happy (4 videos), sad (6 v.), angry (6 v.), fearful (5 v.) or neutral (3 v.). Each presentation is preceded with a 1s. fixation cross, after which the point-light agent composed of 12 markers-white dots appears. After watching the video, participants choose one out of 5 answers referring to the emotional state presented by the

walker. As the paradigm involves a forced-choice task, participants are required to provide an answer in order to proceed to the next video. Because of the uneven number of items in each category, only the total score was calculated by summing all correct classifications.

The task was previously used in a comprehensive comparison of individuals with autism, schizophrenia, and a non-clinical control group, with autistic participants performing significantly worse than the control group (Pinkham et al, 2020).

5.2.3. Statistical Analysis

In the first step of the analysis, social cognitive and neurocognitive composite scores were calculated, by normalizing SCOPE and MCCB scores of the ASD group with regard to the TD participants. The difference between ASD and TD groups was then investigated based on the normalized scores in SCOPE and MCCB measures. No difference in between-group variances were found for neurocognitive composite ($F(1, 56) = 0.57$, $p = .45$) and social cognitive composite scores ($F(1, 56) = 2.14$, $p = .15$), as indicated by Levene's test. However, scores distribution deviated from normal distribution in the ASD group for social cognitive composite ($W = 0.92$, $p = .04$) and in the TD group for neurocognitive composite ($W = 0.01$, $p = .01$). Because of this, non-parametric Welch T-Test was used for a between-group comparison.

As both CID-5 and Gestures tasks involve two types of questions (recognition of intention vs recognition of specific action) and two types of stimuli (communicative vs non-communicative), in order to investigate all the potential effects, two repeated measures ANOVAs were calculated in a 2x2x2 scheme, with task (intention categorization (CAT) vs description of specific action (DESC)) and stimuli (communicative (COM) vs non-communicative (IND)) as within-subject factors and group (ASD vs TD) as a

between-subject factor. For significant effects, Bonferroni corrected post-hoc comparisons were investigated. Because the number of conditions in each factor was not bigger than 2, Sphericity tests were not included. In CID-5 variances between groups were equal in each category. In Gestures Levene's test revealed non-homogenous variances between groups only in case of accuracy in description of individual gestures ($F(1, 56) = 5.76$, $p = .02$).

Independent samples Student's T-Test with total accuracy as an outcome measure and group (ASD vs TD) as an independent variable was used to assess the differences in the EMO-BM task. Between-group variances were homogenous and scores distribution did not deviate from normality.

Additional exploratory analysis was performed to investigate a relationship between different domains of social cognition and neurocognition in ASD and TD participants. A hierarchical block regression model was implemented in both groups separately to investigate whether the performance in biological motion tasks predicted MCCB and SCOPE composite scores. In the subsequent steps, CID-5, Gestures task, and Emotion in BioMotion were entered into the model as predictors.

Finally, the association between the biological motion processing abilities and autism symptoms measured with AQ and ADOS scales was examined in the ASD group.

Due to technical reasons, we encountered some missing data - specifically, 4 participants (2 ASD, 2 TD) did not complete the EBM task, and one participant in the ASD group was not able to finish the CID-5 assignment. Moreover, data from one RMET (ASD) and one PONS assessment were not available. Finally, one person from the ASD group did not return with the AQ questionnaire. Because of the limited size of our sample, we decided not to exclude participants with missing values from other comparisons in which their scores were available.

Statistical power was calculated using the pwr package in R (Champely, 2020), which determined that a sample size of 26 participants or more is sufficient to detect a large effect (Cohen's $d \geq 0.8$).

5.3. Results

5.3.1. Social and Neurocognitive Profile

The ASD group did not deviate from the TD group by more than a half standard deviation in any of the tasks included in the current study.

No between-group differences were found for composite scores in neuro- ($t(55) = 0.97$, $p = .34$, $d = .25$) and social-cognitive ($t(50) = -1.66$, $p = .10$, $d = -.44$) domains.

5.3.2. Inference of Communicative Intentions from Dyadic Point-Light Walkers

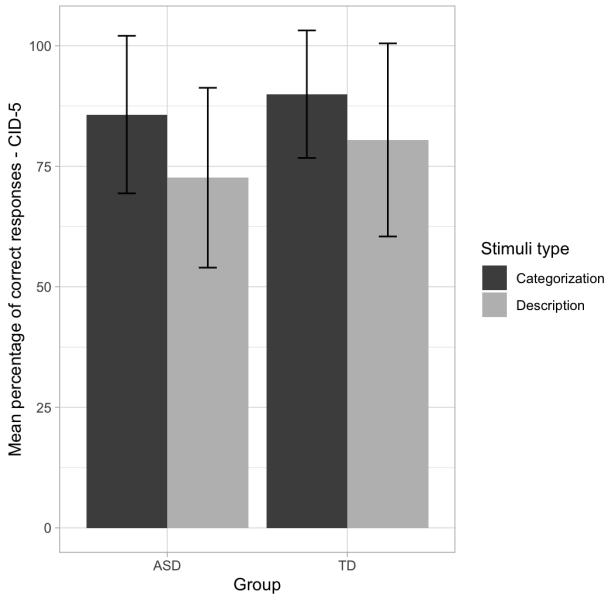
In the CID-5 task, main effects of the type of the Task ($F(1, 55) = 54.10$, $p < .001$; partial $\eta^2 = 0.50$; CAT > DESC), type of the Stimuli ($F(1, 55) = 13.12$, $p < .001$; partial $\eta^2 = 0.19$; IND>COM), and group $F(1, 55) = 6.34$, $p = .15$; partial $\eta^2 = 0.10$; TD > ASD) were observed.

Furthermore, there was a significant interaction between Task and Stimuli ($F(1, 56) = 17.86$, $p < .001$; partial $\eta 2 = 0.25$). Post-hoc comparisons indicated that accuracy was higher in individual than in communicative stimuli only in case of description ($t = -5.05$, $p < .001$, SE = 0.19, Cohen's $d = -1.01$), but not in case of categorization ($t = -1.53$, $p = .73$, SE = 0.19, Cohen's $d = 0.30$).

Figure 4 presents the mean percentage of correct responses in Categorization and Description subtasks in the ASD and TD groups.

Figure 4

Mean percentage of correct responses in Categorization and Description subtasks in CID-5 in ASD and TD groups.



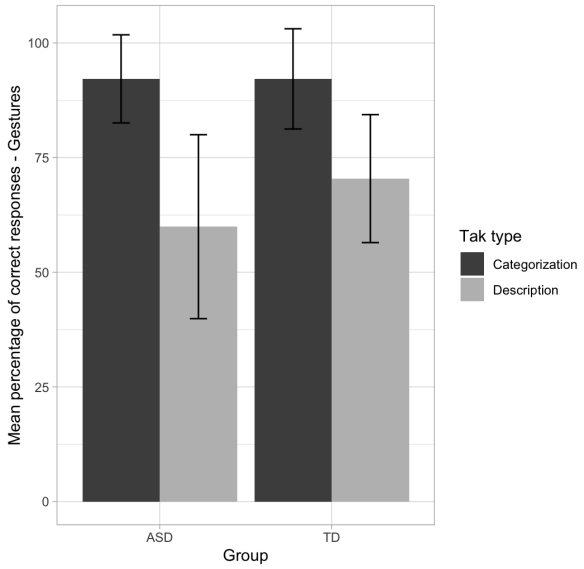
5.3.3. Inference of Communicative Intentions from a Single Point-Light Walker

In Gestures, main effects of Task ($F(1, 56) = 216.31$ $p < .001$; partial $\eta 2 = 0.79$; CAT > DESC) and Group ($F(1, 56) = 4.88$, $p = .03$; $\eta 2 = 0.08$; TD > ASD) were found. Furthermore, a significant Task x Group interaction was observed ($F(1, 56) = 8.15$ $p = .06$; $\eta 2 = 0.13$). Post-hoc comparisons confirmed that the accuracy was higher in TD group compared to ASD group only in the description task ($t = -3.49$, $p = .004$, SE = 0.39, Cohen's $d = -0.74$), but not in the categorization task ($t = 0.00$, $p = 1.00$, SE = 0.39, Cohen's $d = 0.00$).

Figure 5 illustrates the mean percentage of correct responses of stimuli categorization and description in the ASD and TD groups.

Figure 5

Mean percentage of correct responses in Categorization and Description subtasks in Gestures task in ASD and TD groups.



5.3.4. Inference of Affective State from a Single Point Light Walker

There was no between-group difference in total EMO-BM score ($t(1,52) = -1.96$, $p = .06$).

5.3.5. Association Between Social Cognitive Processes

In the ASD group, CID-5 performance explained 24% of social-cognitive performance ($F(1, 26) = 9.56$, $p = .005$). Introduction of additional BM tasks did not significantly increase the amount of the variance explained by the model. No association between BM variables and social cognitive performance was observed in the TD group.

The reverse pattern was found for neurocognitive performance - no association between BM tasks and neurocognitive performance was observed in ASD group, while a model with Emotion in BioMotion (*beta* = .58 $p = .001$) explained overall 31% of variance in neurocognitive performance in TD participants ($F(1, 25) = 12.75$ $p = .001$).

Correlation measures between BM measures and composite scores are presented in Table 5.

Table 5

Correlation between biological motion (BM) measures and social-cognitive and neuro-cognitive composite scores in the autism (ASD) and typically developing (TD) groups.

	ASD		TD	
	Social-cognitive composite	Neurocognitive composite	Social-cognitive composite	Neurocognitive composite
CID-5	$r = 0.52$, $p = 0.005$*	$r = 0.10$, $p = 0.63$	$r = 0.09$, $p = 0.63$	$r = 0.35$, $p = 0.06$
Gestures	$r = 0.44$, $p = 0.02$*	$r = 0.27$, $p = 0.15$	$r = -0.06$, $p = 0.76$	$r = 0.04$, $p = 0.85$
EMO-BM	$r = 0.38$, $p = 0.05$ *	$r = 0.04$, $p = 0.83$	$r = 0.19$, $p = 0.34$	$r = 0.58$, $p = 0.001$*

Note: CID-5 - Communicative Interaction Database 5-AFC; Gestures - Gestures task; EMO-BM - Emotion from Biological Motion

5.3.6. Association with Symptoms

No association between AQ and biological motion tasks or social cognitive composite score was found in the ASD group. However, a positive association between AQ score and neurocognitive composite score was observed ($r = .38$, $p = .047$).

Furthermore, no direct association was found between biological motion tasks and ADOS scores. However, the correlation between ADOS and both neuro- ($r = -.60$, $p < .001$) and social-cognitive ($r = 0.50$, $p = .006$) scores were found. Given the previously observed association between CID-5 and social-cognitive performance in this group, a mediation model with CID-5 as an independent variable, ADOS as a dependent variable and social cognitive composite score as a mediator was tested using PROCESS 4.2 macro and revealed

a significant indirect effect of CID-5 on ADOS via the social cognitive composite score (beta = -.26, CI = [-.72, -.01]).

5.4. Discussion

In the presented analysis, we explored a novel angle for analysis of communicative intention recognition in autistic adults. Two paradigms inspecting the ability to detect communicative intentions from biological motion were introduced, along with a biological motion task assessing emotion recognition.

In line with our predictions (H1.1.), some evidence for difficulties in communicative intention recognition in autism was found. A main effect of the group was observed in both biological motion tasks evaluating intention recognition – that is, people with autism presented a lower overall accuracy in the single-agent as well as in the dyadic point-light task, which was predicted in H1.1a and H1.1b, respectively. However, an additional interaction between group and type of the task was also revealed in the single-agent paradigm – people with autism scored lower than the typically developing group only when they were asked to describe in their own words what the agent was doing, but not when they were categorizing its actions as communicative or non-communicative. Importantly, in contrast to our predictions in H1.1c, we found no difference between ASD and TD groups in the ability to detect basic emotions from the movement of one point-light agent. This surprising effect might point to the fact that recognizing communicative intentions from biological motion requires more effort than processing basic emotions and thus might be a more sensitive and precise indicator of social cognitive difficulties in autistic populations. Importantly, some evidence for an association between recognition of communicative intention from biological motion and autism symptoms was also found. Moreover,

conversely to our predictions (H1.4.), no significant differences between ASD and TD participants were observed with regard to the neurocognitive functioning level. Similarly, contrary to our hypotheses (H1.5.), no differences were observed between ASD and TD participants in theory of mind (H1.5a) and emotion recognition (H1.5b).

Conversely to our predictions (H1.3.), CID-5 was not related to the level of autism symptoms as measured by ADOS protocol. However, in line with H1.7., we observed a significant, indirect effect with a social cognitive composite mediating the relationship between CID-5 and ADOS. Importantly, in line with H1.2., CID-5 score explained 24% of the social cognitive composite score in the ASD group. Finally, although no difference was observed between autism symptoms and social cognitive performance (H1.6b), the AQ score in the ASD group was significantly related to the neurocognitive composite in line with predictions H1.6a.

Taken together, results of our study suggest that difficulties in processing social cues from biological motion can be observed even in a group of individuals with autism who cannot be distinguished from typically developing adults based on neurocognitive and social-cognitive composite scores. Thus, incorporating tasks that require automatic and intuitive detection of communicative cues into the social cognitive assessment might be especially beneficial in case of high-functioning autistic adults, in whom higher-order difficulties might go undetected.

Chapter 6. Social Cognitive Bias in Autism

Q2: Is social cognitive bias decreased in autism compared to the typically developing population?

6.1. Introduction

While a lot of research has been devoted to investigate abilities associated with objective social cognitive capacity in people with autism (e.g. meta-analyses: Velikonja et al., 2019; Yeung, 2022), the current state of knowledge about the presence of social cognitive bias in this group is far from consistent. Available results pointed toward both an increased level of social cognitive bias in autism (Sahuquillo-Leal, 2019), and no difference between ASD and TD in this area (Zajenkowska et al., 2021). Importantly, with purely cognitive perspective considered, some authors indeed reported the "higher rationality" phenomenon in the ASD group, with less reliance on intuition, and decreased proneness to biases and heuristics present in the typically developing population (Rozenkratz et al., 2022), and more "rational" attitudes in the ultimatum game (Jin et al., 2020). However, it has not been established whether this phenomenon can be extended to the social cognitive domain.

At the same time, a vital importance of social cognitive bias in predicting a functional outcome was previously demonstrated especially in people with schizophrenia (Buck et al., 2016a), but also in other clinical populations (Trotta et al., 2021). Importantly, although objective social capacity and social cognitive bias are related, they are not equivalent (Green et al., 2012), and might explain different aspects of social functioning (Okruszek et al., 2022). Additionally, some evidence points toward a mediating role of social cognitive bias on the relationship between social cognitive capacity and social

functioning (Birch et al., 2025). To address the research gap regarding the presence of social cognitive bias in people with autism, we used a set of self-report and vignette-based measures related primarily to negative and hostile attributions in the same group of participants described in Chapter 5.

