Chapter 7

Implicit and Spontaneous Theory of Mind Reasoning in Autism Spectrum Disorders

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Additional information is available at the end of the chapter

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1. Introduction

In a seminal study, conducted almost 30 years ago, Baron-Cohen, Leslie and Frith [1] provided first empirical support for the idea that individuals with autism spectrum disorders (ASD) have a Theory of Mind (ToM) deficit, i.e. they are impaired in the fundamental human ability to attribute mental states like beliefs, desires or intentions to themselves and others and therefore fail to explain and predict behavior in a commonsense way in everyday interactions (see [2]). Baron-Cohen et al. [1] used a task in which story character Sally does not witness story character Anne transferring a ball from a basket to a box and thus falsely believes it is still in its original location. Twelve-year-old participants with ASD systematically based their prediction of Sally's search behavior on their own knowledge about the situation and failed the test, answering she will look for the ball in its new location. Crucially, typically developed children and children with Down's Syndrome who were matched for mental age, passed the task. It was concluded that participants with ASD were specifically impaired in adopting Sally's perspective, that is, in attributing a false belief to her. Since then, a wealth of studies confirmed this ToM deficit in children and adults with ASD (e.g., [3]).

Despite its major contributions to explaining core symptoms of autism (social deficits, deficits in pragmatic language, imaginative play, and empathy), the ToM hypothesis has also been criticized for failing to provide a specific account for the social and cognitive impairments, especially in high functioning individuals with ASD [4]. First, verbal skills strongly predict performance on verbal ToM tasks [5]. In some studies, when verbal ability was entered as a covariate, ToM did not predict the degree of social impairments in children and adults with ASD [6]. Second, ToM deficits are not specific to ASD, but have also been observed in clinical groups with for example schizophrenia [7] and deafness [8]. Third, ToM skills assessed in standard experimental tasks may not be informative of real-world social competencies and deficits, since experimental situations do not pose the kinds of stressful demands on individuals with ASD that real-life social situations do. This may be one reason for the failure of ToM-based interventions to enhance real-world social competencies [9].

In the last ten years, new methods, relying on spontaneous and implicit ToM processing have been productively used to further investigate the social and cognitive impairments in ASD. These methods were first used in infant research; infants and young children under the age of about 4 years, like patients with ASD, fail explicit ToM tasks, but nevertheless show a spontaneous sensitivity to others' mental states in looking-time, eye-tracking, and interactive tasks [10]. An implicit ToM appears to developmentally precede an explicit one (two-systems accounts; [11]).

Explicit ToM reasoning describes the ability to deliberately consider others' mental states and provide reasons in order to explain their behavior ("Sally will look for the ball in the basket because she falsely believes it is still in there"; see [12]). This form of ToM reasoning acts consciously, can be flexibly employed in various situations, and is cognitively demanding. Explicit ToM tasks, like the Sally-Anne task, test this ability by assessing verbal responses to the direct question for the protagonist's mental state and belief-based behavior.

Implicit ToM reasoning refers to the spontaneous sensitivity to others' mental states without the need to deliberately reflect on them. It is supposed to work fast, unconsciously, but rigidly. Implicit ToM tasks, clever nonverbal versions of the Sally-Anne task, assess the participant's gaze in anticipation of the protagonist's belief-based behavior as an indicator of implicit ToM reasoning (e.g., [13]). In the first section of the present chapter, we review the research on implicit ToM processing in ASD.

Not all spontaneous ToM processing is implicit. The spontaneous use of mental state terms in everyday conversations is one of the first signs for an explicit understanding of mental states in child development, with talk about volitional states and emotions, beginning in the second year of life and preceding cognitive language by over one year [14]. While some usages of mental state terms serve conversational functions without genuine reference to mental states [14], there is evidence for specific relations between cognition terms and perspective taking abilities [15] and for predictive relations between preverbal communicative abilities and mental state language [16] in child development. Since the study of mental state language in ASD poses fewer restrictive task demands than experimental ToM tasks, it may add to our understanding of mental state representation in ASD in important ways. The second part of the present chapter focuses on this line of research.

2. Implicit theory of mind reasoning in Autism Spectrum Disorders: Insights from the analysis of eye movements

In the last years, eye tracking gained massive popularity in ASD research [17]. This method aims at linking gaze patterns to cognitive processes [18]. Tracking eye movements while watching social stimuli on a computer screen is especially suited for ASD research because it

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is independent of verbal abilities of the participants and avoids possible aversively experienced social interactions with the experimenter during the test.

Senju, Southgate, White and Frith [19] were the first to combine eye tracking and an implicit ToM task in an experiment with individuals with ASD and found a striking dissociation between explicit and implicit ToM reasoning: Participants with Asperger syndrome did not differ from a neurotypical control group in their performance on explicit ToM tasks. However, their eye movements in the implicit false belief task revealed an intriguing group difference. In this task, just like in the explicit version, the participants watched an agent who did not witness the transfer of a ball from one box to another and thus has a false belief about its location. However, in the subsequent test phase, participants were not explicitly asked where the agent would search for the ball (in the now empty box), but eye movements in anticipation of the following reaching action of the agent were measured. This allowed for assessing whether participants kept track of the agent's belief about the object's location without explicitly asking for it. Whereas neurotypical adults correctly anticipated that the agent would search for the ball in the now empty box, individuals with ASD lacked this anticipation of the false-belief congruent behavior.

