Theory of Mind deficits in Anorexia Nervosa and Autism Spectrum Condition

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Layman's Summary

Understanding that other people have emotions and thoughts of their own is important in human society. This ability is known as Theory of Mind (ToM). When ToM is not working well, it can cause challenges. Researchers have investigated individuals that have to deal with these challenges. They found that individuals with Anorexia Nervosa (AN) and Autism Spectrum (ASC) were not as good at ToM as neurotypical individuals. However, there is a difference between implicit (indirect) and explicit (direct) ToM. People with AN and ASC seem to be able to directly tell whether another person thinks something else, but not be able to indirectly put another person's thoughts in context. Because of this difference, new tests for ToM should be considered that focus on this difference. Moreover, it was found that individuals with ASC and AN had less brain activity in ToM brain areas and neurological treatments such as tDCS was successful in ASC participants. This could be an option for treatment of ToM difficulties in AN participants as well. Further research should combine knowledge of lessened ToM abilities in AN and ASC, leading to new treatment and diagnosis options.

Abstract

Theory of Mind (ToM) is an important ability for people to understand and be able to function in humans' complex social environment. Deficits in ToM are therefore an important subject for research and treatments. In both Anorexia Nervosa (AN) and Autism Spectrum condition (ASC) deficits in ToM have been found. However, there is a difference between implicit and explicit ToM. Both in individuals with ASC and AN, the deficits seem to be in implicit rather than explicit ToM. But more research is needed to confidently establish this. This suggests the re-evaluation of ToM tests, focussing more on multifaceted non-verbal implicit ToM tests, to get the full range of ToM without verbal challenges. Research has found that ToM deficits seem to be linked to hypoactivation of the TPJ. In ASC, treatments such as tDCS on the TPJ have lessened the difficulties these individuals have with ToM. Further research therefore needs to investigate tDCS in individuals with AN. Furthermore, knowledge of both ASC and AN ToM deficits should be combined for better treatment and diagnosis options.

Introduction

The acquisition of effective social skills plays a vital role in normal development, enabling individuals to form and sustain fulfilling social connections and facilitating community adaptation throughout their lives (Cacioppo, 2002). The development of social skills is a complex process that entails the maturation of various cognitive functions collectively known as "social cognition." One of these cognitive functions is Theory of Mind (ToM): the capacity to understand and attribute mental states to oneself and others. The exploration of ToM has been a prevalent focus in various fields such as developmental, educational, neuro-, and social psychology, social neuroscience, and speech therapy. This is mostly because of the wide range of aspects associated to ToM. First of all, false belief understanding is essential for ToM. In addition, other mental-state concepts such as knowledge, emotions, intentions and desires are thought to be important for the ability of a representational ToM (Wellman & Liu, 2004). Researchers have consistently connected ToM abilities to social adaptation, and these ToM skills have been demonstrated to be susceptible to impairment in different clinical conditions (Beaudoin et al., 2020).

Furthermore, there is also a difference between implicit and explicit ToM (Low & Perner, 2012). Implicit ToM tasks draw upon the operations of a simpler, evolutionarily and developmentally older system, functioning rapidly and independently of central cognitive resources such as language or executive function. In contrast, explicit ToM tasks involve the workings of a system that is developed later. It relies on language, executive function and operates with a fully developed conceptual understanding of subjective mental (mis-)representation (Couchman et al., 2012). Children tend to show explicit ToM between the ages of 4 and 5. On the other hand, implicit ToM is thought to occur in children of much younger ages, maybe even the age of one (Kovács et al., 2010).

More specifically, these two aspects significantly differ in their representational functions. Implicit ToM enables an individual to track relational attitudes, which are relationships that agents hold towards situations, such as perceptually registering an event. Through implicit ToM, an agent can engage in level-I perspective-taking by keeping track of what another agent has or has not registered. Importantly, this process doesn't yet involve grasping a crucial aspect of the subjectivity of mental representation, namely their so-called aspectuality. Implicit ToM, limited to representing relational attitudes such as registering an event, lacks the capacity for nuanced distinctions regarding the specific aspects under which an agent encounters an object (Butterfill & Apperly, 2013). On the contrary, explicit ToM entails concepts like "belief," which are inherently aspectual. Ascribing a belief about a given object to an agent through explicit ToM is subjected to the subjective aspects under which the agent represents said object (Oktay-Gür et al., 2018).