We predicted decreased social cognitive bias in ASD compared to TD participants, including lower bias scores in self-report (H2.1a) and vignette based (H2.1b) measures. Moreover, with regard to performance-based measures, we expected a lower negativity bias in facial emotion recognition (H2.1c) and lower intention recognition bias (H2.1d). Additionally, we predicted a relationship between self-report, vignette-based and performance-based measures of social cognitive bias in both ASD and TD groups (H2.2). Finally, we expected that in the ASD group, social cognitive bias will be related to the level of autism symptoms (H2.3).

6.2. Methods

6.2.1. Participants

The group of participants included in the current analyses was fully overlapping with the one described in Chapter 5., section 5.2.3.

6.2.2. Measures

In the presented analysis we used three tasks measuring social cognitive bias: one self-report task (Davos Assessment of Cognitive Biases, Gawęda et al., 2018) and two vignette-based measures (Ambiguous Intention Hostility Questionnaire, Combs 2007; Cognitive Biases Questionnaire for Psychosis, Peters et al., 2014). The tasks were previously utilized mostly in studies with people with schizophrenia. The tasks and scores were selected in order to tap the tendency to make intentional, hostile attributions in

response to the actions of other people. The situations described in CBQP and AIHQ are ambiguous, and might be interpreted with a varying level of intentionality. Additionally, to assess the social cognitive bias in recognition of emotion and intention, three bias indicators from tasks introduced in Chapter 5. were used: misclassification rate from the ER-40 task, and a bias measure from CID-5 and Gestures task described below.

Davos Assessment of Cognitive Biases Scale (DACOBS-18; Gawęda et al., 2018). DACOBS-18 is a self-report questionnaire measuring cognitive distortions. A short version was used, with 18 items referring to four factors: (1) subjective cognitive problems, (2) safety behaviors, (3) attributional biases and (4) social cognition problems. Participants are asked to rate 18 statements on a Likert scale from 1 (strongly disagree) to 7 (strongly agree) in terms of how accurately each sentence describes their thinking patterns. Apart from the total score, the Attributional Bias subscale score was analyzed, as this subscale best reflects a generalized tendency to perceive actions of other people as threatening (e.g. "People cannot be trusted").

Cognitive Biases Questionnaire for Psychosis (CBQP; Peters et al., 2014). CBQP is a tool tapping 5 types of social cognitive biases: (1) jumping to conclusions, (2) intentionalizing, (3) catastrophizing, (4) emotional reasoning and (5) dichotomous thinking, that can be further grouped to 2 main factors: (1) threatening events and (2) anomalous perception. Participants are presented with 30 brief descriptions of ambiguous situations that might possibly trigger distorted interpretations (e.g. "Imagine you are at home; everything is quiet when you hear a sudden fast banging on the walls."). With every item, one out of three possible interpretations are chosen, reflecting either absence of bias ("The neighbours could be doing some kind of home improvements"), possible presence of bias ("The neighbours

might be trying to tell me something"), and presence of bias ("The neighbours are doing this deliberately to upset me").

Ambiguous Intention Hostility Questionnaire (AIHQ; Combs et al., 2007). AIHQ consists of 5 short stories illustrating ambiguous social situations (e.g. "You've been at a new job for three weeks. One day, you see one of your new co-workers on the street. You start to walk up to this person and say hello, but then she/he passes by you without saying hello."). Each story is followed by two open-ended questions, in which participants are asked about their interpretation of the described situation and how they would react if it happened to them. Three questions on the Likert scale are also included, in which participants have to assess the level of intentionality (scale from 1 to 6) and blame (scale from 1 to 5) they would attribute to someone in a similar situation, as well as how upset they would be in this situation (scale from 1 to 5). Because of low psychometric properties of the scores calculated based on the open-ended questions (Ludwig et al., 2017), only a Blame Score calculated as an average of the three Likert scales was used in the presented analysis.

Performance-Based Measures. To assess social cognitive bias reflected in the emotion recognition we calculated an additional bias score based on the misclassification errors produced by the participants in the ER-40, which was a part of SCOPE battery utilized to examine emotion recognition from static faces and has been described thoroughly in Chapter 5. The details of how the indicator was calculated are presented in the Statistical Analysis section.

Moreover, in order to assess the bias in recognition of communicative intentions conveyed by single-agent and dyadic point-light displays, a Signal Detection Theory (Stanislaw & Todorow, 1999) measure of criterion (*c'*) score was calculated based on the responses in categorization subtasks in CID-5 (Manera et al., 2015) and Gestures (Jaywant

et al., 2016). The *c'* score reflects the threshold for detecting communicative intentions, i.e. the tendency to classify each display as either communicative (negative values of c') or non-communicative (positive values of c'). The details of *c'* score computation are provided in the Statistical Analysis section. The full description of CID-5 and Gestures tasks are included in Chapter 5., section 5.2.2.

6.2.3. Statistical Analysis

Between-group differences in specific social cognitive measures assessing hostility and intention attributions (CBQP total, CBQP-Intentionalizing, DACOBS-18 total, DACOBS-18-Attribution Bias, AIHQ-Blame Score) were calculated using a t-Student task with Bonferroni correction for multiple comparison.

Bias toward a given emotion (e.g. anger) was quantified using misclassification rate. Occurrences of each type of misclassification in each participant were first summed, and then divided by 8 (number of presentations is in each category). Then, incorrect classifications were summed across each label (e.g. incorrect classifications of happiness, fear, sadness, and happiness as anger) and divided by 4 (number of non-target labels). Between-group differences in the emotion misclassifications were then investigated with ANOVA in a 5x2 scheme, with emotion (happiness vs anger vs fear vs sadness vs neutral) as a within-subject factor and group (ASD vs TD) as a between-subject factor.

Criterion (*c'*) scores in CID-5 and Gestures were calculated based on the Hit Rate (correct identifications of communicative intentions) and the False Alarm Rate (incorrect identification of non-communicative stimuli as communicative), according to a Signal Detection Theory procedure (Stanislaw & Todorow, 1999). The Hit Rate (H) and False Alarm Rate (F) indices were standardized with regard to a total number of trials. Correction

of the extreme values was performed in line with a loglinear approach described in Stanislaw and Todorov (1999), with a value of 0.5 added to both the number of hits and the number of false alarms, and a value of 1 added to both the number of signal trials and the number of noise trials. The criterion score was then obtained as a negative value of a sum of standardized H and F divided by 2 *(-(Z(H)+Z(F)/2)*. Criterion is typically used as a bias measure, as it refers to a threshold above which display is classified as signal (communicative intention) is present, with 0 indicating an unbiased decision maker, values below 0 indicate a tendency to over-detect the signal (liberal bias), and values above 0 indicate a tendency to under-detect it (conservative bis). To investigate whether each group exhibits a significant bias for either detecting a signal (classifying stimuli as communicative) or not detecting a signal (classifying stimuli as non-communicative), a one sample t-test was calculated with a test value set to 0.

Relationship between autism symptoms and social cognitive bias was assessed by calculating the Pearson correlation measures between AQ, ADOS, DACOBS-18, CBQP-Total and AIHQ. Additionally, to assess the association between autism symptoms, bias in intention recognition and bias toward angry facial expressions, Pearson correlation between AQ, ADOS, CID-5 criterion, Gestures criterion and ER-40 anger misclassifications was calculated. Significance level was adjusted using a Bonferroni correction for a family of 6.

Similarly, to investigate a relationship between self-report, vignette-based and performance-based measures of bias, correlation between DACOBS-18, CBQP, AIHQ, anger misclassifications in ER-40, criterion in CID-5 and criterion in Gestures was calculated. Significance level was adjusted using a Bonferroni correction for a family of 12.

6.3. Results

6.3.1. Social Cognitive Bias

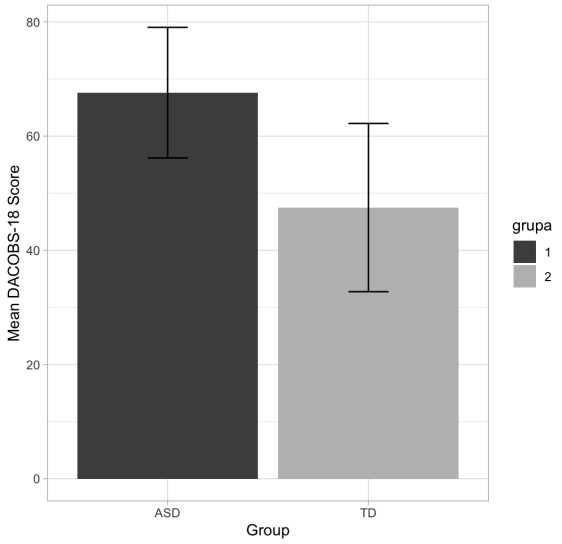
No significant differences were observed between the ASD and TD group in total CBQP score ($t(55) = 1.38$, $p = .43$, Cohen's $d = 0.37$), AIHQ-Blame Score ($t(55) = 0.67$, $p = 1$, Cohen's $d = 0.18$) and CBQP-Intentionalizing score ($t(55) = 1.13$, $p = .65$, Cohen's $d = .30$).

The ASD group had a significantly higher total DACOBS-18 score ($t(55) = 5.75$, $p = .005$, Cohen's $d = 1.52$) and DACOBS-Attribution Bias score ($t(55) = 2.80$, $p = .015$, Cohen's $d = 0.74$) compared to TD.

Difference between ASD and TD group with regard to the DACOBS-18 score is presented on Figure 6.

Figure 6

Difference in the mean DACOBS-18 score between ASD and TD group.



6.3.2. Performance-Based Measures of Bias

Bias in emotion recognition - misclassifications. A significant effect of emotion was found ($F(4, 224) = 11.46$, $p < .001$), with no significant effect of a group ($F(1, 56 = 1.07$, $p = .31$) or an interaction between group and emotion ($F(4, 224) = 2.17$, $p = .07$) observed.

Post hoc comparisons with a Bonferroni correction confirmed a higher rate of misclassifications for anger compared to sadness ($p = .002$) and neutral face expression ($p = .007$), as well as higher rate of misclassifications for happiness compared to fear ($p = .003$), sadness ($p < .001$) and neutral face expression ($p < .001$).

Bias in intention recognition. No significant between-group differences were found with regard to the criterion measure in the single-agent (Gestures; $t(55)= 0.88$, $p = .19$) and dyadic (CID-5; $t(55) = -0.69$, $p = .49$) point-light walkers.

In the ASD group, criterion measure in CID-5 did not differ significantly from 0 ($t(27) = 0.51$, $p = .62$, Cohen's $d = 0.42$; M = 0.04, SD = 0.41). However, the criterion measure in Gestures was significantly above 0 ($t(28) = 3.50$, $p = .002$), which pointed toward a bias in classifying presented actions as non-communicative.

In the TD group, neither CID-5 criterion ($t(28)=1.75$, $p = 0.09$), Cohen's $d = 0.33$, M = 0.11. SD = 0.33), nor Gestures criterion ($t(28) = 1.76$, $p = 0.09$, Cohen's d = 0.31; M = 0.01, SD = 0.31) were significantly different from 0.

6.3.3. Relationship Between Social Cognitive Bias, Intention Recognition Bias and Emotion Recognition Bias

No significant correlations between measures of bias were observed after Bonferroni correction for multiple comparisons had been implemented. A full matrix of zero-order correlations is provided in Table 6.

Table 6

Correlation between questionnaire and performance-based measures of social cognitive bias in participants with autism (ASD) and typically developing participants (TD). None of the correlations was significant after Bonferroni correction (p > .05).

	ER-40 Anger Bias - Misclassifications	Intention Recognition Bias CID-5	Intention Recognition Bias - Gestures
		ASD	
CBQP-Total Score	*r* = 0.04	*r* = -0.46	*r* = -0.31
DACOBS-18 - Total Score	*r* = -0.022	*r* = -0.01	*r* = -0.74
AIHQ-BS	*r* = -0.41	*r* = 0.06	*r* = -0.12
		TD	
CBQP - Total Score	*r* = 0.26	*r* = -0.29	*r* = 0.11
DACOBS-18 - Total Score	*r* = -0.01	*r* = -0.18	*r* = 0.12
AIHQ-BS	*r* = 0.32	*r* = 0.20	*r* = 0.35

Note: CBQP - Cognitive Bias Questionnaire for Psychosis; DACOBS 18 - Davos Assessment of Cognitive Bias Scale; AIHQ-BS - Ambiguous Intentions Hostility Questionnaire; ER-40 - Emotion Recognition-40; CID-5 - Communicative Interaction Database - 5AFC; Gestures - Gestures Task.

6.3.4. Relationship Between Autism Symptoms and Bias Measures in Individuals with Autism

No significant relationship between ASD symptoms and bias measures were observed after implementation of Bonferroni correction for multiple comparisons. A full matrix of zero-order correlations is provided in Table 7.

Table 7

Correlation between social cognitive bias measures and autism symptoms. None of the correlations was significant after Bonferroni correction (p > .05).

	AQ	ADOS
CBQP-Total Score	*r* = -21	*r* = 0.21
DACOBS-18 - Total Score	*r* = 0.20	*r* = 0.36
AIHQ-BS	*r* = 0.12	*r* = 0.16
CID-5 criterion	*r* = 0.26	*r* = 0.10
Gestures criterion	*r* = -0.02	*r* = -0.22

*Note:*CBQP - Cognitive Bias Questionnaire for Psychosis; DACOBS 18 - Davos Assessment of Cognitive Bias Scale; AIHQ-BS - Ambiguous Intentions Hostility Questionnaire; ER-40 - Emotion Recognition-40; CID-5 - Communicative Interaction Database - 5AFC; Gestures - Gestures Task; AQ - Autism Quotient; ADOS - Autism Diagnostic Observation Scale.

6.4. Discussion

In the presented analysis, social cognitive bias in autism was investigated using a set of self-report, vignette-based and performance-based measures in order to address a common assumption of an “increased rationality” and decreased proneness to biased thinking in autistic individuals that might potentially extend to both non-social and social

information processing (Rozenkratz et al., 2022). Thus, we predicted that measures of social cognitive bias in ASD individuals would be decreased compared to the TD group.

Contrary to our expectations (H2.1a), ASD group exhibited a higher level of self-reported social cognitive bias, measured by DACOBS-18 Total score and DACOBS-18 Attribution Bias subscale. Moreover, despite our predictions, no differences were observed between ASD group and TD group in vignette-based measures of social cognitive bias (H2.1b). Importantly, incorporated measures might tap the partially diverging mechanisms, with generalized negative assumptions about other people reflected in DACOBS-18, and the interpretation of ambiguous situations based on the contextual cues in CBQP and AIHQ.