Senju et al.'s [19] groundbreaking findings corroborated two-systems accounts of ToM. Furthermore, the findings suggest that while the explicit ToM deficit can be alleviated by compensatory strategies [20], the implicit ToM reasoning deficit is sustained and not addressable with learning strategies [21].

The following section reviews recent empirical findings on implicit and explicit ToM in ASD to shed light on the cognitive characteristics of ToM reasoning in ASD. In the beginning we provide a short rationale of why and how eye movements can be utilized to draw conclusions on the cognitive nature of ToM reasoning. Subsequently, we review the fast growing body of evidence on implicit ToM reasoning in ASD in the light of two-systems accounts. We will particularly discuss the fit of recent empirical findings with the notion of a sustained implicit ToM deficit which cannot be compensated for.

2.1. What eye movements reveal about ToM reasoning

In the past years the analysis of gaze behavior became more and more popular in ToM research. The investigation of eye movements aims to relate gaze patterns to cognitive processes. In two-dimensional scenes two basic types of eye movements occur: First, fixations, the persistence of the center of sharp vision for a specific amount of time on an item in the scene; second, saccades, jump-like movements of the eyes from one fixation to the next. Since visual information is only obtained during fixations, fixation patterns can very precisely reveal what visual information is taken into account at a given point in time [18]. On the basis of such data, conclusions can be drawn on the cognitive processes that underlie visual search [22]. Eye tracking systems provide an abundance of precise information about the focus of visual attention in time and space. These systems record gaze data from one or both eyes, providing x-and y-coordinates of the fixated location of a screen. This happens on a millisecond level with a spatial resolution of around 0.1° of visual angle, depending on the system, sampling rate, and accuracy of calibration. But how can this method tell us something about ToM reasoning?

In the 1990s eye movements started to be employed in ToM research. Clements and Perner [13] investigated whether eye movements in the false belief task reveal children's understanding of others' mental states. Video recordings of children's looking behavior were decoded and raters judged which of the two locations in a false belief task the child was looking at. Although the 3-year-olds provided a wrong answer, supporting the claim that children before 4 years of age are not able to understand false beliefs [23], their looking patterns suggested sensitivity to the character's false belief. This pioneering eye tracking work started a line of research and a heated debate on when and how children are able to attribute mental states [24]. Furthermore, this study showed that the analysis of eye movements might be an interesting approach to indicate ToM reasoning.

Psycholinguistic research employing the visual world paradigm [25] showed that eye movements are influenced by mental representations. An example of how this paradigm can be used comes from Altmann and Kamide [26]: In their experiment they presented a scene depicting a woman and table, for example. A bottle and a glass were on the floor. Subjects listened to the sentence "The woman will put the glass on the table. Then, she will pick up the bottle, and pour the wine carefully into the glass." This scene either remained unchanged (experiment 1) or it was completely removed before the sentence was spoken (experiment 2). Eye movements towards the table, or towards the location where the table had been, after hearing "pour" revealed an influence of the mental representation of the glass (according to the sentence it should now be on the table) on fixation patterns.

If one's own current and past mental representations of an object's locations in a scene influence eye movements, they might also be sensitive to the processing of another's mental representation. Adapting the visual world paradigm Ferguson and Breheny [27] reported evidence that eye movements indeed provide insight into the real-time processing of others' mental states. In an interactive video task, a participant and a confederate watched movie clips of an object that was put into one of two boxes and subsequently was pulled out of it again. After that the object was either put back into the same place or transferred to the other box. In half oft he trials the confederate did not witness whether there was a transfer or not. Thus, unlike the participant, the confederate was unsure about the final location of the object. At the end of the trial the confederate verbally described the situation as in the following scheme: "The [object] is in box [A/B]". The participants' fixations on the boxes were linked to the onsets of critical words in this verbal description. This analysis revealed a tendency to fixate the box in which the object actually ended up. Only when the confederate did not witness the object transfer, this gaze pattern changed towards an increased probability to anticipatorily fixate the alternative box, which was empty, but the confederate might have assumed that it could have been in there. This suggests that participants took into account what the other had or had not seen.

First, this finding demonstrates that neurotypical adults are rapidly and spontaneously sensitive to other's mental states during communication. Second, this study shows that eye movements are a sensitive indicator of spontaneous and "online" ToM reasoning without

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explicitly asking for mental states of others. Thus far, the fast growing field of eye tracking research on ToM has employed a number of paradigms and measures (Box 1 provides an overview of hitherto used eye movement measures).

Anticipatory eye movements. The analysis of predictive saccades and fixations is an appealing way to address ToM reasoning. If the location where someone will fruitlessly search for an item (because of a false belief about the objects' location) is anticipated by predictive saccades and fixations, these eye movements are indicative of cognitive processes that account for the other's false belief (Schneider, Bayliss, Becker & Dux, 2012; Schneider, Lam, Bayliss & Dux, 2012; Senju, Southgate, White & Frith, 2009; Southgate, Senju & Csibra, 2007).