Because of the difference between implicit and explicit ToM, ToM testing tasks also differ between measuring implicit or explicit ToM. An example of an explicit false belief measure is the Sally and Ann task. This task starts off with a scenario involving two dolls (Sally and Ann) being presented to a child. The child watches the dolls interact with each other, whereafter questions are asked. The interaction starts by Sally putting her marble in a basket and leaving the scene. Ann then takes the marble from the basket and places it in a box. When Sally returns, the child is asked where Sally would search for the marble. Success in this task requires the child to respond with "in the basket," despite their awareness that the marble is actually in the box. This particular setup allows researchers to assess a child's capacity to comprehend that a person's mental state goes beyond a simple reflection of reality. It indicates the child's ability to construct a theory about where Sally would think the marble is, compared to where the marble actually is (Happé & Loth, 2002). In this task, children explicitly have to tell the researcher whether they understand that Sally and Ann have a different belief of the marble. Therefore, this is an explicit false belief task. Children are expected to pass this test around the age of 3 to 4 (Holroyd & Baron-Cohen, 1993).

Another way of testing ToM is through the TOM test (Theory Of Mind test). The TOM test is an example of a test that evaluates a larger scala of ToM aspects than only false-belief. The TOM test contains three subcategories. It tests the precursors of TOM (e.g. the recognition of emotions or pretences), it tests the first basis of real ToM (e.g. the first understanding of false-belief) and it tests more advanced aspects of ToM (e.g. higher-order false-belief and humour). The test consists of stories, drawings and

printouts about which children have to answer a set of questions. The answer can be evaluated by the executioner of the test, using scoresheets included in the test package. The TOM test is meant for children between the ages of 5 and 12 years old (Murris et al., 1999). This test reviews a much broader range of ToM than the Sally-Ann test, however, the Sally-Ann test can be used for children of much younger ages.
The Reading the Mind in the Eyes Test (RMET) is a test that specifically measures emotion recognition. It can not be used for very young infants, but it is an alternative test that has been linked to ToM as well. In this test, participants have to match a description of an emotions to a picture of a persons face expression an emotion. This way the ability of participants to recognize facial emotion expressions can be tested (Baron-Cohen et al., 2001). However, there is some critique about the RMET. Researchers argue that only emotion-recognition is tested and it cannot be said that the RMET is a ToM test. Emotion-recognition is an aspect of ToM, but other aspects need to be tested to confidently say a participant is or is not capable of ToM (Oakley et al., 2016).

Successfully completing the initial Sally-Ann test demands a substantial cognitive load, involving various cognitive abilities like memory, reaction inhibition, and the ability to verbally understand instructions, along with a false-belief ability. Consequently, an individual's inability to pass this test does not necessarily indicate an impairment in their false-belief reasoning (Clements & Perner, 1994). A more straightforward and completely nonverbal ToM task, know as the implicit ToM task, offers an alternative assessment method. Implicit false-belief can be tested using the Sally and Ann test as well. During an implicit false-belief test, eye-tracking of the participant during the Sally and Ann test can show the implicit false-belief processing in participants. Eye tracking can reveal where children think Sally will look for the marble, because of the focus on the empty basket instead of the box with the marble. This implicit false-belief test can already be successfully performed at the age of two years old (Schneider et al., 2014).
The violation-of-expectation (VoE) is another implicit test method. It is used to explore infants' comprehension of other's goals and involves scenarios where infants' expectations are contradicted. In this test, infants were acquainted with an actor reaching for and grasping one of two toys defined as the target toy. Subsequently, the positions of the two toys were switched, and the actor reached for either the target or the nontarget toy. Infants consistently showed longer looking times when the actor reached for the nontarget toy. These findings imply that the infants had determined the target toy as the actor's intended goal object, anticipating them to reach for it in its new location. The increased attention response when they deviated from the expected action indicates infants' ability to detect deviations from anticipated scenarios (Egawa et al., 2022). Both of these studies, however, only look at the false belief aspect of ToM.
Another study by Kliemann et al. (2013), has developed a face puzzle task, in which both implicit and explicit emotion recognition can be tested. For the implicit task, the top half of an emotion expression face picture needed to be matched with the correct bottom half of the picture. For the explicit task, the whole picture of a person expressing an emotion needed to be matched with the correct emotional label. With this face puzzle task, the difference between implicit and explicit emotion recognition can be measured within the same task.