Additionally, contrary to our predictions, no differences between ASD and TD groups were observed with regard to the negativity bias related to facial emotion recognition measured by misclassification rate (H2.1c), and bias in intention recognition from biological motion measured by criterion score (H2.1d). However, only in the ASD group criterion measure in the Gestures task was higher than 0, which might point toward an increased tendency to recognize presented PLD actions as non-communicative. Finally, contrary to our predictions, no significant association was observed between self-report, vignette-based and performance-based measures of SC bias (H2.2) in TD and ASD participants, as well as between measures of SC bias and level of autism symptoms in the autistic group (H2.3).

With all things considered, obtained results do not confirm the previously postulated decreased level of social cognitive bias and increased rationality that was reflected in few cognitive theories of autism (e.g. Crespi & Badcock, 2008; Ciaramidaro, 2014). While some evidence was found for potentially increased social cognitive bias in the ASD, the results should be scrutinized with regard to potentially conflated self-report measures.

Chapter 7. Neural Correlates of Social Cues Processing in Autism

Q3: What are the neural underpinnings of difficulties in intention recognition in people with autism?

7.1. Introduction

Available research results point toward possible alterations of the structural integrity, functional activity and connectivity patterns within social perception, emotional processing and mentalizing networks in people with autism (Philip et al., 2012; Sugranyes et al., 2011). These alterations are observed within the key regions associated with the "social brain", including STS, TPJ, mPFC and amygdala (Yang et al., 2015). Importantly, although difficulties in communicative intention recognition from biological motion might play an important role in abnormal social cognitive functioning in autism (Kauser et al., 2024; Yang et al., 2015), no study to date assessed the neural correlates of this ability in autistic population.

To address this gap, we investigated a pattern of differences between ASD and TD individuals in neural activity related to communicative and affective cues perception. The analysis was primarily focused on the specific subregions of the STS/TPJ complex associated with basic biological motion recognition (pSTS-BM), animacy recognition (pSTS-ANIM) and mental state inference (TPJ) as identified by the well-established localizer tasks (Barch et al., 2013; Deen et al., 2015; Sput & Adolphs, 2014). Additionally, to investigate specific activity within the emotion processing (Behrouzi et al., 2025) and mentalizing regions (Nijhof et al., 2018), between-group differences in amygdala and mPFC activity were also analyzed.

We expected to find a decreased cortical thickness of the superior temporal and middle frontal cortex (H3.1a) and decreased amygdala volume (H3.1b) in people with ASD compared to the TD group. Furthermore, we expected that observation of communicative dyadic PLWs will elicit a lower activation of the mentalizing network, especially within the TPJ, mPFC and pSTS subregion specialized for intention processing, in people with ASD compared to TD participants (H3.2a). Additionally, we predicted a lower activation of the emotional processing network, including decreased amygdala engagement, during affective exchange observation in people with ASD compared to TD participants (H3.2b). Finally, we expected to observe a lower activation of the social perception network, including the pSTS subregion specialized for biological motion, during the observation of individual actions of two point-light agents in individuals with ASD compared to the TD group (H3.2c).

7.2. Method

7.2.1. Participants

As neuroimaging data was not available for all ASD participants from the sample described in Chapter 5. and Chapter 6., only ASD participants and head-to-head matched TD participants for whom the full neuroimaging data was available were included in the currently presented analyses. The presented analysis included 42 participants from the ASD and TD group, matched with regard to their gender, age (+/- 2 years), and education level. Thus, the mean age (TD: M = 31.19, SD = 6.95; ASD: M = 31.19, SD = 7.13), mean years of education (TD: M = 14.86, SD = 2.15; ASD: M = 14.38, SD = 2.60) and gender distribution (13 F + 8 M in each group) did not differ significantly between groups.

7.2.2. Image Acquisition

Anatomical and functional imaging was conducted using a Siemens 3T Trio Tim scanner with a 32-channel head coil.

Standard anatomical three-dimensional T1-weighted images were collected with a magnetization prepared rapid gradient echo (MPRAGE) sequence. Following settings were used: repetition time [TR] = 2.53, echo time [TE] = 3.33, flip angle = 7 , field of view [FOV] = 100, matrix = 256 x 256, slice thickness = 1, voxel size = 1x1x1, reference line = 1.

Echo Planar Imaging pulse sequence sensitive to blood oxygen level-dependent (BOLD) contrast was used to collect task-based T2*-weighted functional data, with the following acquisition settings: TR= 1.5, TE = 29 , multi band [MB] acceleration factor = 3, percent phase FOV = 100, reconstruction matrix = 96, slice thickness = 2.2, spacing between slices = 2.2, number of slices = 40, voxel size = 2x2x2, phase encoding direction = j-. Identical settings were implemented for all paradigms.

7.2.3. Measures

To investigate the activity related to inference of social cues from the biological motion, we used a Social Perception and Interaction Task (SoPIT; Okruszek & Chrustowicz, 2020).

Four robust localizers, including two localizers from the Human Connectome Project (HCP) pipeline, were also used in order to pinpoint regions of interest (ROI) related to specific social cognitive processes. Activation maps from the main contrast in each task were used to extract specific subregions of the STS/TPJ complex responsible for basic biological motion recognition (Biological Motion Localizer task; Deen et al., 2015) and

intention and mental state inference (HCP-ToM; Barch et al., 2013; WhyHow; Spunt & Adolphs, 2014). Moreover, HCP-EMO (Barch et al., 2013) and Why How tasks were also used to localize the activity of amygdala and mPFC, respectively.

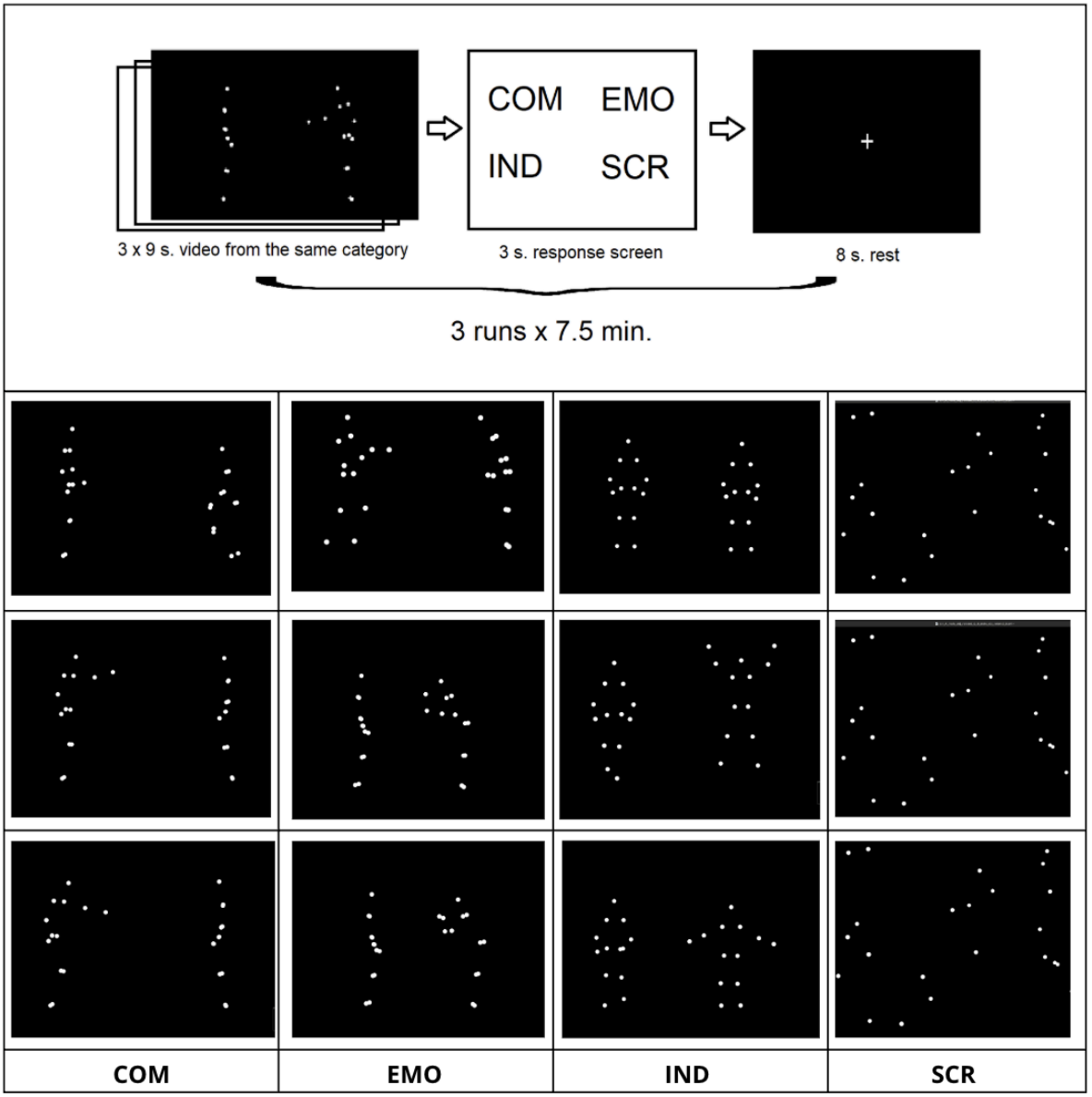
Social Perception and Interaction Task (SoPIT). The main paradigm utilized for the task-related functional neuroimaging analysis was designed using the stimuli from the Social Perception and Interaction Database (SoPID; Okruszek & Chrustowicz, 2020). SoPIT was designed as a tool to investigate different levels of social information processing, by examining activity in social perception, emotional processing and mentalizing brain networks in response to either nonsocial stimuli, dyadic individual actions and either neutral or affective communicative interactions. Four categories of displays representing varying aspects of social perception were included: (1) COM videos, presenting a stereotypical communicative interaction based on the communicative gesture of one of the point-light agents and corresponding response of other agent (e.g. A asks B to get up, B gets up), (2) EMO videos, presenting an affective exchange between two agents (e.g. A starts to shout and wave hand angrily at B, B starts to talk back), (3) IND videos, presenting individual actions of two PLWs (e.g. A is doing squats, B is doing jumping jacks), and (4) SCR videos, presenting a 100% scrambled motion of PLWs produced from COM, EMO and IND stimuli utilized in the remaining categories of the tasks.

Each of the COM, EMO and IND videos presents actions of two point-light walkers, each consisting of 13 white dots placed in the area of head, arms, elbows, wrists, hips, knees and ankles. The stimuli presented in the tasks was counterbalanced with regard to the gender of the presented actors (either two male or two female actors) and, in the case of the COM and EMO actions, the side of the screen where the agent initiating the interaction is placed.

The whole paradigm was divided into 3 runs and was performed in a mixed block/event-related design. Each block consisted of the presentation of three consecutive animations from the same category, displayed for a total time of 9 seconds. Stimuli presentation was followed with a 3-second response screen, during which participants were asked to classify the presented block of actions as either COM, EMO, IND or SCR using the response pads. Each stimulus was presented with no audio information and participants were asked to make their judgments only on the basis of the information presented by the point-light motion. Between the subsequent blocks of the tasks, a fixation cross was presented for 8 seconds. Overall, 15 stimuli were presented from each category during the task. Each run lasted 7.5 minutes, with a total time of 22.5 minutes with a short break between the runs. Prior to the completion of the task within the scanner, participants were familiarized with the stimuli and the structure of the task as well as completed one training block for each condition outside of the scanner. Exemplary stimuli used in the task is presented on Figure 7

Figure 7

Schematic presentation and examples of the stimuli from the Social Perception and Interaction Task.



Note: COM - communicative displays; EMO - affective displays; IND - non-communicative displays; SCR - scrambled displays

Biological Motion Localizer (BioLoc). The task is utilized as a localizer of the pSTS region specialized for BM processing (Deen et al., 2015). The task included animations of a single PLW presented with a frame rate of 30 Hz, using 13 markers placed in the locations of major joints, performing a simple action like walking or waving, as well as animations of rotating 3D point-light objects and scrambled motion of PLWs in control conditions. The stimuli were implemented in a blocked design, with 2-second animations presented in blocks of 9 videos from the same category and 0.25 second gap between each presentation. To ensure participants' engagement, during each block of trials participants are asked to press the response-pad button if the presented stimulus is the same as the one presented in the previous trial (one-back task). In total, 12 blocks lasting 20.25 seconds each are presented, with 18 seconds fixation time at the start, middle and in the end, which accounted for a total of 4.57 minutes presented in a single run.

Human Connectome Project - Social Cognition/Theory of Mind Localizer (HCP-SOC). The task was proposed by the HCP to identify the region responding to the intentional (vs random) actions of the presented agents, including the animacy-sensitive subregion of the pSTS, as well as mentalizing network regions including TPJ and mPFC (Barch et al., 2013). The paradigm includes a set of 20-second videos of geometric objects moving either in a way suggesting a meaningful interaction (ToM condition) or in a random way (Random condition). The task was presented in a blocked design and included two 3.27 minute runs with a short break between them. Participants were asked to evaluate each video with regard to the presence of meaningful interaction between the presented objects. Each run had 5 video blocks (2 ToM and 3 Random in the first run, and 3 ToM and 2

Random in the second run) with 5 fixation blocks lasting 15 seconds in between presentations.

Human Connectome Project - Emotion Processing (HCP-EMO). HCP-EMO is a localizer for the emotional processing network, and has a long-standing history of being used as an amygdala region localizer task (Barch et al., 2013). The task included pictures of facial emotional expressions and geometric shapes in a control condition. Three objects of the same type were presented simultaneously, and the participants were asked to choose one out of two objects at the bottom of the screen that is identical with an exemplary object presented on the top. Stimuli were presented in a blocked design, with 6 trials of the same type in each block, presented for 2 seconds with a 1 second interval. Before each block, a verbal task cue ("face" or "shape") was presented for 3 seconds. In total, each block lasted 21 seconds. In accordance with HCP protocol, two 2.5-min runs were presented, each including 6 blocks (3 face + 3 shape).