Location of first fixation. The direction of the first saccade on a scene can reveal what item is prioritized (Fletcher-Watson, Findlay, Leekam & Benson, 2008). A tendency to direct the first saccade towards the location where subjects believe an object is, rather than towards the location where the story character falsely believes it is located, may reflect an interference from one's own perspective in a false belief task (Rubio-Férnandez & Glucksberg, 2012).

Fixation latency. How long does it take after trial onset until a certain part of a scene is fixated? The latency until the fixation of a false belief-congruent location is informative about the characteristics of false belief attribution (Rubio-Férnandez & Glucksberg, 2012).

Number of fixations and fixation duration. Analyzing how often and for how long an item is fixated when viewing a scene provides information on the importance this item had in processing the scene and also on the influence of anothers' belief about that item (Keysar, Lin & Barr, 2003). Klein, Zwickel, Prinz and Frith (2009) employed fixation durations on items that elicited mental state attribution as an indicator of processing depth and interpreted it in terms of a high cognitive load, required when we ascribe mental states.

Probability of fixating an object as a function of time. Ferguson and Breheny (2012) showed that when another person might falsely assume an object could be in a certain location, the probability of fixating this location rose when the person started to report his or her assumption about the object's location. This procedure can reveal sensitivity to other's mental states with a crucial advantage: it serves as online measure of ToM reasoning in a natural social interaction without overtly asking for other's mental states (cf., Tanenhaus & Spivey-Knowlton, 1996).

Pupillary dilation. It may also be worthwhile to consider pupillary dilation. Changes in the diameter of the pupil can be linked to attentional shifts and changes in mental states (Laeng, Sirois & Gredebäck, 2012). This might not only be useful to detect if subjects react to another's mental state, but also to see which information at what point in time has led to such a response.

Box 1. Extractable eye movement measures in Theory of Mind (ToM) research

When interpreting eye movements in terms of underlying cognitive functions, a few methodological limitations have to be considered. When an item is fixated during a task, it may be because crucial information of that item is processed, but this must not inevitably be the case. It might also be that during the recorded fixation no information at all or different information is processed, for example in the periphery of the visual field. Aslin [28] pointed to a limitation of global looking time measures that also affects the investigation of the microstructure of eye movements via eye tracking: looking times consist of active information processing as well as blank stares. It cannot be premised that for example in free visual exploration of a scene each recorded fixation reflects active information processing of the fixated item. Furthermore it is possible that during a fixation, not the focused item is regarded, but rather different information is processed. Relevant information about objects can also be obtained in periphery [29]. Additionally, if a fixation reflects cognitive processing of the fixated information, conclusions to a specific cognitive process have to be drawn carefully. Depending on the employed paradigm, observed fixation patterns may reflect the detection, identification, discrimination, categorization or integration of visual stimuli. These factors have to be considered carefully when designing eye tracking paradigms to test ToM reasoning.

In sum, the rapidly increasing number of eye tracking studies on ToM reasoning suggests that the analysis of eye movements is a sensitive measure to address implicit ToM reasoning (cf., [30]). Furthermore, eye tracking appears to be especially well suited to test participants with ASD. First, it allows for inferences on social cognitive processes independent of the verbal abilities of the participants. Second, video presentation takes advantage of a strong preference of individuals with ASD for electronic screen media [31]. Third, unlike in classical false belief tasks (e.g. [32]), eye tracking versions of this task do not entail actual social interactions during stimulus presentation and assessment of measures of interest. In this way social cognition can be studied without possible aversively experienced interactions with the experimenter (cf., [33]). This promises to reduce the burden for participants with ASD to engage in the task and to enable tapping social cognitive process, otherwise masked by a disadvantageous test setting.

A recent study by Chevallier et al. [34] provides empirical support for this idea. In this study children with and without ASD completed a ToM task in a social (instructions by an experimenter) and a nonsocial setting (computer-based instructions). Intriguingly, the ToM performance gap between children with ASD and neurotypical children, consistent with previous literature, was only found in the social setting. Accordingly, recording eye movements while presenting stimuli on a computer screen seems to provide comparable test conditions for participants with and without ASD. To be clear, research on social cognition in ASD should entail the study of real reciprocal social interactions (see [35]). However, one must be aware that such studies might impose too much demand on social interaction and obtained results might lead to an underestimation of social cognitive competencies of individuals with ASD.

2.2. Implicit ToM reasoning and compensatory learning in ASD

To date, the implicit ToM deficit, assessed with an implicit version of the Sally-Anne task, has been documented in adults [19] and eight-year-old children with ASD [36]. Recently, Gliga et al. [37] expanded these findings by showing that this implicit ToM deficit can not only be found in participants with an ASD diagnosis, but also in three-year-old children with an older sibling with ASD. Those children being at risk of developing a disorder from the autism spectrum, differed from a control group in their anticipation of a false-belief congruent action. Morever, Gliga et al.'s results tentatively suggest a gradient in spontaneous sensitivity to others' mental states in the autism spectrum. Within the at-risk group, only children who received an ASD diagnosis themselves later on significantly differed in their anticipatory looking from the control group. Neither at-risk children who developed typically, nor at-risk children who showed subclinical abnormalities later on, differed in their gaze behaviors from the control group. This study suggests that an implicit ToM deficit may not merely originate from isolated intra-individual factors, but may be genetically and/or environmentally determined. Further research is needed to characterize the implicit ToM deficit in the broader autism spectrum.