Earlier research into ToM has investigated the brain regions affecting ToM in individuals. Like many cognitive functions, ToM likely has a specific neurobiological foundation. Drawing insights from single-neuron recordings in non-human primates, Brothers et al., (2002) proposed that the orbitofrontal cortex (OFC), superior temporal sulcus (STS), and amygdala play important roles in primate social cognition; collectively forming a 'social brain.' The inferotemporal cortical regions, including the temporal pole, and the cingulate gyrus were also highlighted for investigation in social cognition. Brothers defined social cognition as the processing of information leading to the accurate perception of the dispositions and intentions of other individuals. This definition, more straightforward and comprehensive than the traditional ToM definition, focuses on the perception of 'dispositions and intentions,' aspects common to both human and non-human primates.

Later research, however, has made a distinction between brain regions associated with implicit and explicit ToM separately. fMRI research has suggested a network of regions that show a higher level of activation when individuals make explicit judgments regarding the mental state of a protagonist, as opposed to making judgments related to physical aspects. These regions include: the medial prefrontal cortex (mPFC), the temporoparietal junction (TPJ), the superior temporal sulcus (STS), the praecuneus and the temporal poles. Especially the right TPJ was involved in a variety of ToM tasks (Saxe, 2009). The TPJ has also been found to be important for implicit belief processing and therefore implicit ToM, but not a lot of research has been done to identify other brain regions associated with implicit ToM (Filmer et al., 2019).

The previously explained tests for Theory of Mind (ToM) are employed to assess the capacity of both neurotypical individuals and individuals with neurodevelopmental disorders. It has been found that both individuals with Autism Spectrum Condition (ASC) and/or Anorexia Nervosa (AN) exhibit deficits in ToM (Sedgewick et al., 2019). Through different kinds of research into the deficits of ToM in these disorders, different treatment suggestions were formed. In addition, the different kinds of research have given insight into the brain areas associated to deficits in ToM for these disorders. This review delves into the investigations conducted for ASC and AN, exploring the findings' implications for identifying and, potentially, treating deficits present in both conditions. By comparing the outcomes of these tests and treatments, a comprehensive understanding of the ToM capabilities in individuals with ASC and AN can be developed, contributing valuable insights to the broader field of neurodevelopmental research. The parallel exploration of ToM deficits in these distinct disorders offers an opportunity to uncover shared mechanisms, which can help develop more effective therapy or treatment methods for both disorders.

ToM and Autism

ASC is a neurodevelopmental condition that has been studied intensively. Autism is thought to be on a spectrum because it varies greatly in symptoms and severity between different people. In addition, ASC can occur at all levels of ability. ASC is known to have an early onset in life, but the diagnosis is often much later than the onset of the disease (Lauritsen, 2013). In the latest version of the diagnostic and statistical manual of mental disorders (DSM-5-TR), ASC is diagnosed based on two areas: 'social communication' and 'restricted, repetitive and/or sensory behaviours of interest'. In order for ASC to be diagnosed, children must have difficulties with and/or difference from what's typical in both previously mentioned areas and have had these difficulties and differences from early childhood. Symptoms can be picked up only later in life, but they must have originated from early childhood (DSM-V-TR authors, 2022). The causes of ASC are mostly genetic. There is no know medical "cure", but it is also not needed to medically cure ASC. With the right behavioural treatment, effects can be lessened and individuals with ASC can learn to cope with the difficulties they encounter (Uta Firth, 2001).