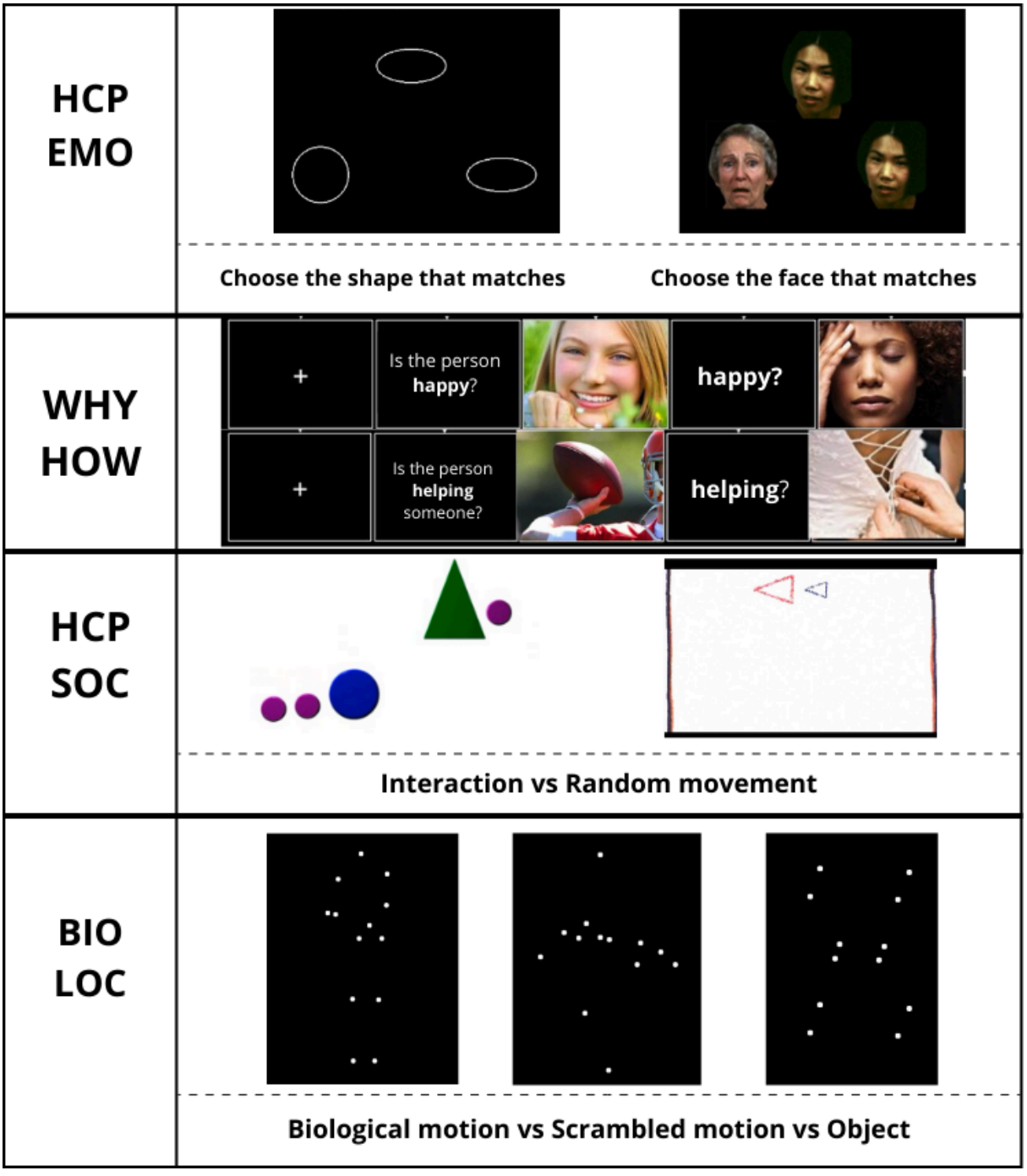
Why-How Task. The task was introduced as a functional localizer for a mentalizing network, including mPFC, TPJ and anterior STS (Spunt & Adolphs, 2014; Spunt & Lieberman, 2012 a, b). The task was presented in a blocked design, with 72 images presented in 16 blocks. Each block was preceded with either a WHY question, that related to internal states and motivations (e.g. "Is this person happy?") or HOW questions, that related to the type of the actions performed by the presented person (e.g. "Is this person pressing a button?"). Stimuli included pictures of either faces or hands, with 50% of pictures in each category. Images were presented for 1.7 seconds, with a short reminder between each stimulus in a block (e.g. "happy?", "pressing a button?"). Each block contained 5 presentations to which the correct answer was "yes", and 3 presentations to which the

correct answer was “no”. A single run (16 question blocks x 8 trials) was presented, with a total runtime of 5 min 12 seconds.

Before the neuroimaging session participants were instructed about the procedure and underwent a short training session for each task outside of the MRI scanner. Stimuli used in each localizer task is presented on Figure 8.

Figure 8

Schematic presentation and the stimuli from the localizer paradigms: Human Connectome Project - Emotion Processing (HCP EMO); Why How Task (WHY HOW); Human Connectome Project - Social Cognition (HCP SOC); Biological Motion Localizer. (Bio-Loc).



7.2.4. Data Preprocessing and Statistical Analysis

Structural MRI data were analyzed using FreeSurfer (FS) which is an automated brain image morphometric software used to perform a segmentation and parcellation of T1-weighted anatomic images (e.g. Dale et al., 1999; Fisch & Dale, 2000). It has been shown that surface-based analyses provided by the FS workflow may be more sensitive to the alterations of the cortical and subcortical structures in psychiatric populations, compared to the standard volumetric approach (Chen et al., 2022). It provides summary statistics of subcortical volume as well as cortical thickness. The FS software is documented and freely available online (http://surfer.nmr.mgh.harvard.edu/).

A standard, non-edited FS workflow for preprocessing was used that involved the following stages. First, skull stripping was performed with a motion artifact correction, and resampling of the images into 1 mm vertices. Then, segmentation of the subcortical white matter (WM) and deep gray matter (GM) volumes was performed, with an intensity normalization and tessellation of GM-WM boundaries. Automated topology correction was performed, followed by a surface deformation that used intensity gradients to optimally assign each vertex into a GM vs WM vs cerebrospinal fluid type. After the cortical models were completed, the surface inflation was performed to create a 2D mesh structure and the images were co-registered to a spherical atlas with individual cortical folding patterns. Finally, parcellation of the cerebral cortex units was performed based on gyral and sulcal structure and co-registered to the built-in Destrieux atlas (Destrieux et al., 2010). Details of the FS pipeline have been described in previous publications (e.g. Dale et al., 1999; Fischl et al., 2004). T-tests were then used to assess between-group differences with regard to the cortical thickness of the superior temporal cortex and medial prefrontal cortex, as well as with regard to the bilateral amygdala volume.

Functional data was preprocessed with Statistical Parametric Mapping (SPM-12). To remove movement artifacts, time-series images were first realigned using a least-squares approach and a rigid body [6 parameters] transformation, with a first slice used as a point of reference. A set of realignment parameters were then saved and used as additional regressors during a statistical analysis. Estimation was performed for realigned images with default parameters (high quality, FWHM = 5 mm.). Next, time series were co-registered and resliced using a rigid-body model. Realigned time series data from each run and a mean realigned image from all runs were transformed using a T1w image as a reference (fixed image). Registration was done using the normalized mutual information (MNI) function, and 4x2 mm vector of separation, as well as Gaussian histogram smoothing. Anatomical data from each subject was then segmented and classified into different tissue classes based on a tissue probability map using a non-linear deformation field. The tissue types included grey matter, white matter and cerebrospinal fluid. Deformations calculated in the segmentation procedure were used to normalize coregistered data using a 4th degree B-Spline interpolation, 2x2x2 voxel size and 2x3 bounding box. Normalized time-series were then additionally smoothed with an 8x8x8mm FWHM Gaussian smoothing kernel.

First-level General Linear Model (GLM) was calculated for each subject with a default high-pass filter of 128 seconds. Serial autocorrelations were managed with an autoregressive AR(1) model using Classical (ReML) parameter estimation. Additionally, data with 6 movement parameters (3 for translation and 3 for rotation) was used as multiple regressors.

GLM also contained onsets and durations of each block for the task-related conditions of interest in SoPIT (COM, EMO, IND, SCR); HCP-SOC (ToM, RAND);

HCP-EMO (Face, Shape), Why How (Why, How) and BioLoc (Biological Motion, Scrambled Motion, Object Motion) tasks.

A full factorial model was specified to calculate group-level activity in each localizer, with condition as a within-subject factor. Main contrasts of interests were then calculated for each task with a cluster correction (FWEc), which included: BM > SCR (BioLoc; FWEc = 422), ToM > RAND (HCP-SOC; FWEc = 437), Face > Shape (HCP-EMO; FWEc = 52163), Why > How (Why How; FWEc = 416).

Group-level activity (averaged activity in all participants) in the localizer tasks was then used to select regions of interest for the subsequent ROI analysis. The clusters of activity related to the main contrast in each localizer task listed above were identified. Coordinates for peak activity within the bilateral pSTS specialized for BM processing (pSTS-BM; BioLoc: BM > SCRt), bilateral pSTS region specialized for animacy processing (pSTS-ANIM; HCP-SOC ToM>RABD), bilateral TPJ (Why How: Why>How), mPFC (Why How: Why>How) and bilateral amygdala (HCP-EMO: Faces>Shapes) were determined. Then, ROIs were built using a MarsBar toolbox (Brett et al. 2002), with peak coordinates included as a centre of sphere, and a radius of 6 mm.

The between-group activity in COM, EMO, IND and SCR conditions within the specified ROIs was then investigated using a repeated measures ANOVA in a 4 x 2 scheme, with condition as a within-subject factor (COM vs EMO vs IND vs SCR) and group (ASD vs TD) as a between subject factor. Post-hoc comparisons with Bonferroni correction were used to investigate differences between each condition.

Secondly, a whole-brain approach with a cluster correction was used for the exploratory analysis of the between-group differences beyond the pre-defined functionally localized ROIs. Second-level (group-level comparison) 2 (group) x 4 (condition) full

factorial model was specified in SoPIT using the contrasts calculated in the first-level analysis representing the averaged activity in each condition (COM vs EMO vs IND vs SCR) in order to compute group statistics. The group (ASD vs TD) condition was included as a between-subject factor with assumed independence between measurements. The condition was included as a within-subject factor, and dependency between measurements was assumed. The analysis covered the engagement of main social brain circuits responsible for social perception, emotional processing and mental state inference related to following contrasts: communicative interaction and affective exchange compared to a non-interactive condition (COM + EMO > IND; FWEc = 385), affective exchange vs communicative interaction (EMO > COM; FWEc = 440) and individual actions of PLWs vs scrambled motion of PLWs (IND > SCR; FWEc = 493).

7.3. Results

7.3.1. Structural Analysis

No difference between ASD and TD group with regard to the left (LH: $t(40) = 0.93$, $p = .36$) and right (RH: $t(40) = 0.60$, $p = .55$) amygdala volume was observed. Moreover, no between-group differences in the cortical thickness of the medial frontal (LH: $t(40) = .22$, $p = .83$; RH: $t(40) = -0.89$, $p = .38$) and the superior temporal cortex (LH: $t(40) = 0.57$, $p = .58$; $t(40) = -0.38$, $p = .70$) was observed between ASD and TD participants.

7.3.2. Behavioral Differences - Social Perception and Interaction Task

No significant differences between the ASD and the TD group were observed in the overall accuracy ($t(41) = 1.39$, $p = .17$), as well as in each condition separately (COM: $t(41) = 1.40$, $p = .17$; EMO: $t(41) = -0.82$, $p = .42$; IND: $t(41) = 1.29$, $p = .20$; SCR: $t(41) = 1.17$, $p = .25$).

7.3.3. Functional Analysis - Region of Interest

Coordinates for each ROI can be found in Table 8. Localization of the ROIs is presented on Figure 9. Mean activity and standard deviation for each SoPIT condition within a predefined ROI is included in Supplementary Table 4.

pSTS-BM (BioLoc). There was a significant effect of a condition within the pSTS-BM cluster in the right hemisphere (RH: $F(2.22, 88.64) = 64.70$, $p < 0.001$) and in the left hemisphere (LH: $F(3, 120) = 30.60$, $p < 0.001$). No significant group effect (RH: $F(1, 40) = 0.33$, $p = .56$; LH: $F(1, 40) = 0.01$, $p = .93$) or group x condition interaction (RH: $F(2.22, 88.64) = 0.46$, $p = .65$; LH: $F(3, 120) = 0.14$, $p = .94$) was observed. Both left and right pSTS-BM regions were engaged more by the interactive conditions compared to the individual condition (COM, EMO > IND), and by the individual compared to the random condition (IND>SCR).

Amygdala (HCP-EMO). A significant effect of a condition was observed both for the right (RH: $F(3, 120) = 8.87$, $p < 0.001$) and left amygdala (LH: $F(3, 120) = 5.07$, $p = .002$). No significant effect of a group (RH: $F(1, 40) = 1.82$, $p = .19$; LH: $F(1, 40) = 2.21$, $p = .15$), or interaction between group and condition (RH: $F(3, 120) = 0.55$, $p = .64$; LH: $F(3, 120) = 0.29$, $p = .83$) were observed. Activation of the amygdala was stronger for affective exchange compared to communicative and individual actions (EMO>COM, IND; RH and LH) and compared to the random motion of PLWs (EMO>SCR; RH).

pSTS-ANIM (HCP-SOC). A significant effect of a condition was observed for the right (RH: $F(3, 120) = 70.50$, $p < 0.001$) and left pSTS-ANIM (LH: $F(3, 120) = 31.28$, $p < 0.001$). No significant effect of group (RH: $F(1, 40) = 0.19$, $p = .67$; LH: $F(1, 40) = 0.22$, p

= .88) or interaction between condition and group (RH: $F(3, 120) = .83$, $p = 0.45$; LH: $F(3, 120) = 0.03$, $p = .96$) were found.

Activity of the pSTS-ANIM was increased for the communicative and affective conditions compared to the non-interactive condition, and in the non-interactive compared to the random condition (COM, EMO > IND ; IND > SCR)

TPJ (Why How). A significant effect of condition was observed for the right ($F(2.1, 84.19) = 6.41$, $p = .002$), but not left TPJ ($F(3, 120) = 2.67$, $p = .05$). No significant effect of a group (RH: $F(1, 40) = 0.07$, $p = .94$; LH: $F(1, 40) = 0.43$, $p = .51$), or an interaction effect between condition and a group (RH: $F(2.1, 84.18) = 0.35$, $p = .79$; LH: $F(3, 120) = 0.36$, $p = .79$) were observed.

Within the right TPJ, the activity during all BM conditions was higher compared to the random condition (COM, EMO, IND > SCR).

mPFC (Why How). A significant effect of a condition was observed ($F(3, 120) = 11.08$, $p < 0.001$), with no significant effect of a group ($F(1, 40) = 0.10$, $p = .75$), or condition x group interaction ($F(3, 120 = 0.63$, $p = .59$).