Both ToM reasoning systems, the explicit and the implicit one, appear to be affected in ASD. However, there seems to be a dissociation with respect to the possibility to tackle an explicit and an implicit ToM deficit by compensatory strategies (see [2,21]): On the one hand, individuals with ASD are able to alleviate an explicit ToM deficit through compensatory learning. Experience with social situations may have led to the acquisition of non-mentalistic routes to deal with mental states of others. Evidence that high functioning individuals with ASD pass explicit ToM tasks supports this notion [20].

On the other hand, based on the finding that those participants with ASD who passed explicit ToM tasks, showed no spontaneous sensitivity to a character's false belief in an implicit ToM task [19], it was argued that this implicit ToM deficit is pervasive and cannot be modulated by compensatory learning. Moreover, if implicit ToM reasoning runs automatically, without top-down control [38], it should not be susceptible by alternative, non-mentalistic, strategies.

Callenmark, Kjellin, Rönnqist and Bölte (2013) [39] report a similar dissociation between explicit and implicit social cognitive processes. In an explicit version of a social cognition task (multiple-choice rating of other people's thoughts about violations of social norms) adolescents with ASD did not differ in their performance from neurotypical controls. However, in a more implicit version of this task (free interview instead of multiple-choice format) the ASD group performed more poorly as compared to the neurotypical control group. In a similar vein to Senju et al [19], the authors concluded that in explicit but not in implicit tasks, compensatory strategies which were acquired through learning and experience with social situations, can be employed.

A limitation of the above described implicit false belief tasks is that they only employed one critical test trial to assess gaze behavior that indicates a lack of spontaneous sensitivity to mental states in ASD. However, claiming that individuals with ASD have a persisting implicit ToM deficit requires testing whether atypical gaze behavior is sustained over time. Such an implicit ToM deficit, impenetrable by learning from experience, should be observable in the consecutive presentation of multiple test trials and should not be alleviated by the repetition of those trials.

Using a methodologically refined version of the implicit false belief task, Schneider, Slaughter, Bayliss and Dux [40] tested this hypothesis in adults with ASD. First, they replicated the previously observed group difference between participants with and without ASD in false-belief congruent anticipatory looking. Second, for both groups gaze behavior remained stable over the repetition of test trials: Whereas the neurotypical control group showed sustained false belief-congruent anticipatory looking, individuals with ASD revealed a persisting lack of this false belief tracking. Additionally, just like in Senju et al.'s [19] study, the same participants passed explicit ToM tasks. This empirically underpins the proposal that individuals with ASD can employ explicitly learned strategies to face an explicit ToM deficit and that those strategies are useless to tackle an implicit ToM deficit. Furthermore, these findings critically extend previous suggestions by adding the notion that experience with the implicit false belief task (through repeating the test trials) does not trigger spontaneous compensatory learning.

In contrast to the finding by Schneider et al. [41], Schuwerk, Vuori and Sodian [42] reported apparently contradictory results. They also adapted Senju et al.'s [19] paradigm to test learning effects on false belief-congruent anticipatory looking in adults with ASD. In order to assess the impact of experience on gaze behavior, the critical false belief test trial was repeated once. Eye movement patterns in the first presentation of the false belief test trial revealed the well-documented group difference between the participants with ASD and the neurotypical controls. However, in the subsequent repetition of the test trial, anticipatory looking of the ASD group no longer differed from the neurotypical control group.

Why did Schneider et al. find no effect of experience in a total of ten subsequently presented false belief trials whereas in Schuwerk et al.'s study the single repetition of the false belief trial was sufficient to make the group difference disappear? One task property, which was changed by Schuwerk et al., but not by Schneider et al., can serve as explanation of those discrepant findings. In contrast to previous versions of this implicit false belief task, Schuwerk et al. presented the belief-corresponding action (the agent is searching for the object in the now empty box), and its outcome (the actor does not find the car). Therefore it is possible that presenting a perception-action contingency (agent does not witness the transfer – agent searches for the object in the wrong box) provided a basis for individuals with ASD to learn about the association between the agent's gaze direction and the subsequent action. Notably, this learning from experience can result in the observed alternation of gaze behavior without the need to actually consider the actor's mental state. Thus, this finding suggests that individuals with ASD are sensitive to behavioral cues to learn about perception-action contingencies. Furthermore, this knowledge can be employed as compensatory strategy to rapidly adapt action predictions in an implicit ToM task.

2.3. Summary

In sum, evidence is accumulating that implicit ToM reasoning is impaired in individuals with ASD and also their younger siblings. Moreover, compensatory non-mentalistic strategies, which are useful in explicit ToM tasks, fail to alleviate the deficit to spontaneously appreciate another's mental state. However, recent findings show that the strict distinction that explicit, but not implicit ToM reasoning can be addressed by compensatory learning, may not be tenable. It rather seems that also the implicit ToM deficit can be modulated by compensatory strategies: if individuals with ASD are provided perception-action contingencies, they may also be able to rapidly use this information to anticipate another's false belief-based action. We propose that the implicit ToM deficit in ASD is not as persistent and impenetrable as it seems. Future research has to evaluate possibilities to tackle the lack of spontaneous belief appreciation with learning from experience. More evidence for compensatory learning in implicit social cognition would support the previously tentatively stated idea that compensatory strategies can be taught to face impaired implicit social cognitive processes in ASD [43].