Individuals with ASC commonly have impairments in reciprocal social interactions. However, these impairments do not seem to be a general information processing deficit or social communication deficiency. Rather, the failure of social communication is thought to be caused by a more specific cognitive deficit. A large part of this deficit is caused by the inability to have insight in what other people think or want. The "mind-blindness" theory of autism explains the difficulties at a cognitive level (Uta Firth, 2001) This theory states that individuals are normally capable of ToM, but this capability is often impaired either in a mild or a severe form in individuals with ASC. A study by Hamilton et al. (2009) has made a distinction between visual perspective taking 1 (VPT1) and visual perspective taking 2 (VPT2). They define VTP1 as "the ability to know if a person can see an object or not" and VTP2 as linked to

ToM. They found that children with ASC only suffered from deficits in explicit tasks directed to VTP2. This is in line with the notion that children with ASC have difficulties with ToM.

Furthermore, a study by Gao et al. (2023) found that individuals with ASC performed worse than typically developing (TD) individuals in all four of the ToM tests they performed. They tested: reading comprehension, perceptual scene comprehension, comprehensive scene comprehension and self-other processing. However, this study made no distinction between explicit and implicit ToM. They advised to consider evaluating the degree of cognitive and affective processing that is involved in the ToM task. Lots of adults with ASC have difficulty with executive functions, language processing and self-other distinction, which may influence the results of the tests (Lartseva, Dijkstra, & Buitelaar, 2015).

Additionally, a study by Penuelas-Calvo et al. (2019) did a meta-analysis of 18 studies using the RMET emotional test in neurotypical and ASC participants. Their findings suggested that in the combined data of those 18 studies, ASC individuals had deficits in RMET performance. Also, they found RMET performance to be positively correlated with IQ in neurotypical individuals and negatively correlated in ASC individuals. Also suggesting the test is not optimal for ASC participants.

A study by Baren-Cohen & Hill (2007), used a non-verbal explicit false-belief test in order to see whether verbal impairments had an effect on performance in an explicit false-belief test and a non-verbal true-belief test. They found that children with ASC showed impairment in ToM in both of their non-verbal test. These test, however, still required some extend of language processing skills, as the test was a Sally-Ann test in which the children were asked to point to where the marble was and where Sally thought the marble would be. The participating children still needed to understand what they had to point at, even though the pointing task in itself was non-verbal. A study by Happé (1995) expanded on this research by comparing the verbal ability of neurotypical or ASC participants to their scores in an explicit false-belief test. They found that the verbal ability of the participants was positively correlated with their score on the explicit false-belief test. This means that the impairments in false-belief testing results in children with ASC could be explained by their language impairment. Especially since they found the ASC participants that passed the explicit false-belief test to have a higher level of verbal ability than the ASC participants that did not pass.

An explicit ToM task with limited verbal aspects is the Firth-Happé task. The Firth-Happé task was used in adults with ASC for measuring ToM. In this task, participants observed the movements of triangles representing either action movements, simple interactions, or complex social interactions. Participants had to watch the movements of the triangles and say whether the movements were random, goal-directed or responding to each other's mental states (Livingston et al., 2020). Researchers found that a group of adults with autism demonstrated lower accuracy when categorizing the Frith-Happé animations based on the presence or absence of mental respondence. Additionally, ASC individuals exhibited less proficiency in identifying the correct emotions associated with the triangles in mental state animations (White et al., 2011).

A study by Callenmark et al. (2014) tested the difference between an explicit ToM test (Dewey Story Test with a multiple-choice answering format) and an implicit ToM test (free interview). They found no difference between individuals with ASC or TD individuals in the explicit test, but they did find a significant difference in the implicit ToM test. They stated that the impairments of ASC in ToM are primarily in implicit situations. They specifically state that participants with ASC performed worse than TD participants in spontaneous perspective taking and implicit social awareness. They advise to do an implicit ToM task instead of an explicit ToM task, with a more naturalistic way of evaluating implicit social understanding.

Contrastingly, a study by Deschrijver et al. (2016) did not find a significant difference between an ASC participant and a neurotypical participant in an implicit ToM reasoning task. They find a trend, but not enough to significantly state a difference. They did use a completely different task than Callenmark et al. (2014). Deschrijven er al. (2016) used a variation of the VoE implicit task. With the VoE task it is easier to quantify the data than with a free interview, because of the objective nature of the VoE task and the subjectiveness of a free interview.