Activity of the mPFC was higher during the affective exchange compared to non-affective communicative and non-interactive conditions (EMO > COM, IND), and during the non-interactive exchange compared to the random condition (IND>SCR).

Table 8

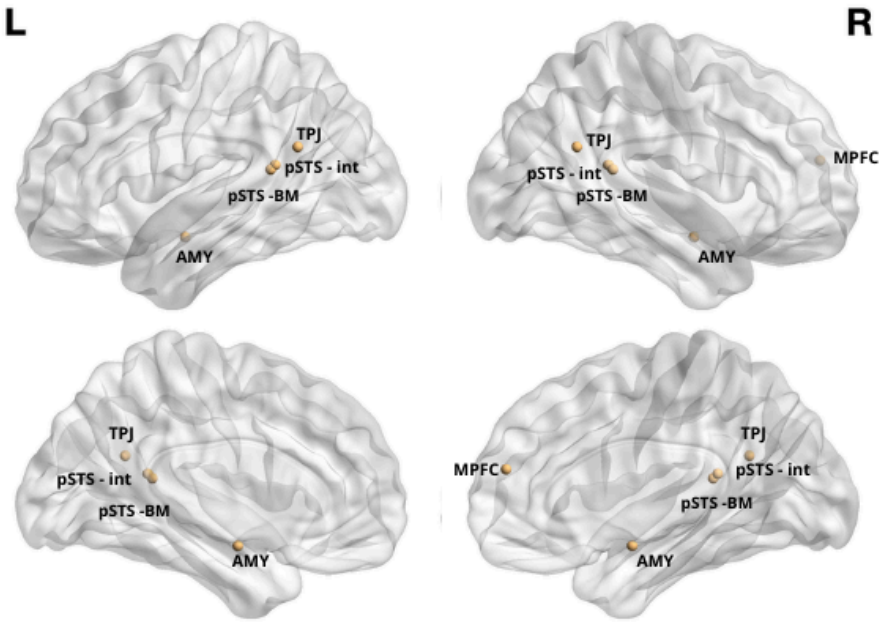
Coordinates for the maximum activations within the cluster extracted with localizer tasks: Biological Motion Localizer (BioLoc); Human Connectome Project - Emotion Processing (HCP EMO); Human Connectome Project - Social Cognition (HCP SOC) and Why How Task.

Task	Structure	Side	Coordinates for the cluster maximum
BioLoc	pSTS-BM	Left	-54 -44 14
BioLoc	pSTS-BM	Right	58 -40 14
HCP-EMO	AMY	Left	-20 -6 16
HCP-EMO	AMY	Right	20 -4 16
HCP-SOC	pSTS-ANIM	Left	-54 46 16
HCP-SOC	pSTS-ANIM	Right	54 42 16
Why How	TPJ	Left	-52 -56 24
Why How	TPJ	Right	52 56 24
Why How	mPFC	-	4 52 18

Note: pSTS- posterior superior temporal sulcus; AMY - amygdala; TPJ - temporo-parietal junction; mPFC - medial prefrontal cortex; BM - biological motion; ANIM - animacy

Figure 9

Region of interest (ROI) localization based on the peak activity within the posterior superior temporal sulcus (pSTS) and temporoparietal junction (TPJ) complex, medial prefrontal cortex (mPFC) and amygdala (AMY) regions .



7.3.4. Functional Analysis - Whole Brain Analysis

Presented task effects across all participants were observed in the second level analysis of SoPIT.

Social perception (IND > SCR). Increased activity was found in the bilateral superior temporal gyrus (STG), the middle temporal gyrus (MTG) and left TPJ, as well as in bilateral precuneus, bilateral cuneus and right inferior occipital cortex.

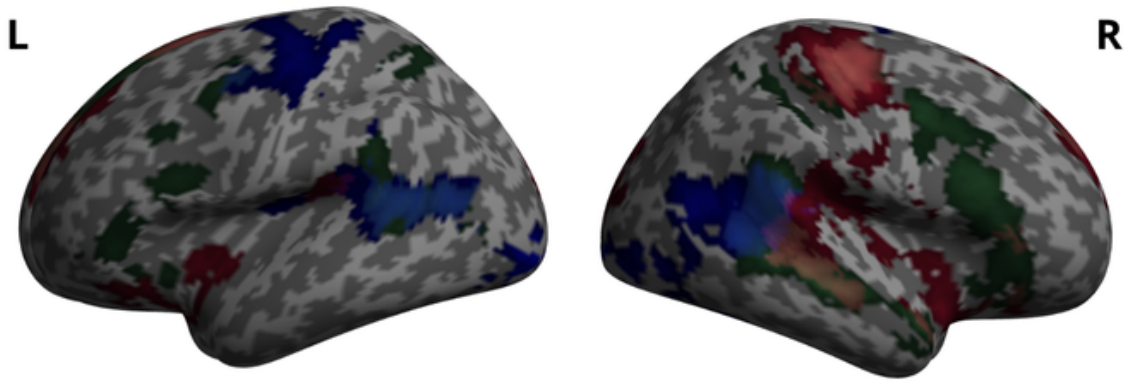
Emotional processing (EMO > COM). Increased activity was found within the right precentral and postcentral areas, left cerebellum, left fusiform gyrus, and in the left occipital areas, including cuneus and precuneus.

Mentalizing (COM + EMO > IND). The analysed contrast revealed a higher activity within the bilateral STG, bilateral MTG and left TPJ, along with bilateral supplementary motor area (SMA), right midcingulate cortex (MCC), left insula and left inferior parietal cortex (IPC). Increased activation was also found within right-sided putamen, caudate, pallidum and thalamus.

No differences for any of the analyzed contrasts were found between individuals with autism and typically developing individuals. Clusters of the group-level activity accompanying each contrast are presented on Figure 10.

Figure 10

Clusters of activity for each contrast of interest: communication + emotion > individual (green), emotion < communication (red) and individual > scrambled (blue) observed during the whole-brain analysis



7.4. Discussion

The main goal of the presented analysis was to investigate neural correlates associated with social information processing in autism. We expected to observe structural alterations (H3.1.) accompanied by decreased activity (H3.2.) related to multi-level processing of social information from biological motion in people with autism compared to typically developing individuals. Specifically, we predicted differences between TD and ASD participants with regard to the activity of mentalizing (pSTS, TPJ, mPFC; H3.2a), emotional processing (AMY; H3.2b) and social perception (pSTS; H3.2c) regions during observation of communicative and affective social cues. To investigate these differences, a novel dyadic point-light paradigm was incorporated. The task was designed in a way to stratify the activity of different brain networks with regard to specific contrasts implemented in the study, with a higher engagement of mentalizing network for interactive vs non-interactive conditions (COM + EMO > IND), emotion processing network for affective vs non-affective communicative exchange (EMO > COM) and basic social perception network in case of non-communicative displays vs scrambled motion of point-lights (IND > SCR).

In line with previous reports regarding the neural correlates of communicative interaction perception (Centelles et al., 2011; Okruszek et al., 2017), increased engagement of the mentalizing network related to the processing of interactive vs individual conditions in SoPIT was observed. The observed pattern of activation both in case of ROI analysis and whole-brain analysis confirmed the expected sensitivity to task conditions related to multi-level social information processing. In line with Deen et al. (2015), we observed a higher engagement of STS/TPJ subregions specialized for intention and mental state inference processing during interactive conditions (COM and EMO), compared to the

non-interactive condition (IND). Moreover, higher engagement of amygdala and mPFC for affective exchange compared to non-affective and non-interactive conditions was also observed in both ROI and whole-brain analysis.

Importantly, the discussed areas specialized for dynamic social perception, including pSTS, TPJ and amygdala, were previously linked to social cognition difficulties in autism (Yang et al, 2015). However, contrary to our expectations, no differences between ASD and TD were observed in the current analysis. Specifically, no difference between ASD and TD was observed with regard to the thickness of superior temporal and medial frontal regions (H3.1a), as well as with regard to the volume of AMY (H3.1b). Moreover, no difference between ASD and TD was observed in the engagement of mentalizing network, i.e. TPJ, mPFC and pSTS during the observation of communicative interactions (H3.2a). Similarly, no between-group differences in the engagement of amygdala during the observation of affective cues from biological motion were observed (H3.2b). Finally, observation of individual actions of a PLW was not related to decreased activation of the pSTS in people with ASD compared to TD participants (H3.2c).

While it is difficult to make an unequivocal interpretation, several factors might have contributed to the observed null results. As discussed in previous chapters, our clinical groups included mostly people with high neurocognitive abilities. Similarly, as no differences have been observed with regard to the overall social cognitive profile in Chapter 5., we should consider a possibility that the functional and structural differences between ASD and TD participants were very subtle, and did not emerge in a small study sample. It should also be noted that contrary to the results of the behavioral part of the project presented in Chapter 5., no differences in the accuracy of classifications were described. Although surprising, this finding might be partially explained by the study design, which

included blocks of 3 videos from the same category, which might have facilitated the classification. Finally, it is possible that in people with ASD presenting a moderate profile of cognitive difficulties, alterations might only be observed with regard to connectivity patterns, rather than in the structural or activation differences (e.g. Alaerts et al., 2017; Nair et al., 2020).

In summary, no specific differences within the social perception, emotional processing and mentalizing circuits were found between ASD and TD participants, with regard to communicative and affective cues recognition from biological motion. As many factors, including the level of functioning of the participants and design of the task, could have accounted for these surprising results, the possibility of neural alterations related to communicative intentions recognition in people with ASD should be further investigated in larger sample studies.

Chapter 8. Specificity of Social Cognitive Patterns in Autism and Schizophrenia

Q4: Are social cognitive difficulties in autism similar to those observed in schizophrenia?

The presented chapter is based on the article currently in the revision process: Krawczyk, M., Pinkham, A. & Okruszek, Ł. Similar or opposite? Differences in the recognition of communicative intentions from biological motion in adults with autism and schizophrenia, *Journal of Psychiatric Research*. Methodology (8.2) and Results (8.3) were included with minimal edits and adjustments. Moreover, section 8.4 (Discussion) includes an overview of the main findings that was based on the Discussion section in the quoted article.

8.1. Introduction

Although autism and schizophrenia are diagnosed based on a presence of non-overlapping symptoms with social-communicative and restricted behaviors in ASD, and a combination of positive, negative and disorganization symptoms in SCZ (APA, 2013), both conditions are linked to the decreased social functioning (Lemmers Jensen et al., 2023; Pallathra et al., 2018). Moreover, in both cases the robust association between social information processing, social functioning and functional outcome has been repeatedly observed (Lemmers-Jensen et al., 2023; Riddiford et al., 2022). Importantly, several recent large-scale studies and meta-analyses directly comparing social cognition autism and schizophrenia pointed toward an overlapping pattern of difficulties in emotional processing and theory of mind (Oliver et al., 2021; Rashidi et al., 2025). Given the comparable magnitude of social cognitive deficits, along with a distinguishable symptomatology of autism and schizophrenia, it has been suggested that both conditions may constitute a

neurodevelopmental spectrum, with a pattern of decreased mental state inference in autism, and increased mental state inference in schizophrenia (Ciaramidaro et al., 2014; Frith, 1992).

While most of the available studies comparing autism and schizophrenia focus on emotion recognition and theory of mind, both disorders have been related to possible disturbances in detection of communicative intentions from biological motion (Centelles, 2011; Okruszek et al., 2018a). However, no study to date made a direct comparison of people with schizophrenia and autism with regard to this ability. As discussed before, assessing different domains of social cognition─might help to understand specific neurodevelopmental pathways leading to disorganized social functioning in different clinical populations and in consequence - deepen our understanding of autism and schizophrenia (Sasson et al., 2011). Hence, the current study aims to examine the difference between adults with autism and schizophrenia in their ability to recognize communicative and affective cues from biological motion stimuli, presented by either one or two point-light agents. Since distinct mechanisms might contribute to understanding of communicative cues presented by single or dyadic displays, introducing both types of stimuli might help uncover diverging patterns of social cognitive struggles in autism and schizophrenia. Based on previous findings, we expected to see a non-specific pattern of social cognitive difficulties, i.e. a similarly decreased performance in emotion recognition (H4.1a) and theory of mind (H4.1b) in the SCZ group compared to TD participants, as the same pattern was expected with regard to ASD participants compared to the TD group. Moreover, while neurocognitive difficulties were expected in both SCZ and ASD compared to TD participants, a higher magnitude of those deficits was also expected in SCZ compared to ASD participants (H4.2). Finally, we expected to observe more difficulties in recognition of communicative intentions

from single-agent (H4.3a) and dyadic (H4.3b) point-light paradigms, as well as in recognition of affective states from a single-agent paradigm (H4.3c) in the ASD compared to the SCZ group (H4.3).

8.2. Method

8.2.1. Participants

The presented analysis was conducted on a total sample of 111 participants: 29 participants with ASD and 29 TD participants compared and described in Chapter 5. and Chapter 6., and 53 individuals with schizophrenia (SCZ), who took part in a study on social cognition in schizophrenia which utilized an analogous set of neuropsychological tasks as discussed in Chapter 5.

Fifty-three individuals with schizophrenia were included into the analysis (18F, 35M; Age: M = 31.74, SD = 6.33). While both projects from which the data was included had equivalent inclusion criteria, SCZ participants were slightly older than participants with autism. Hence, to ensure that the groups were comparable in terms of age, we included individuals with schizophrenia aged 43 or younger (age of the oldest participant in the autism group). All patients included in the study were clinically stable, i.e. did not present major changes in symptom severity or did not undergo any modifications in the medication for at least 4 weeks before the assessment.

Symptoms of participants with schizophrenia were assessed with PANSS (Positive and Negative Syndrome Scale; Kay et al., 1987). PANSS ratings are based on a structured clinical interview that taps major areas of dysfunction in schizophrenia, including delusions, hallucinations and disorganization. Based on these results, the clinical domains were calculated in line with the PHAMOUS consortium, indicating the level of positive, negative,

affective and cognitive symptoms (van der Gaag et al., 2013). Medication doses for each SCZ patient were converted to chlorpromazine (CPZ) equivalent (M = 447 mg, SD = 292).

Groups did not differ regarding age (F(2, 108) = 2.61, p = .08). However, gender distribution differed between groups ($X^2(4) = 13.82$, p = .09), with significantly more men in the schizophrenia group.

8.2.2. Procedure

Neurocognitive functioning was assessed with a MATRICS battery. Next, recognition of communicative and affective cues from the biological motion stimuli was assessed with CID-5, Gestures task and EMO-BM. Finally, Social Cognitive Psychometric Evaluation measures were introduced to assess theory of mind (Hinting Task, RMET), facial emotion recognition (ER-40) and non-verbal cues recognition (PONS). Detailed description of the measures can be found in Chapter 5.