To conclude, the analysis of eye movements has substantially advanced our understanding of ToM reasoning in ASD. The advantage of eye tracking to tap into more implicit social cognitive

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processing makes this method an integral part of future research on two-systems accounts of functional and dysfunctional ToM.

3. Explicit theory of mind reasoning in Autism Spectrum Disorders

3.1. Early explicit ToM in spontaneous mental state language

In the second year of life, typically developing children begin to refer to invisible and abstract entities, like their own and others' psychological states. Such states can be volitional states (e.g., "want"), ability terms (e.g., "hard to do"), perceptions (e.g., "see"), physiological states (e.g., "hungry"), emotional states (e.g., "sad"), moral terms (e.g., "good"), or cognitive states (e.g., "know") (cf. also [44]). All of these states have in common that they describe intangible processes within a person. One key aspect of children's mental state references is that they indicate the development of children's explicit, verbally expressible ToM, which begins to emerge in the second year of life. Mental state vocabulary may serve a variety of conversational functions in discourse (e.g., "you know?" is often used in a colloquial way rather than to inquire after someone's knowledge state) and thus might not always indicate psychological comprehension. However, there is evidence for genuine references to mental states (desires, knowledge, beliefs, emotions) early in development [14].The definition of what a ToM is has different shades of meaning across different areas of research. According to Premack and Woodruff [45] ToM is the ability to attribute mental states to one self and others. This ability can be understood as a "theory" because mental states cannot be observed but have to be inferred. Thus, just like a scientific theory helps researchers explain their data, a ToM helps humans explain the underlying causes of the observable behaviour of others. Since autistic children are impaired in their mental state representation, as assessed in ToM tasks, it seems likely that their spontaneous mental state language production should also be impaired.

The evidence on the development of mental state language in ASD is scarce and partly contradictory. While some studies indicate impairments across a broad range of internal state term categories, others provide evidence for specific impairments or, dependent on the context, even no impairments. For instance, when playing with their preferred toys, children with ASD were specifically impaired in their use of cognitive terms (e.g., "think") and were less other-oriented than neurotypical controls by using fewer mental state terms to call for attention [46]. To detect specific impairments in autistic children, Tager-Flusberg [46] compared 6 boys with Down syndrome (DS) to 6 boys with autism matched for age (range 3 to 6 years) and mean length of utterance (MLU). The children with autism exceeded controls in their use of desire terms (e.g., "want") and references to causes and antecedents of desires. However, they were impaired in their use of cognitive terms and used fewer mental state terms to call for attention. With increasing MLU, autistic children were shown to increase their use of desire, emotion, and perception terms, but not their use of cognitive terms. In contrast, another study [see 9] reported in a sample of 30 autistic children from age 4 to 13 years that in interactions around a wordless picture-book they produced fewer internal state words in any category (emotion, volition, cognition, or perception). Tager-Flusberg [46] reports that in their study the mothers were asked to select activity toys or games that would best suit the individual interests of the children. Thus, parent-child object play with a familiar toy, due to its interactive nature, might have elicited more desire, perception, and emotion talk in autistic children than would normally be the case. This is corroborated by the fact that in the Tager-Flusberg [46] study autistic children's conversational use of desire terms by far exceeded the genuine use of desire terms. Studies using storybook narratives and memory narratives rather than toys showed that children with ASD were less likely to include terms that referred to cognitive, emotional or perceptual states [46]. Even when using as many internal state terms as controls, children with ASD made less effort to explicate the causes of mental states in their narratives and they were also limited in their ability to monitor and sustain listeners' attention when compared to the narratives of matched controls [47]. This indicates that internal state language might not always be indicative of autistic children's awareness of their own and other's psychological states. This could explain why training autistic children's mental state understanding is not related to their mere use of mental state terms when narrating a wordless picture-book [9], while training their communication of internal state terms in a truly intentional way might be. However, some studies indicate interrelations between autistic children's cognition talk and their overall comprehension of the mind, including more complex emotion understanding. For instance, two studies found significant positive associations between autistic children's use of cognitive terms (while narrating stories to others) and their ToM abilities [48], as well as more specifically, their false belief abilities [49]. In contrast, Losh and Capps [47] found that autistic children's use of mental state terms in personal and storybook narratives (cognitive or affective) were significantly associated with their ability to define emotions, but not to ToM abilities. Recent work [50] showed that autistic children's general ToM scores were related to their use of emotion terms during a wordless picture book interaction, but not to their use of cognition terms. Differences across studies might have to do with context effects on internal state talk. In some contexts autistic children might communicate psychological meaning, in some contexts they might not. Note that internal state talk was assessed differently in each study. Further, as tasks tap into different facets of ToM, including children's comprehension of hidden emotion, moral and irony, developmental links between talk about psychological states and children's conceptual comprehension might also become increasingly complex. In regard to ToM development, consistent with the development of mental state talk in English-speaking (Bartsch & Wellman, 1995) [14], as well as in children speaking other languages [51], typically-developing children [52] usually first come to understand own desire and own beliefs, before they come to understand perceptions and others' false beliefs, as well as hidden emotions and finally, children grasp that other people can misconstrue others' minds (second-order theory of mind) [53]. In contrast, autistic children show the same developmental sequence up to a point, but in the later steps of progression, they show a significantly different sequence of understandings [54]. While they lag behind several years, like in typically-developing children, autistic children's understanding of desires precedes an understanding of belief. In addition, they comprehend knowledge and ignorance before they develop a grasp that someone can hold a belief that differs from reality and is false. In contrast to typical development, autistic children were shown to understand hidden (or false) emotions slightly earlier than false beliefs.