On a more neurological level, some research focusses on knowing what brain regions are active when a ToM task is performed. Or even more specific: what brain regions are necessary for the performance of a ToM task. In a study by Apperly et al. (2004) it was investigated what brain regions were active when a non-linguistic believe reasoning task with reduced executive demands was performed. They tested a series of 12 brain-damaged patients with damage in the prefrontal cortex (PFC) or the temporo-parietal cortex (TPJ). They found that errors in the belief-reasoning task by patients with damage to the PFC were due to executive function problems. On the other hand, the errors of the patients with damage to the TPJ were thought to arise because the patients had difficulty with the representation of beliefs instead of executing a belief-reasoning task. The belief-reasoning task they used is not the same as a theory of mind task. However, there could be overlap, because belief-reasoning is necessary for individuals to be able to have theory of mind (Ermer et al., 2006). Another study by Wang et al. (2016) has investigated the role of the right TPJ theta oscillations in embodied perspective taking. They specifically looked at embodying another's viewpoint compared to only tracking another's visual perspective in the world. By using Magnetoencephalography (MEG) and dual pulse Transcranial Magnetic Stimulation (dpTMS) they found that the right TPJ is a crucial network hub for embodied perspective taking and substantiating how the differences between self and other representations may be overcome. In the end they state that the kind of perspective taking they have found to be associated to the right TPJ is indeed a stepping stone for advanced ToM.

Going back to the findings about the connection between ASC and ToM. A study by Lombardo et al. (2011) has found neurological results in individuals with ASC. They investigated through fMRI scans on individuals with ASC what brain regions respond atypically, compared to neurotypical patients in the control group. They found the right TPJ to respond atypically during mentalizing tasks about self and other. The severeness of atypical responses was correlated with the severeness of social impairment in the ASC individuals. They believe this social impairment to be the underlying cause of the ToM deficit in individuals with ASC. This is in line with previously explained results that individuals with ASC have impaired ToM and that the TPJ is the most important brain region for ToM to arise.

With this information in mind, thoughts started on neuronal interventions in the right TPJ for improvement of the ToM in individuals with ASC. One of those interventions is transcranial direct current stimulation (tDCS). This is a non-invasive neuromodulatory technique that delivers low-intensity, direct currents to cortical areas from the outside with electrode stickers. These low-intensity currents can either facilitate or inhibit spontaneous neuronal activity. This inhibition or facilitation of neuronal activity can result in permanent neuroplasticity changes. In turn leading to changes in neuropsychologic, psychophysiologic and motor activity in the targeted brain areas (Brunoni et al., 2012). As the TPJ is also a cortical structure and therefore lies directly next to the skull, tDCS can be used to change the neuroplasticity of the TPJ. Research found that after anodal tDCS on the right TPJ in individuals with high AQ-scores (severe ASC traits), the performance of these individuals on a false belief task and a self-other judgment task was significantly improved. However, they did not improve in an explicit false photograph task or self-other judgments of physical features task (Padrón et al., 2021). These last two results could be explained by the function of the right TPJ, which is primarily ToM and more specifically reasoning about the content of mental states. The false photograph task and the self-other judgements of physical features task require little to no demand for ToM (Saxe & Kanwisher, 2003). In addition, this research proves that neurological intervention methods such as tDCS together with our current knowledge about ToM and brain areas can help individuals with ASC to improve their mentalizing processes (Padrón et al., 2021). Aside from neurological interventions, therapeutic interventions can also benefit from the knowledge that ToM is impaired in children with ASC. It was, for example, investigated whether therapeutic forms of ICT can also help individuals with ASC with ToM. As said earlier, early treatment of ASC can help improve the severity of symptoms later in the person's life (Uta Firth, 2001). With the use of ICT these treatments can become even more specified for the patient and can link the special education of the patient with digital learning, psychology and neurosciences. Concluding that the use of ICTs in therapy can also improve the children's cognitive and social-emotional skills through attractive structed ICT experiences (Victoria & Drigas, 2022).