8.2.3. Statistical Analysis

Raw MCCB and SCOPE scores were used to compute neurocognitive and social cognitive profiles in each group, by normalizing and averaging them with regard to the TD group in a way described in Chapter 5. Between-group differences in neurocognitive and social cognitive composite scores were then investigated using a One-Way ANOVA and post-hoc comparisons with Bonferroni correction. Thus, in case of SCOPE and MCCB measures the analysis was performed on standardized scores, while in CID-5, Gestures and EMO-BM we used raw scores that reflected the number of correct answers in each category.

For both the CID-5 and the Gestures task, repeated measures ANOVAs were used in a 2x2x2 scheme, with task (intention classification vs. description of specific action) and

stimuli (communicative vs. non-communicative) as within-subject factors and group (ASD vs TD vs SCZ) as a between-subject factor. For factors with significant effects, Bonferroni corrected post-hoc tests (between-subject factors) and Bonferroni corrected pairwise comparisons based on marginal means (within-subject factors and interactions) were estimated.

One-way ANOVA was used to assess differences in recognition of emotion from biological motion, with total accuracy in EMO-BM as the dependent variable, and group (ASD vs TD vs SCZ) as the independent variable.

8.3. Results

8.3.1. Social Cognitive and Neurocognitive Profile

Table 9 presents raw scores in all MCCB and SCOPE measures. Standardized scores, along with group statistics in particular tasks and domains are presented in Table 10.

The SCZ group scored lower than ASD and TD in both neurocognition (ASD $p < .001$; TD $p = .001$) and social cognition (ASD $p = .003$; TD $p < .001$) composite scores. Moreover, the SCZ group scored lower than the TD group in Processing Speed ($p < .001$), Working Memory ($p = .015$), Hinting Task ($p = .001$), PONS ($p < .001$) and RMET ($p < .001$) and lower compared to ASD group in Processing Speed ($p = .002$), Reasoning/Problem Solving ($p = .011$), Attention/Vigilance ($p = .007$), Verbal Learning ($p = .002$), Working Memory ($p = .015$), RMET ($p = .038$) and PONS ($p < .001$).

Comparative social and neurocognitive profile is presented on Figure 11.

Table 9

Raw MATRICS Consensus Cognitive Battery (MCCB) and Social Cognition Psychometric Evaluation (SCOPE) battery scores in people with schizophrenia, people with autism and typically developing groups.

	Schizophrenia		Autism		Typically Developing	
	Mean	SD	Mean	SD	Mean	SD
Neurocognition - MCCB						
TMT	32.85	10.05	31.66	13.04	28.48	10.34
BACS	46.62	10.27	58.55	14.27	61.28	13.64
HVLT-R	26.11	5.42	29.76	3.06	28.48	4.05
WMS	16.42	3.66	17.14	3.06	18.28	2.70
LNS	14.13	3.63	17.07	3.00	15.93	2.89
NAB	17.62	5.87	21.21	3.95	20.28	5.00
BVMT-R	23.83	8.48	28.38	6.99	27.10	6.33
Fluency	23.32	5.06	28.07	5.71	28.59	5.2
CPT	2.33	0.80	2.87	0.63	2.59	0.74
Social Cognition - SCOPE						
ER-40	31.77	3.91	32.66	3.98	33.59	2.72
RMET	24.11	5.11	26.73	3.16	27.83	3.50
Hinting Task	15.09	2.76	16.36	2.79	17.31	2.05
MiniPONS	43.48	5.67	48.69	3.86	49.46	5.01

Note: TMT - Trail Making Test; BACS - Brief Assessment of Cognition in Schizophrenia; HVLT-R - Hopkins Verbal Learning Test Revised; WMS - Wechsler Memory Scale; LNS - Letter Number Span; NAB - Neuropsychological Assessment Battery; BVMT-R - Brief Visuospatial Memory Test - Revised; CPT - Continuous Performance Test; ER-40 - Emotion Recognition - 40 Task; RMET - Reading Mind in the Eyes; MiniPONS - Mini Profile of Nonverbal Sensitivity

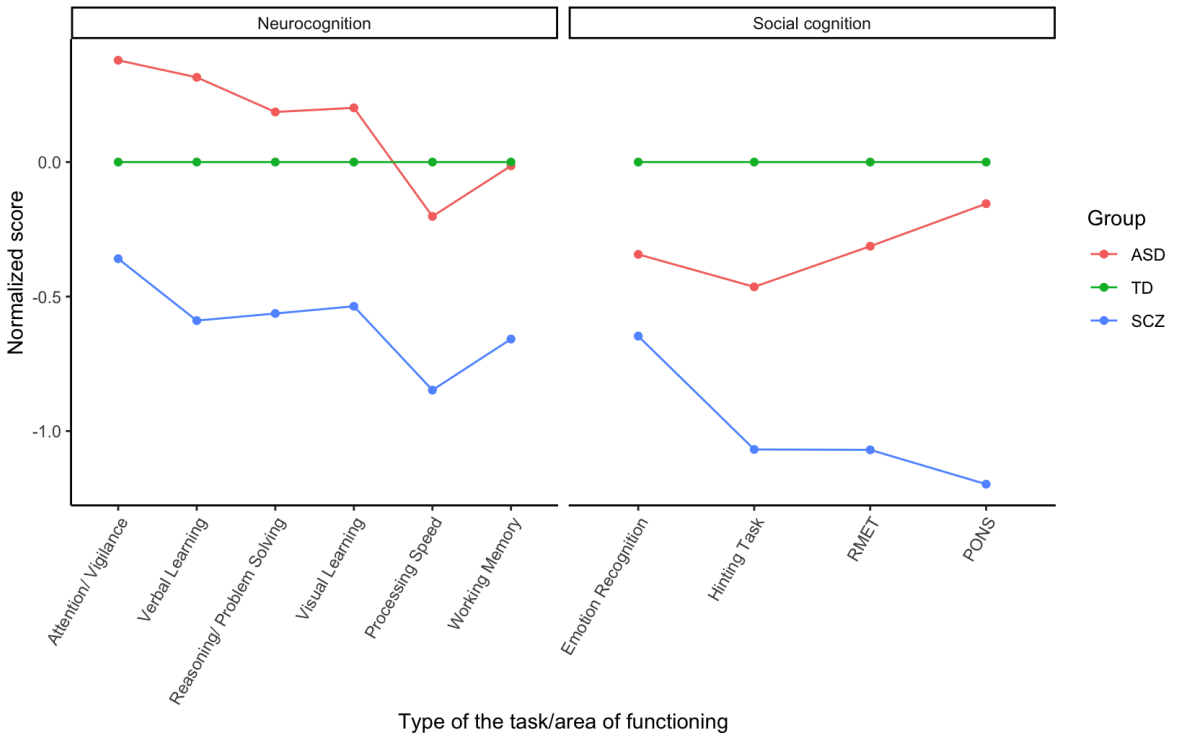
Table 10

Standardized MATRICS Consensus Cognitive Battery (MCCB) and Social Cognition Psychometric Evaluation (SCOPE) battery scores in individuals with schizophrenia (SCZ), autism (ASD) and typically developing individuals (TD).

	Schizophrenia	Autism	Group statistics and significant differences
Neurocognition - MCCB			
Attention/Vigilance	-0.34	0.38	$F(2,107) = 4.87$, $p = 0.009$; SCZ < ASD
Verbal Learning	-0.59	0.32	$F(2,108) = 6.58$, $p = 0.002$; SCZ < ASD
Reasoning/Problem Solving	-0.53	0.19	$F(2,108) = 5.21$, $p = 0.007$; SCZ < ASD
Visual Learning	-0.52	0.20	$F(2,108) = 3.03$, $p = 0.53$
Processing Speed	-0.84	-0.20	$F(2,108) = 13.03$, $p < 0.001$; SCZ < TD, ASD
Working Memory	-0.66	-0.01	$F(2,108) = 5.90$, $p = 0.004$; SCZ < TD, ASD
Total neurocognitive composite	-0.58	0.14	$F(2,108) = 11.21$, $p < 0.001$; SCZ < TD, ASD
Social cognition - SCOPE			
Hinting Task	-1.08	-0.46	$F(2,107) = 7.14$, $p = 0.001$; SCZ < TD
ER-40	-0.67	-0.34	$F(1,108) = 2.36$, $p = 0.10$
Mini PONS	-1.20	-0.15	$F(2,102) = 16.11$, $p < 0.001$; SCZ < TD, ASD
RMET	-1.10	-0.31	$F(1, 105) = 7.86$, $p < 0.001$; SCZ < TD
Total social cognitive composite	-1.01	-0.32	$F(2,108) = 13.58$, $p < 0.001$ SCZ < TD, ASD

Figure 11

Neurocognitive and social cognitive profile in the participants with autism (ASD), schizophrenia (SCZ) and typically developing participants (ASD).



Note: Presented scores were standardized with regard to the TD group performance, by first calculating mean and standard deviation in the TD group, and then transforming each raw score following a formula: raw score – mean score/SD. RMET - Reading Mind in the Eyes; PONS - Profile of NonVerbal Sensitivity

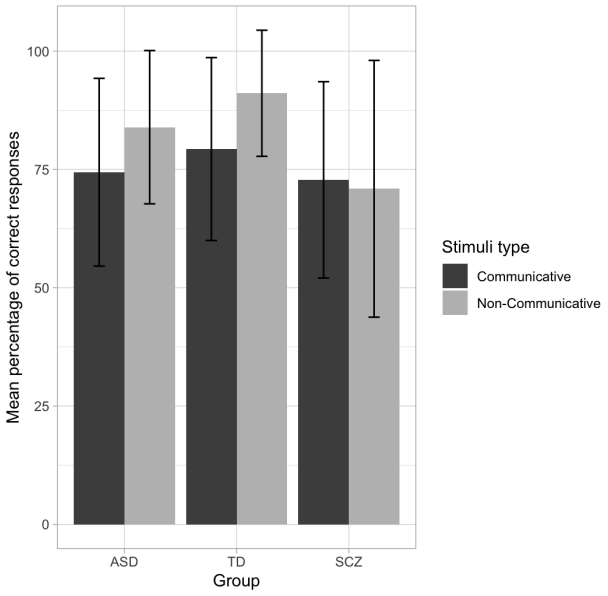
8.3.2. Inference of Communicative Intentions from Dyadic Point-Light Walkers

In CID-5, significant main effects of the Task ($F(1, 107) = 61.36$, $p < .001$), Stimuli ($F(1, 107) = 8.28$, $p = .005$) and Group ($F(2, 107) = 13.52$, $p < .001$) were observed for recognition of communicative intentions from dyadic PLWs. Lower accuracy was observed for the description compared to the categorization ($p < .001$) and for the non-communicative compared to the communicative stimuli ($p = .005$). Moreover, accuracy in the SCZ group was lower than in the TD group ($p < .001$) and in the ASD group ($p = .020$).

Two significant interactions were observed. There was an interaction between the effect of the task and the type of the stimuli presented ($F(1, 107) = 24.44$, $p < .001$), with higher accuracy observed for non-communicative compared to communicative displays, but only in the description task ($p < .001$). An interaction between stimuli and group ($F(2, 107) = 4.31$, $p = .016$) was also found, with higher accuracy observed for non-communicative compared to communicative displays in both the TD group ($p = .006$) and the ASD group ($p = .028$), but no difference between individual and communicative stimuli in the SCZ group ($p = .54$). Means and standard deviations for each group are presented in Table 11. The mean percentage of correct responses in each group is presented on Figure 12.

Figure 12

Mean percentage of correct responses in the dyadic point-light task in participants with autism (ASD), schizophrenia (SCZ) and typically developing individuals (TD).



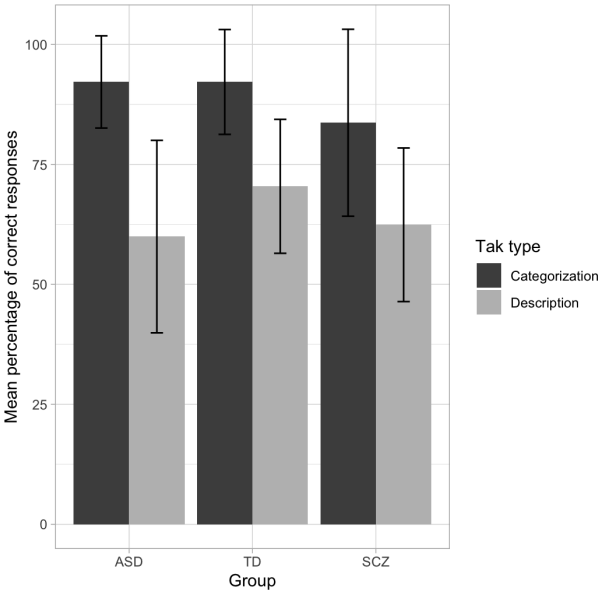
8.3.3. Inference of Communicative Intentions from a Single Point-Light Walker

In CID-5, significant effects of both Task ($F(1, 108) = 294.00$, $p < .001$) and Group ($F(2, 108) = 5.39$, $p = .006$) were observed. Lower accuracy was observed for the description task compared to the categorization task ($p < .001$). The accuracy in the SCZ group was also lower compared to the TD group ($p = .004$). No significant differences were found between SCZ and ASD, as well as between TD and ASD. Moreover, two interaction effects were observed. There was a significant interaction between type of the stimuli and type of the task ($F(1, 108) = 4.38$, $p = .039$), with accuracy in non-communicative displays higher than in communicative displays, but only in the categorization task ($p = .014$). There was also an interaction between task and group ($F(2, 108) = 5.71$, $p = .004$). In the categorization task, accuracy in the SCZ group was lower than in the ASD group ($p = .01$)

and TD group (p = .01), while no significant difference was observed between TD and ASD. In the description task, accuracy in both SCZ and ASD was lower compared to the TD group (SCZ < TD, p = .044; ASD < TD, p = .016) and no significant difference was observed between ASD and SCZ. Means and standard deviations for each group are presented in Table 12. The mean percentage of correct responses in each group is presented on Figure 13.

Figure 13

Mean percentage of correct responses in the single-agent point-light task in participants with autism (ASD), schizophrenia (SCZ) and typically developing individuals (TD).



8.3.4. Inference of Affective State from a Single Point-Light Walker

In EMO-BM, there was a difference in the emotion recognition accuracy (F(2, 104) = 4.29, p = .016), with SCZ scoring lower than TD (p = .013), and no difference between ASD and TD (p = .38), as well as between ASD and SCZ (p = .75).