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In order to provide a fuller picture, future research needs to explore context effects on autistic children's internal state language. For instance, situations that prove motivating for autistic children are likely to be nonsocial in nature and might involve mechanical systems (e.g., mechanical toys) [55]. These situations might provide autistic children with opportunities to talk about their own volitional and eventually, also emotional states. Consistently, autistic toddlers were found to exceed boys with Down syndrome in their use of desire terms (e.g., "want") and references to causes and antecedents of desires when playing with their own toys [46]. Further, children with autism were found to use less mental state language when describing picture-sequences involving human intentions than controls, while they did not differ from controls when describing pictures depicting behavioral interactions or mechanical actions [56]. Finally, when describing mechanical or intentional launching effects of animated stimuli, 6-to 15 year old autistic individuals [57] were found to use as many mental state terms as controls. What remains unclear is if this kind of mental state talk is related to child ToM. Further, studies need to explore if and how autistic individuals' impaired social attention (e.g., [58]) is related to both children's talk about and comprehension of the mind. According to socio-constructivists, triadic interactions, which emerge at about the end of the first year of life and involve the infant, another person and an object, event, or mental states, are thought to be the basis of children's ToM development (cf. [59]). Note that consistent with the socio-constructivist view of language development, longitudinal work in typically-developing children showed that joint attention skills are developmentally related to children's internal state language vocabulary [16]. A rather general main proposal of the socio-constructivist view is that children actively construe [60] a ToM by interacting and communicating with other individuals, as opposed to "passively" acquiring a theory of mind. According to socio-constructivists, triadic interactions, which emerge at about the end of the first year of life and involve the infant, another person and an object, event, or mental states, are thought to be the basis of children's theory of mind development. For instance, talk about cognitive states within the family is thought to be causally related to inter-individual differences in ToM development. The developmental process itself is gradual and cumulative. This view corresponds to the contextual view of semantic development [61]. In summary, the contextual view emphasizes the relevance of early communicative exchanges in establishing the meaning of mental verbs. It is the functional use of mental state terms in familiar and recurrent contexts, in which children communicate pre-linguistically and verbally with others, which according to this view plays a central role for the development of mental state language. This view suggests that the pre-verbal obtainment of objects (such as the use of proto-imperatives [62] is at the centre of joint attentional communicative exchanges from which desire verbs emerge and that the subsequent linguistic development involves expanding the number of ways of talking about desires within communicative acts. For instance, children have to learn that "like" is used to describe a general preference which is distinct from seeking to obtain something for the moment being, as would be indicated by "want". In sum, the contextual view considers semantic development to be the product of the social practices, framing the purpose of words, the pragmatic purposes of the words, the peculiar syntactic properties of the verbs, and the relevant cognitive development. Turnbull & Carpendale [63] found numerous examples of criteria displays (pointing to a person's puzzled look and describing the person to be "thinking") in typically-developing mother-child dyads.

One direct implication of the contextual view is that if the criteria that are normally displayed in parent-child dyads are impaired, as is the case in autism, this might be related to children's delayed ToM performance. Further, mothers might also be influenced by children's skill level. Recent research by Slaughter, Peterson, & Carpenter [64] suggests that mothers' mental state talk is connected to both infants' joint visual attention and their emerging pointing skills. For instance, mothers seem to switch their conversational focus from their infants' visual behaviour and experiences to the object of their mutual attention and children's imperative pointing gestures are directly followed by mothers' talk about volitions and intention, while later, declarative gestures are followed by both, epistemic and cognitive state talk. If children point less, this might lead parents to talk less. For instance, in a case study [65], all parental talk directed to a young child with autism at home over a day-period was analysed for internal state language focusing explicitly on the thoughts, feelings, and perceptions of animate beings. Compared to what has been found in parents of typically developing children, the parents rarely elaborated on the causes and consequences of these internal states and they primarily referred to sensory and desire terms (the mother did so in 24% of her utterances, while the father did so in 33% of his utterances).

3.2. Later explicit, spontaneous ToM: Mind-Mindedness

There is ample evidence for a deficit in ToM for others in adults with ASD (see [66] for a review). More specifically, autistic adults are severely impaired in their ability to decode affective (e.g., reading emotions from the eye region) and cognitive states. There is, however, a growing dissatisfaction with the tasks used to assess ToM abilities in adults with ASD.