ToM and Anorexia Nervosa

Anorexia nervosa (AN) is a complex mental health condition marked by substantial self-induced weight reduction, a heightened anxiety about gaining weight, distorted body image, and additional health issues stemming from malnutrition (Schmidt et al., 2016). This disorder involves a wide range of factors, encompassing biological, psychological, and social influences, that contribute to both the risk and persistence of the condition (Herpertz-Dahlmann et al., 2019). AN has the highest mortality rate and causes the highest amount of health system costs amongst all psychiatric disorders. The reported likelihood of achieving complete recovery is still below 50%. The prevalence of AN is particularly pronounced among female adolescents aged 15 to 19, and there is a suggested decline in the age of onset (Martinez-Gonzalez, 2020). Recent reviews indicate a more favourable outlook for children and adolescents compared to those experiencing first-onset AN in adulthood. This underscores the importance of early identification, diagnosis, and treatment to prevent relapse and the potential development of a chronic, prolonged, or enduring course for this disorder (Mairhofer et al., 2021).

AN is distinguished by significantly low body weight, an intense fear of weight gain, and distorted body image (Schmidt et al., 2016). While not a central part of AN's diagnostic criteria, emerging evidence suggests additional deficiencies in crucial aspects of social functioning. Individuals with AN tend to exhibit social withdrawal, reporting smaller social networks, fewer social interactions, and a reduced number of close friends. There is also indication of pre-existing social issues, such as heightened levels of loneliness, feelings of inferiority, and shyness (Krug et al., 2013). Moreover, there is a connection with anxiety disorders, particularly social phobia. Currently, the primary focus in treating eating disorders is on behavioural aspects, specifically addressing eating behaviours. Interventions primarily target the thought processes related to food and body image. While these treatments are crucial for symptom management, they might not offer sufficient guidance for the long-term and successful recovery of patients (Ziser et al., 2018). The high rate of relapse in anorexia nervosa (AN) suggests that outpatient management of this illness often falls short. Differences in the activation of the network involved in processing social cognition in patients who have recovered or partially recovered from AN were found. Further investigations exploring the connection between Theory of Mind (ToM) and the pathology of AN could provide a biological understanding of AN, aiding in the development of optimal treatment strategies (McAdams & Krawczyk, 2011).

A study by Schulte-Rüther et al. (2012) has investigated what brain regions were hypo or hyperactive while patients with AN participated in ToM tasks. They performed an examination of 19 adolescent patients diagnosed with AN and 21 controls of the similar age groups. Functional magnetic resonance imaging (fMRI) was used to observe brain activity while participants engaged in a ToM task at two different time points for the in-patient group: upon admission to the hospital and after achieving weight recovery at discharge. The clinical progress of the patients was assessed one year after their initial admission. With this research they found hypoactivation in different brain networks associated with ToM, same as the research by McAdams & Krawczyk (2011) found. One of those brain regions was the TPJ, which is the same brain regions that was associated with impaired ToM in patients with ASC. In addition, a research by Leslie et al. (2020), has investigated the brain areas related to ToM in individuals with AN. Building on previous findings in individuals with AN, they proposed that young women with current or past AN would demonstrate a diminished neural response in the mPFC, IFG and the TPJ while engaging in a ToM task. For this study, they enlisted 73 young women with AN, 45 weight-restored (WR) young women, and 70 young women without a history of AN. During fMRI scans, participants completed the Frith-Happé task (earlier mentioned with ASC participants). Increased brain activation in regions including the right TPJ, bilateral mPFC, cerebellum, and dorsolateral prefrontal cortex was associated with viewing trials featuring more complex social interactions in the Frith-Happé task. These results suggest that the neural basis of spontaneous mentalizing is largely preserved in most young women with AN. Contrastingly, a research by Sedgewick et al. (2019) has found no quantitative but only qualitative difference between AN participants a neurotypical participants in the Frith-Happé task.

They also included AN participants that had ASC as well and stated that not all participants with both AN and ASC should be assumed to have difficulties with ToM.