Table 11

Descriptive statistics in the dyadic point-light task in participants with autism (ASD), typically developing participants (TD) and participants with schizophrenia (SCZ).

	ASD		TD		SCZ		Overall	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CAT - COM	5.04	1.10	5.21	0.86	5.15	0.86	5.14	0.92
CAT- IND	5.25	0.84	5.58	0.68	4.42	1.59	4.93	1.33
DESC - COM	3.89	0.99	4.31	1.26	3.58	1.06	3.85	1.13
DESC - IND	4.82	1.06	5.34	0.89	4.09	1.67	4.61	1.45

Note: CAT - Categorization; DESC - Description; COM - Communicative; IND - Non-Communicative

Table 12

Descriptive statistics in Gestures task in the ASD and TD group.

	ASD		TD		SCZ		Overall	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CAT- COM	11.55	1.35	11.72	1.22	10.68	2.34	11.20	1.91
CAT - IND	12.41	0.98	12.24	1.57	11.08	2.72	11.70	2.19
DESC- COM	8.17	2.56	8.86	1.97	8.19	2.25	8.36	2.27
DESC- IND	7.41	2.64	9.44	1.61	8.04	1.92	8.24	2.18

Note: CAT - Categorization; DESC - Description; COM - Communicative; IND - Non-Communicative

8.4. Discussion

The presented analysis aimed to analyze the specificity of social cognitive and neurocognitive deficits across the neurodiversity spectrum, by comparing the performance of ASD and SCZ participants on a set of tasks measuring the recognition of intentions and affective states from a biological motion, along with a battery of social cognitive and neurocognitive measures. We expected to see a non-specific pattern of emotion recognition and theory of mind difficulties in both ASD and SCZ compared to TD participants (H4.1.), as well as lower neurocognitive functioning in SCZ compared to ASD (H4.2.) and decreased recognition of social cues from biological motion in ASD compared to SCZ (H4.3.).

In line with our expectations, compared to TD participants, participants with schizophrenia presented decreased levels of emotion recognition abilities (H4.1a) and theory of mind abilities (H4.1b). However, as described in Chapter 5, no differences between ASD and TD participants with regard to social cognitive functioning were observed. At the same time, performance of SCZ participants on a battery of social cognitive measures was also lower compared to the performance of ASD participants. Moreover, in line with our hypotheses, SCZ participants presented a lower level of neurocognitive functioning compared to both TD (H4.2a) and ASD (H4.2b) participants. Furthermore, contrary to our expectations (H4.3.), participants with schizophrenia exhibited more profound difficulties in the recognition of communicative intentions from biological motion than ASD participants. Conversely to our predictions, the accuracy of SCZ individuals was lower compared to ASD individuals both in case of single-agent displays (H4.3a) and dyadic PLDs (H4.3b). However, in case of the single-agent task, additional interaction between group and condition was observed, such as the accuracy was lower in SCZ compared to ASD in the

categorization, but no difference was found in the description task, while both clinical groups scored significantly lower than the TD group. Finally, in contrast to our expectations (H4.3c), no difference between SCZ and ASD participants were observed with regard to the recognition of affective states presented by a single PLW agent, although only SCZ, but not ASD group, performed worse than TD participants in this domain. Thus, while some previous studies reported that individuals with autism and schizophrenia are mostly indistinguishable in terms of the pattern of social cognitive impairments (e.g. Pinkham et al., 2020; Fernandes et al., 2018), the current analysis points toward an area of divergence between the two clinical groups. Specifically, people with schizophrenia presented a more robust and generalized pattern of deficits than those with autism. Moreover, the fact that both groups presented difficulties in recognition of communicative intentions from biological motion, although only people with schizophrenia exhibited social cognitive deficits points toward potentially different pathways leading to abnormal social functioning in the two neurodevelopmental disorders. At the same time, the fact that there was no difference between people with ASD and SCZ in recognizing emotion from biological motion might point toward the possibility that measures of communicative intention recognition reflect more nuanced social perception mechanisms in different psychiatric populations. Hence, incorporating highly sensitive biological motion measures in research practice might be of great relevance in assessing heterogeneous mechanisms leading to altered social cognitive abilities across the neurodiversity spectrum (Pinkham et al., 2020).

Chapter 9. Overview of the Main Findings and General Discussion

9.1. Overview of the Main Findings

The main goal of the presented project was to investigate the behavioral and neural aspects of communicative intentions recognition in autism. Furthermore, the specificity of the behavioral findings was investigated by comparing them with patterns observed in another clinical group (patients with schizophrenia). To address this issue, we analyzed a dataset coming from two corresponding projects on social cognitive functioning in autism and schizophrenia.

In Chapter 5., differences between individuals with autism and typically developing individuals in the recognition of communicative gestures from biological motion were analyzed. We observed a significantly decreased ability to recognize communicative intentions both from dyadic, and from single-agent displays in individuals with autism compared to the typically developing group, although in the latter case the difficulties were found only with regard to the free-generated descriptions of point-light walkers. Moreover, difficulties in the recognition of communicative intentions from biological motion were not accompanied by deficits in emotion perception, theory of mind or neurocognitive functioning. An indirect relationship was also observed between recognition of communicative intentions from dyadic point-light walkers and autism symptoms, which was mediated by the overall level of social cognitive abilities.

In Chapter 6., the analysis of objective social cognitive capacity was expanded by the investigation of social cognitive bias. An increased level of social cognitive bias was observed in people with autism on self-report, but not vignette-based or performance-based

measures. However, some evidence for bias in interpreting single point-light agent's actions as non-communicative in people with ASD was also found.

In Chapter 7., we analyzed the neural mechanisms underlying the social cognitive difficulties in people with autism. We used a novel paradigm, stratifying the activity of social brain circuits with regard to different aspects of multi-level social information processing, including social perception, emotion processing and theory of mind. Despite behavioral differences described in Chapter 5. and 6., no differences were observed between ASD and TD individuals with regard to the activity of brain regions implicated in emotion and intention recognition, including specialized subregions of the STS/TPJ complex, amygdala and mPFC. Additional exploratory whole-brain analysis did not document any significant differences between individuals with autism and typically developing individuals. Moreover, no significant structural abnormalities within the main social brain hubs were found in the ASD, compared to the TD group.

In Chapter 8., the specificity of social cognitive difficulties in people with autism was investigated, compared to people with schizophrenia. Both shared and distinct patterns of social cognition were discovered in the two neurodevelopmental disorders. Specifically, although evidence for difficulties in the recognition of intentions from biological motion was found in both autism and schizophrenia, the performance of people with schizophrenia was also decreased compared to individuals with autism. Importantly, no difference between ASD and SCZ group was observed with regard to free-generated descriptions of single-agent point-light displays. Finally, people with SCZ presented lower levels of social cognitive and neurocognitive functioning compared to ASD individuals.

9.2. General Discussion

The presented research project was aimed at analyzing communicative intention processing in the autistic population. In line with our predictions, the presented study provided some evidence for possible abnormalities in processing of communicative intentions in a group of people with autism spectrum disorders that could not be differentiated from a typically developing group based on a set of well-validated social cognitive and neurocognitive measures. Apart from decreased accuracy in the recognition of communicative intentions from biological motion stimuli, evidence was also found for a bias toward classifying single-agent PLWs as non-communicative. Interestingly, contrary to our predictions, the observed decrease in communicative intentions recognition was accompanied by the increase on the self-report measure of social cognitive bias. However, contrary to our expectations, no difference between ASD and TD participants in the engagement of brain circuits related to communicative and affective cues processing was observed. Finally, both ASD and SCZ participants alike exhibited difficulties in the recognition of communicative intentions from biological motion, which partially supported our hypotheses.

To assess the expected differences between ASD and TD participants with regard to the recognition of the social cues from BM (Q1), we incorporated two tasks measuring the recognition of communicative intentions from the movement of either one point-light agent presenting a communicative or object-oriented gestures, or two point-light agents engaging in a communicative exchange or in individual actions.

The obtained results partially confirmed observations made by Centelles et al. (2013), suggesting a decreased capacity to recognize communicative interactions presented by two point-light walkers. In line with our predictions (H1.1b), in the dyadic point-light

paradigm lower accuracy was found in people with autism compared to the typically developing group, regardless of the type of the stimulus (communicative vs non-communicative) or type of the task (categorization vs description). However, contrary to our expectations (H1.1a), in case of the single-agent paradigm the main effect was modified by the type of the task - although no difference between ASD and TD was observed with regard to the categorization of gestures presented by one point-light agent, people with autism presented lower accuracy with regard to free-generated descriptions of presented gestures. Moreover, contrary to our predictions (H1.1c), no difference between ASD and TD participants in the recognition of affective states presented by a single PLW were observed. Furthermore, as predicted by the H1.2, CID-5 accuracy explained 24% of the social cognitive composite score in people with autism, but not in the typically developing group.

Importantly, while no differences in the accuracy between people with autism and a typically developing group were previously reported in a study by von der Lühe et al. (2016), a decreased effect of interpersonal predictive coding was still observed. In other words, in people with autism recognition of the point-light agent's actions was not improved by the presence of a second actor, who responded to the communicative gestures in a congruent way, which has been observed in typically developing people. It can then be hypothesized that because of the decreased IPC effect, recognition of dyadic actions might be more challenging for people with autism than for typically developing individuals, which could partially explain why categorization of point-light agent's actions in the autistic group was decreased in case of dyadic, but not single-agent actions. Importantly, the tasks implemented in our study do not allow for the direct analysis of the interpersonal coding

phenomenon and the allegedly decreased interpersonal predictive coding effect should be further investigated in people with autism using an appropriate measure.

Surprisingly, contrary to our expectations, no differences between ASD and TD participants were observed with regard to the level of neurocognitive functioning (H1.4.). Similarly, no difference between ASD and TD group was observed with regard to social cognitive functioning level (H1.5.). As discussed in Chapter 1., it was previously hypothesized that recognition of social cues based on the whole-body motion can be regarded as essential for later-emerging mental state inference skills (Pavlova, 2012). However, in our case, the normative level of social cognitive abilities was observed despite the decreased accuracy in recognition of communicative intentions from biological motion, which suggests an alternative pathway to obtain proper skills in theory of mind and facial emotion recognition

Importantly, as noted in ICD-11 (WHO, 2022), some individuals with autism might function adequately across a variety of social situations because of the "exceptional effort" they put in adjusting to the social demands, which makes their deficits less discernible. Use of such compensatory mechanisms in autism was documented and might constitute a phenotype more typical for women with ASD (Corbett et al., 2021). Crucially, although different compensation strategies might be distinguished, all of them rely on using domain-general cognitive abilities to bypass difficulties in the area of social cognition, which allows for an adequate functioning in the social environment (Livingston & Happe, 2020). Thus, it is possible that engaging in compensation might also support the performance in social cognitive tasks that are essential for everyday social functioning, including mental state inference or emotion recognition.

Apart from differences in the accuracy of communicative intentions recognition between ASD and TD participants, some evidence for the association between recognition of communicative cues and autism symptoms was also observed. Contrary to our predictions (H1.3.), ADOS score was not directly related to the recognition of communicative intentions from point-light displays. However, in line with H1.7., additional exploratory analysis revealed a significant mediatory effect, such as the CID-5 and ADOS were related indirectly, through social cognitive composite as a mediating variable. With all things considered, a possible interpretation can be made, according to which worse recognition of communicative intentions presented by dyadic point-light displays might negatively influence social cognitive abilities, and in consequence - impede social communication. At the same time, as discussed above, while difficulties in emotion recognition or theory of mind might have not been detected because of the engagement in compensation strategies, reduced ability to recognize communicative intentions might still influence functioning of ASD individuals in the social realm. Importantly, some evidence for association between BM perception and autism symptoms was also previously presented in the literature (Miller & Sayigin, 2013). Crucially, because of the limited sample size the mediatory analysis presented above should be viewed as preliminary and interpreted with caution.

Interestingly, conversely to our predictions in H1.6a, no relationship between ADOS score and overall neurocognitive composite was observed in the autistic group. However, there was a significant positive correlation between a self-report AQ score and neurocognitive, but not social cognitive composite. It should however be noted that apart from autism symptoms, AQ questionnaire taps traits referring to general domain difficulties or a cognitive style typically associated with autism, including the enhanced memory for

numbers or processing strategies focused on details (Baron-Cohen, 2001). Moreover, the validity of self-report measures of autism symptoms, including AQ, has also been challenged, as high level of false positives, false negatives and a low predictive value were noted with regard to various instruments (Ashwood et al., 2016; Mazefsky et al., 2011).

The second part of the presented analysis was aimed at investigating social cognitive bias in people with ASD. Contrary to our expectations, and despite between-group differences in the accuracy of communicative intentions recognition from single-agent and dyadic PLWs, no differences between ASD and TD participants were observed with regard to the bias in the recognition of intention from BM, measured by the criterion score (H2.1d). However, in the ASD group the criterion measure in the Gestures task was significantly higher than 0, i.e. in the single-agent PLW task individuals with autism presented a tendency for classifying displayed actions as non-communicative, which might potentially point toward a tendency to overlook intentional cues, as previously postulated in the theoretical accounts of decreased intentionality in autism (Bara et al., 2011).

At the same time, contrary to our expectations (H2.1a), individuals with autism presented a higher level of social cognitive bias, i.e. a higher tendency to interpret actions of other people as intentional, which was reflected in a self-report questionnaire. However, no difference between autistic and typically developing participants was observed in vignette-based measures of social cognitive bias (H2.1b) and performance-based measure of bias in facial emotion recognition (H2.1c). The discrepancy between vignette-based and self-report measures of social cognitive bias might be explained by partially diverging mechanisms that those measures assess. While in case of AIHQ and CBQP descriptions of ambiguous situations that might trigger biased interpretations are provided (Combs et al., 2007; Peters et al., 2014), measure of bias in DACOBS-18 taps the generalized inner

representations of world and other people as threatening (Gawęda et al., 2018). As previously presented, tendency to make hostile attributions varies greatly with the available contextual cues both in TD and ASD individuals (Zajenkowska et al., 2021). Hence, it is possible that negative assumptions about social relationships observed in participants with autism might not be apparent in many situations in which additional contextual cues are present. Importantly, a lower accuracy in some areas of self-assessment in autism was also previously demonstrated, which might have also contributed to observed discrepancy between more subjective DACOBS-18 and measures based on textual vignettes (De Brabander et al., 2021). Importantly, contrary to our expectations, social cognitive bias level was not significantly related to the level of autism symptoms (H2.3.). Similarly, no evidence was found for association between self-report, vignette-based and performance-based measures of social cognitive bias (H2.4.).