One prominent task to measure autistic individual's emotion understanding (affective ToM) is the Reading-the-Mind-in-the-Eyes task (RME task; [3]). The task contains 36 black/white photographs of the eye region expressing complex mental states in terms of emotions, such as 'jealous', 'bored', or 'admiring'. Participants have to distinguish the correct mental state from three distractors (i.e., mental state terms with the same emotional valence as the target) on each trial. Previous research has shown that the performance on the RME task is inversely correlated with the degree of autistic impairments and is significantly lower in autistic adults when compared to controls (e.g., [67,68]). Autistic individual's comprehension of cognitive states is usually measured with the Strange Stories-test [69]. This test is also called the short stories task and comprises five mental short stories referring to five different advanced ToM abilities: double bluff, white lie, deception, misunderstanding, emotion understanding. The short stories require participants to provide mental state justifications for story characters' nonliteral statements and thus measure ToM for others. Research has shown a general deficit on advanced ToM tasks in adults with ASD which appears on the social-perceptual level, as well as on the conceptual level, with reference to self and others (e.g., [70]), In regard to ToM for other, the worse performance of the ASD group on the RME task compared to controls provides further evidence for an impairment of social–perceptual processes, which enable mental state decoding from nonverbal cues (i.e., eye gaze), in ASD (e.g., [3]). The results from the mental

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short stories clearly indicate that adults with ASD have difficulties in providing mental state justifications for story characters' nonliteral statements (i.e., double bluff, white lie, deception, misunderstanding), as well as in emotion understanding. In most studies, the deficit in mental state reasoning observed in ASD appears largely independent of verbal and non-verbal intelligence. Few studies have explored ToM for self, with results indicating severe and specific deficits in self-knowledge in ASD (see [71]). In sum, the assessments of ToM abilities and deficits in adults with ASD are highly specific, posing considerable verbal demands, and neglecting a wide range of competencies underlying spontaneous mentalizing.

In developmental research, the concept of Mind-Mindedness (MM) has been productively used by Meins and her colleagues to capture individual differences in the spontaneous tendency to conceive of a person in mentalistic (as oposed to behavioural) terms. Meins, Fernyhough, Russell & Clark-Carter, 1998 [72] first studied the concept in mothers by letting them describe their children. They found that mothers differ in the degree to which they reflect upon their children in mentalistic terms rather than based on their outward appearance or behaviour. Thereby, a greater number of mental terms (e.g., "*he is reflective*") instead of behavioural terms (e.g., "*he likes to ride his bike*"), physical (e.g., "*he has brown hair*") or general terms (e.g., "*he is my neighbour*") indicate a higher degree of mindedness in regard to others' mind (mind-mindedness) (cf. [73]). Meins and colleagues [73] have since extended the concept to friends, romantic partners and works of art.

If individuals with ASD are impaired in their everyday, spontaneous ability to conceive of themselves and others as mental agents, then this deficit should be reflected in their person descriptions. To date, the concept has only been employed in one study [74] with respect to self-descriptions. Few studies have investigated self-concepts of individuals with ASD at all (e.g., [75]). In an early study, Lee and Hobson [76] employed a self-understanding interview [77] in a sample of children and adolescents with and without ASD and found that participants with ASD produced significantly fewer self-descriptors scored as "social" compared to controls. Further, an elaborated analysis of the content of psychological statements highlighted qualitative differences: More than half of the psychological self-descriptors in the ASD group referred to preferred activities (e.g., 'I like swimming.'). The study by Kristen, Rossmann, Sodian, [74], used the MM-task adapted from Meins & Fernyhough (cf. [73,78]). Since MM was assessed in adults, a representational measure of MM was used. Participants were given a simple, open-ended instruction: "Can you describe yourself for me? What kind of a person are you? Tell me everything you consider as important to describe yourself!" Participants were not given any hints on how to answer the question. The results suggest that when compared to typically-developing controls, individuals with ASD use fewer mental self-descriptors, which appears to point to their inability to reflect on their own mental states in a mind-minded way. This result remained stable when controlling for verbal and non-verbal IQ.

The following paragraph is an example (translated from German) of an autistic male's self-description referring mainly to general information and physical aspects.

"First, my age and I have siblings and so on. I am 37 years of age and will turn 38 on the 29th of november. My hobbies are varied: I hike, I ride my bike, I watch TV, I go to the theatre and to the ballet, the opera. I perform on stage and I write poems. I have brown-blond hair and blue eyes. I always smile. I have had

surgery, but I don't want people to know. I'm autistic and this is important for people to know. I also repeat myself sometimes. But I will manage this problem. I work 8 hours a week. I'm very interested in the weather, that is my work and in maps, as a hobby. Sometimes I read books".

The following paragraph constitutes a more mind-minded description from a participant from the control group. Note that even a less talkative person's self-reflection can contain a high percentage of mind-minded comments. This demonstrates that mind-mindedness is independent of verbosity. The paragraph also shows the relatively low levels of general and behavioral information in a typically-developing person's self-description.

"I am a very considerate person. I reflect a lot upon myself and others. I am also very sensitive and interested in artistic aspects of human existence. I am also a bit arrogant, or at least, others might think I am arrogant. But I am also honest and trustworthy. "

ToM for self does not take into account the accuracy or appropriateness of mental state ascriptions (cf. [73]). Thus, it remains an open question how appropriately autistic adults reflect on themselves. Consequently, studies need to address not only if, but how appropriately ASD patients ascribe mental states to themselves.