Furthermore, there is a suggested similarity between AN and ASC. Both conditions share common traits such as rigidity, aloofness, and social disengagement. Additionally, they display similar patterns of neurocognitive dysfunction, including impaired set-shifting, weak central coherence, and compromised false-belief ToM abilities (Zucker et al., 2007). Though, ASC individuals have more problems with the emotional aspect of ToM than AN individuals (Leppanen et al., 2018). As mentioned in the previous chapter, individuals with ASC have challenges when dealing with implicit rules, but they demonstrate a strong grasp of explicit social rules (Callenmark et al., 2014). Similarly, in the context of AN, there is a suggestion that while the semantic understanding of social rules may remain intact, complexities emerge when these rules are embedded in social scenarios. Individuals with AN may encounter difficulties in detecting when social rules are violated. Collectively, these findings imply that the spontaneous application of social rules to abstract stimuli may be similarly affected in both AN and ASC (Leppanen et al., 2018). This overlap in deficiency in implicit ToM between ASC and AN can help research into treatments for both disorders.

The big question is whether the ToM that is affected in individuals with active AN stays that way after recovery. A study by Oldershaw et al., (2010) has investigated whether the emotional theory of mind and emotional awareness was recovered in AN patients using the RMET. They investigated whether difficulties in inferring emotions and emotional theory of mind observed in individuals with ASC extend to a stable deficit in adults recovering from AN, aligning with the observed similarities between the two disorders. They compared a group of fully recovered AN participants (n = 24) with currently ill AN patients (n = 40) and HCs (n = 47) using forced-choice tasks assessing emotion recognition, basic or advanced eToM in others, utilizing sensory stimuli, and a written task measuring eToM ability for both self and others. They found that individuals who recovered from AN performed well on eToM tasks and outperformed individuals who are currently suffering from AN in inferring emotions in themselves and others. However, those recovered from AN exhibited slight impairments in emotion recognition compared to HCs, particularly in recognizing positive emotions. These results suggest near-complete normalization of emotion recognition and restoration of eToM in recovered AN patients, despite difficulties observed in both domains in individuals currently suffering from AN. The findings imply that similarities between AN and ASC in impaired eToM are confined to the current ill state of AN, and these challenges in AN may be influenced by the effects of starvation. Altogether these findings suggest that the ToM deficiencies in individuals with AN could maybe be temporarily lessened.

The same as with ASC, for AN tDCS might also be a way of treatment. A review by Chmiel et al. (2023), has investigated the effect of tDCS on AN by different studies. In their literature search, five articles were identified that offer initial indications of tDCS influencing eating behaviour, body weight and food intake, along with a reduction in depression symptoms. In all trials, the stimulation was directed at the left dorsolateral prefrontal cortex (DLPFC). While the number of included studies was limited, efforts were made to explore the potential mechanisms underlying tDCS effects in individuals with AN, and recommendations for future tDCS research in AN were provided. They concluded that the reviewed studies suggest that tDCS stimulation of the left DLPFC has a positive impact on AN clinical symptoms, as evidenced by various assessment measures. They plead a need for more comprehensive research on the potential benefits of tDCS for AN treatment, incorporating well-designed studies with advanced neuroimaging techniques, such as functional magnetic resonance imaging (fMRI), to enhance our understanding of tDCS mechanisms in AN. These studies provide evidence that tDCS might be a good treatment method for individuals suffering from AN. However, they state that more research is needed and in these previously mentioned studies. They only incorporated studies that stimulated the DLPFC, no other brain areas. Lastly, they suggest also incorporating other neuroimaging techniques such as fMRI to maximize the effectiveness of the treatment.

Discussion

Understanding the intricacies of ToM is fundamental to grasping the social cognition deficit in conditions such as ASC and AN. This discussion aims to delve into the multifaceted aspects of implicit and explicit ToM, exploring its manifestations, neurological underpinnings, potential interventions and the parallels and distinctions between ASC and AN.