Despite some between-group discrepancies observed on the behavioral level, no significant differences between individuals with autism and typically developing people were observed with regard to the neural correlates of communicative cues processing. The overall pattern of results suggested that the implemented task successfully stratified the engagement of social perception, emotional processing and theory of mind circuits, including specialized subregions of the STS. Based on the previous research, we expected that the engagement of affective and mentalizing areas will be decreased in people with autism (Yang et al., 2015). For instance, a meta-analysis of fMRI studies investigating neural correlates of emotional processing and theory of mind in autism provided evidence for abnormal patterns of activation within the mPFC, STS and amygdala (Sugranyes et al., 2011). However, contrary to our predictions (H3.2), no differences between ASD and TD participants in the engagement of key hubs of the social perception, emotional processing

and mentalizing networks were observed during the observation of communicative and affective cues from biological motion. Specifically, no differences between ASD and TD groups were observed with regard to the engagement of the pSTS, TPJ and mPFC during the observation of interactive dyadic PLDs (H3.2a). Moreover, contrary to our expectations (H3.2b), no difference in the activation of amygdala related to the observation of affective cues from BM stimuli was observed between ASD and TD participants. Furthermore, no difference between ASD and TD in the engagement of pSTS was observed during the observation of non-communicative PLDs (H3.2c). Finally, contrary to our hypotheses, no between-group differences were observed with regard to the cortical thickness of medial frontal and superior temporal areas (H3.2a) and with regard to the amygdala volume (H3.2b).

Few possible explanations might be given to these null findings. First of all, our sample size might have been underpowered, especially considering the fact that the analysis consisted of a subset of the group included in the behavioral assessment, in which the difference between ASD and TD participants in the recognition of communicative intentions from BM was found. In contrast, the analysis of participants' performance in the SoPIT task did not show any significant difference between ASD and TD individuals with regard to the accuracy of the of the presented videos classification (communicative interaction vs emotional exchange vs individual actions vs scrambled motion of point-light displays). This inconsistency might be partially explained by the mixed event-related/blocked design implemented in the fMRI SoPIT task. Specifically, three videos from the same category were presented consecutively before the participants made the decision, which might have in consequence facilitated the correct recognition. Moreover, the task included three runs which lasted 21.5 minutes in total, which might have potentially resulted in participants

getting accustomed to the task. Importantly, the scanning session was scheduled after the behavioral assessment. As it was previously postulated, the naïve and informed observers might differ in their responses even in case of simplified biological motion paradigms (Thornton, 2013). With all things considered, given the length of the paradigm and limited temporal resolution of the neuroimaging methods, it is possible that the minor alterations which could be associated with the early stages of the stimuli processing could have gone undetected. This possibility may be further strengthened by some previous studies which have shown increased latency of the EEG event-related potentials elicited by the social stimuli in individuals with ASD, even when no between-group differences in the amplitude are detected (Monteiro et al, 2017). Furthermore, a large body of evidence pointed toward aberrant connectivity patterns in people with autism, including alterations within the default mode network (Nair et al., 2020) and increased connectivity effective connectivity between pSTS and mPFC (Alaerts et al., 2017). Thus, a possibility that altered functional connectivity underlying communicative cues perception might be present in people with ASD despite no apparent alterations in the activation patterns should be acknowledged.

The final goal of the project was to investigate specificity of the observed communicative intention recognition difficulties in autism, in comparison to schizophrenia.

Contrary to our predictions reflected in hypothesis H4.3., deficits in communicative intention recognition were bigger and more generalized in individuals with schizophrenia compared to autistic individuals. Specifically, contrary to our hypotheses (H4.3b), while ASD and SCZ individuals presented a decreased accuracy compared to the TD group in the dyadic PLW task, the accuracy of the SCZ group was also lower compared to the ASD group (TD>ASD>SCZ). Surprisingly, although both in the autistic and typically developing group accuracy of the recognition of non-communicative dyadic actions in the CID-5 task

was higher than the recognition of communicative actions, such difference was not observed in the schizophrenia group. Moreover, contrary to our expectations (H4.3a), accuracy of the categorization in the single-agent PLW task was lower in participants with schizophrenia compared to both autistic and typically developing participants. However, no difference between ASD and SCZ groups was found in the accuracy of free-generated descriptions of a single point-light walker's actions, and both groups showed similarly decreased performance in this manner compared to the TD group. Finally, contrary to our predictions (H4.3c), no difference between ASD and SCZ participants was found in the recognition of emotion from biological motion, although only SCZ participants scored lower than the typically developing group. Interestingly, more pronounced difficulties in the recognition of intention from biological motion in individuals with schizophrenia partially contradict previous accounts pointing toward more pronounced difficulties in lower-level social cues recognition in autism compared to schizophrenia (Rashidi et al., 2025). Simultaneously, in line with our predictions (H4.2), participants with schizophrenia presented a lower overall level of neurocognitive functioning than the ASD group, as measured by composite scores in the MCCB battery (Green et al., 2004). However, in contrast to our expectations regarding a similar level of emotion recognition and theory of mind in SCZ and ASD individuals (H4.1), participants with schizophrenia presented a lower composite score based on a SCOPE battery (Pinkham et al., 2017). Additionally, only individuals with SCZ presented decreased social cognitive and neurocognitive capacity compared to TD participants. Hence, while both groups presented difficulties with regard to recognition of communicative intentions from biological motion, decreased performance in more complex tasks, including theory of mind measures, was only found in people with schizophrenia. Importantly, as described above, SCZ and ASD groups differed with regard to specific

patterns of communicative intention recognition deficits, with more nuanced difficulties observed in people with autism. Taken all together, it can be suspected that while mechanisms leading to disturbed recognition of intentional cues are shared between different neurodevelopmental conditions, their manifestation and combination might be unique and in consequence - might lead to specific manifestations of social cognitive difficulties in autism and schizophrenia. Few additional factors might have accounted for the observed pattern of results, including gender differences and heterogeneity of autistic population.

Gender specific presentations of both autism and schizophrenia symptoms were previously described. In autistic women, a distinctive pattern of social communication and sensory difficulties (Lai, 2011) and more extensive engagement in compensation were described as central aspects of a "female autism phenotype" (Corbett et al., 2021). In contrast, no gender-specific pattern of social cognitive difficulties was established in schizophrenia, although differences with regard to the core symptoms presentation were described (Falkenburg & Tracy, 2012). Thus, considering an overrepresentation of women in our ASD research sample, we cannot exclude the possibility that the obtained results might reflect a presentation typical for women with autism.

Moreover, a high heterogeneity of the autism population should also be taken into account, as it was recently suggested that separate profiles of ASD presentation might be distinguished, which differ with regard to the clinical and functional outcome (Litman et al., 2025). Considering the social cognitive and neurocognitive composite scores, our study sample might have included mostly people with a "moderate" phenotype. Thus, the pattern of results might be specific for individuals with ASD presenting relatively minor problems

related to social information processing and social functioning and should not be generalized to the broadly affected population.

A possible influence of neurocognition on the obtained results should also be considered, including a high level of neurocognitive skills in participants with autism and neurocognitive deficits in participants with schizophrenia. Importantly, this gap in neurocognitive functioning between schizophrenia and autism was in line with our expectations - it was recently confirmed by one meta-analysis that neurocognitive deficits are more pronounced in people with schizophrenia compared to people with autism without co-occurring intellectual disability (Ozbek et al., 2023). However, it is important to note that in previous studies this discrepancy did not account for the differences in social cognitive performance in both clinical groups (Rashidi et al., 2025). Moreover, social cognition and neurocognition are related to different aspects of functional outcome (Fett et al., 2011; Green et al., 2019), with social cognition mediating the relationship between neurocognition and social functioning (Sasson et al., 2020). At the same time, high neurocognitive resources might have a buffering role, as accounting for the neurocognitive functioning resulted in more profound social cognitive difficulties in the autistic population (Ozbek et al., 2023).

Moreover, although a power analysis was conducted, the results should be scrutinized with regard to the limited sample size in our study, as considering the effect sizes, we cannot rule out the possibility that some of the null findings might have resulted from a limited statistical power, which might apply especially to the exploratory mediation analysis in Chapter 5. and fMRI analyses in Chapter 7.

The limitations of the current methodology suggest several future directions, which could be explored to extend the current findings. Firstly, it has been shown that while some

individuals with ASD can eventually grasp basic social cognitive skills, their spontaneous implementation might still be problematic, which constitutes a crucial factor accounting for decreased social communication (Senju, 2013). Thus, future research should include more ecological and challenging measures, including complex measures of emotion recognition that require integration of contextual cues and measures of implicit theory of mind (Schneider et al., 2013). Moreover, considering our results and previous findings regarding the opposite patterns of interpersonal predictive coding effects in autism and schizophrenia, the incorporation of measures that allow for direct investigation of the IPC facilitation in communicative cues recognition could shed more light on mechanisms responsible for social cognitive difficulties in autism and schizophrenia. Similarly, an instrument that could allow for the direct assessment of under- and over-mentalizing tendencies could help elucidate specific mechanisms of social cognitive deficits in ASD and SCZ. Crucially, future research on neural underpinnings of intention recognition in autism should include the analysis of underlying functional connectivity patterns. Moreover, including electrophysiological methods with a better temporal resolution could provide additional insight into the specific mechanisms contributing to decreased social functioning in the ASD group.

9.3. Conclusions

Presented analyses provide some evidence for abnormal processing of communicative intentions in different neurodevelopmental conditions, as both individuals with schizophrenia and individuals with autism presented difficulties in recognition of the communicative cues based on the point-light agents actions. Importantly, people with schizophrenia presented a more generalized pattern of difficulties, including lower accuracy

in communicative intention recognition compared to people with autism, and lower level of social cognitive and neurocognitive functioning. At the same time, difficulties in recognition of social cues in people with autism were not accompanied by decreased neurocognition, theory of mind and emotion recognition abilities. Considering this dissimilarity, a possibility that different mechanisms leading to abnormal social functioning in autism and schizophrenia should be considered. At the same time, individuals with autism presented an increased level of self-report social cognitive bias, which was previously discussed mostly with regard to psychosis. However, as heightened social cognitive bias in people with autism was not reflected in the vignette-based measures, different mechanisms including integration of contextual cues and low reliability in self-assessment measures in autism could also account for these observations. Finally, no difference with regard to neural activity related to social perception, emotional processing and theory of mind circuits was found between individuals with autism and typically developing individuals. Although surprising, the observed effect might have resulted from a small research sample that included individuals presenting moderately affected ASD phenotype. Thus, further research should investigate neural underpinnings of communicative intentions processing in a larger, more heterogeneous group of autistic people.

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Supplementary Materials

Supplementary Table 1

Psychological intervention reported by participants in the ASD group.

N	Type of intervention as reported by participants with ASD
8	only individual psychotherapy
4	individual and group psychotherapy
1	Social Skills Training (SST)
1	peer support intervention
1	peer support + SST
2	intervention recalled, but no specific details given
4	no intervention recalled (past or present)

Supplementary Table 2

List of CID-5 (Manera et al., 2010) items used in the current study

Type	Item	Description
Communicative	Pick this up	A points to B something to pick up. B picks something up
	Move this down	A asks B to move something. B moves something
	Squat down	A asks B to squat down. B squats down
	Look at the ceiling	A asks B to look at something behind him on the ceiling. B turns around
	Sit down	A asks B to sit down. B sits down
	Choose which one	A asks B to choose between two objects. B takes an object
Individual	Turn over	A turns over. B squats down
	Sneeze	A sneezes. B turns around
	Look under the foot	A looks under his foot. B moves something
	Lateral steps	A makes some lateral steps. B takes something and eats it
	Drink	A drinks. B sits down
	Jump	A jumps. B picks something up

Supplementary Table 3

List of Gestures items used in the current study (Jaywant et al., 2016)

Communicative items	Individual items
Blowing a kiss	Call (phone)
“Calm down”	Combing hair
“Come here”	Drinking water
“Enough”	Eating
“Get out”	Fishing
“Good job”	Hammering a nail
“I’m cold”	Juggling
“I’m not listening”	Opening a bottle
“I’m sleepy”	Shoveling
“I’m watching you”	Stirring
“Over there”	Sweeping the floor
Shrug	Washing
Rubbing tummy	Writing

Supplementary Table 4

Mean activity (percent signal change) in each condition in Social Perception and Interaction Task task, along with differences between conditions, within a predefined regions of interests.

Task	Structure	Side	COM	EMO	IND	SCR	Significant differences
BioLoc	pSTS-BM	L	2.16; 0.28	2.15; 0.35	1.71; 0.32	1.13; 0.31	COM>IND, p = .010; EMO>IND, p = .003; COM, EMO, IND>SCR, p < .001
BioLoc	pSTS-BM	R	3.15; 0.31	3.50; 0.34	2.49; 0.31	1.63; 0.31	EMO>COM, p = .045; COM>IND, SCR, p < 001; EMO>IND; p < .001
HCP-EMO	AMY	L	-0.07; 0.18	0.22; 0.18	0.01; 0.15	-0.01; 0.16	EMO>COM, p = .004; EMO>IND, p = .041
HCP-EMO	AMY	R	0.19; 0.21	0.55; 0.29	0.27; 0.18	0.22; 0.17	EMO>COM,IND, p < .001; EMO > SCR, p = .004
HCP-SOC	pSTS-ANIM	L	2.00; 0.28	2.00; 0.35	1.54; 0.32	0.95; 0.31	COM, EMO<IND, p = .004; COM, EMO, IND > SCR, p < .001
HCP-SOC	pSTS-ANIM	R	2.94; 0.28	3.15; 0.30	2.26; 0.29	1.39; 0.27	COM>IND, SCR, p < .001; EMO>IND, p < .001; IND>SCR, p < .001

Task	Structure	Side	COM	EMO	IND	SCR	Significant differences
Why How	TPJ	L	0.34; 0.31	0.37; 0.36	0.07; 0.34	0.05; 0.36	-
Why How	TPJ	R	0.44; 0.30	0.44; 0.32	0.28; 0.30	-0.12; 0.31	COM>SCR, p = .044; EMO > SCR, p = .008; IND> SCR, p = .025
Why How	mPFC	-	-2.13; 0.42	-1.22; 0.42	-2.26; 0.44	-1.56; 0.44	COM<EMO, p < .001; EMO>IND, p < .001; SCR<IND, p = .007

Note: BioLoc - Biological Motion Localizer; HCP-EMO - Human Connectome Project Emotion Processing; HCP-SOC - Human Connectome Project Social Cognition; pSTS-posterior superior temporal sulcus; AMY - amygdala; TPJ - temporo-parietal junction; mPFC - medial prefrontal cortex; BM - biological motion; ANIM - animacy; COM - communicative interaction; EMO - affective exchange; IND - individual; SCR - scrambled.