Since impaired ToM for self is connected to an impaired episodical, autobiographical memory it might also be seen as a valid indicator of an impaired identity development in autism. In contrast to semantic traces, episodic traces cannot be formed (i.e., events cannot be encoded as experienced) without a ToM. According to Tulving [79,80] and colleagues [81], the involvement of self (autonoetic) consciousness is assumed to be critical for episodic autobiographical memory in adulthood. Thus, episodic memory deficits in adults with autism might be due to a diminished level of self-consciousness at encoding. The work by Kristen et al. [74] showed a specific correlation between MM for self and personal episodic memory that was independent of verbal and non-verbal IQ and that can be interpreted in terms of introspection. Introspection is essential for ascribing mental states to oneself as well as for re-experiencing personal episodic memories. A study by Perner et al. [82] showed that a modality-specificity test of ToM, which required introspection, yielded the highest predictive value of episodic memory performance compared to other ToM tasks. This was seen as evidence that introspection is functionally related to children's understanding of the sources of their experience. More specifically, when children re-experience (i.e., remember actively) a past event, they have to understand that the origin of this experience lies in the past (understanding source of experience) and that this experience is a representation of the original experience (meta-representational understanding). Further, the correlation might reflect autobiographical meaning making skills. It has been proposed that the construction of autobiographical memories constitutes a complex, narrative process [83,84]. Thereby, the use of mental state terms is a good indicator that one has formed organized explanatory accounts of past events that are integrated with a subjective perspective on one's own thoughts and emotional reactions to autobiographical events [85]. Further, if autobiographical memories are less coherently constructed this, in turn, might lead to the need for more prompts to retrieve personal episodic memories. In support of this view, a study of young school-children [86] suggests that controlled retrieval processes are required to tell about one's past. Like younger children, individuals with ASD might have a less coherently constructed cognitive memory network (i.e., they might not have linked causes to consequences of events) and thus, they might also encounter difficulties in triggering specific nodes within that semantic network (cf. [87]).

3.3. Summary

In sum, studies in autistic children as well as in adults demonstrate a clear deficit in referring to internal states. Further, autistic individuals also lack the ability to comprehend mental states. Thereby, early in development children might lack implicit understanding needed for interactions involving joint attentional cues [88], which in turn, might lead to delayed and impaired mental state language development. Further, work from our own laboratory (Kristen, Vuori, Sodian,[89] submitted) suggests that even if autistic children refer to internal states, it is only the internal state language they utter in a joint attention context in combination with their sustained attention that is related to children's more complex ToM-skills. One possible reason is input poverty, since parents might use less complex internal state language towards children who provide them with fewer joint attention cues and are less attentive. As a result, as adults autistic individuals are not only impaired in their spontaneous explicit ToM, involving implicit decoding skills (as measured by the REM task), but also show deficits in explicit mental verb usage (as measured by the Mind-Mindedness task) that might be based on joint attention deficits.

To conclude, studies on spontaneous explicit ToM support the idea of a ToM deficit in autism. Impairments occur independently of verbal and non-verbal IQ. Thus, the deficit seems to be specific.

4. General conclusions

The empirical investigation of implicit and spontaneous ToM reasoning in ASD is still in an early stage. Yet, the available evidence supports the ToM hypothesis by indicating specific impairments in ASD. With regard to implicit ToM processing, available eye tracking evidence consistently indicates that implicit ToM reasoning is impaired in ASD even in high-functioning adults with ASD, who pass experimental explicit ToM tasks. Individuals with ASD seem to lack a spontaneous sensitivity to other's mental states. This specific deficit might be one origin of social-cognitive deficits and difficulties in social interactions. Further research is needed to evaluate how persistent this implicit ToM deficit is and if learning through experience, or even explicit instructions, can compensate for it. To this end more within-subject studies that systematically assess implicit and explicit ToM task performance, as well as the influence of different forms of training, are desirable.

Moreover, for a better understanding of social-cognitive deficits in ASD we need to gain more knowledge about how individuals with ASD process social signals in general, not only how they process false beliefs. According to a recent account, sensitivity to ostensive signals, such as direct gaze or addressee-directed speech, is essential for learning through social interaction [90]. An impaired processing of ostensive signals in ASD could result in insufficient learning from others, another burden in the life of individuals with ASD.

Another important issue in research on implicit and explicit ToM in autism concerns task analysis: To what extent do certain tasks require automatic, on-line tracking skills (e.g., non-verbal decoding skills) versus conscious and learned reflection on mental states (e.g., the use of mental state vocabulary when describing oneself). The REM task, for instance, requires both types of processing, since one has to decode emotions but also to ascribe the correct verbal label to the emotion. Therefore, it is difficult to pinpoint the nature of autistic individuals' impairments in the task. Similarly, self-descriptions pose complex demands on different levels of processing. Impairments of individuals with ASD may arise from deficits in the fast and automatic retrieval of self-related information as well as from an inability to express their ideas about themselves with a mentalistic vocabulary they have not fully acquired, thus leading to a less detailed and mentalistic account of themselves as individuals. Future research needs to further analyze the relative contribution of implicit and explicit skills in solving a wide array of ToM tasks.

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