Autism Spectrum Condition (ASC):

ASC has been widely studied in regard to ToM. Both explicit and implicit ToM tasks have been performed and the differences between neurotypical and ASC participants was stated. In explicit false-belief tasks (Gao et al., 2023; Baren-Cohen & Hill, 2007; Uta Firth, 2001) significant differences between neurotypical and ASC participants' performance were found. However, for implicit ToM there have been conflicting results. Callenmark et al. (2014) have found significant differences in an implicit ToM measure between ASC and neurotypical patients, but Deschrijver et al. (2016) have not. The tasks they used were very different from one another. Callenmark et al. (2014) used interview questions to measure implicit ToM, yet Deschrijver et al. (2014) used a variation of the VoE implicit ToM task. The extreme differences of quantification between the VoE task and a free interview, could have led to this difference in outcome. With a free interview being much more subjective than the VoE task.
Furthermore, another aspect of ToM is emotion. A study by Penuelas-Calvo et al. (2019) found there to be a significant different between performance of neurotypical and ASC participants in the RMET. Another aspect of ToM, with a completely different test, which could indicate that individuals with ASC do lack ToM skills. Substantiated by the research about ToM related brain regions (e.g. the TPJ) being hypoactive in individuals with ASC (Apperly et al., 2014; ermer et al., 2006; Wang et al., 2016).

Anorexia Nervosa (AN):

AN is a complex eating disorder that has also been thought to have a link with ToM. As neurological research suggested that the same brain regions associated with ToM (e.g. the TPJ) are less active in participants with active AN (McAdams & Krawczyk, 2011; Schulte-Rüther et al., 2012). Thereafter research comparing ASC and AN participants' performance in false-belief and emotional ToM tasks show that both ASC and AN participants had lower performance scores than neurotypical participants (Zucker et al., 2017; Leppannen et al., 2018; Callenmark et al., 2014; Leslie et al., 2020). The deficit in the emotional aspect of ToM is more severe for AN participants than ASC participants (Leppannen et al., 2018). That might be a reason why recovered AN participants show much better results in eToM than active AN and ASC participants. However, another research by Sedgewick et al. (2019) found no quantitative differences between AN participants and neurotypical participants in the frith-happé test that was also used by Leslie et al. (2020). They only found qualitative evidence.

ToM in ASC and AN

The parallels between ASC and AN extend beyond neurological commonalities. Both conditions share traits like rigidity, aloofness, social disengagement, and patterns of neurocognitive dysfunction, including impaired set-shifting and compromised ToM abilities (Zucker et al., 2007). Notably, there is a suggested overlap in the deficiency of ToM between ASC and AN (Leppanen et al., 2018). Both individuals with AN and ASC have difficulties with both false-belief and emotional ToM tests. For ASC the differences in scoring between implicit and explicit ToM tests was explicitly investigated. For AN, however, it was only suggested that the deficiency of individuals with AN in ToM lies in the implicit area of ToM, indicated by the hypoactive brain areas and RMET scores. For individuals with ASC, it was thought that implicit ToM tests are better for detecting the impairments in the ToM. More specifically an implicit ToM test for which no high levels of language processing are needed. Individuals with ASC have difficulty with language processing. When a test requires too much language processing, the test scores do not represent ToM deficits per se, but they do screen language processing deficits (Lartseva, Dijkstra, & Buitelaar, 2015). Though individuals with AN do not have the language impairments ASC individuals have, they do have difficulty placing semantic rules in the right social context. This could lead to differences in test scores between implicit and explicit ToM tests in AN participants. In the future, it should be tested whether the deficiencies of ToM in patients with AN are also more implicit than explicit. In addition, it should be tested which implicit ToM test are the most reliable for both AN and ASC, with the focus on a non-verbal multiple aspect ToM test. There are big differences between implicit ToM tests, from a quantitative test to a free interview. These big differences may explain the conflicting test results between different implicit ToM tests. It would therefore be good to test all participants with different implicit ToM tests and compare results in future studies. In addition, the focus of ToM tests should not only lie on false-belief processing, but on a wider range of ToM aspects.

Furthermore, both ASC and AN seem to have hypoactivity in the TPJ area, which is linked to ToM and maybe even only implicit ToM. First, more research needs to be performed on the link between ToM and the TPJ. The TPJ might only be linked to implicit ToM, but not enough research focusses on the differences between implicit and explicit ToM in correlation with the TPJ to make such a statement.
The fact that the TPJ has a crucial factor in ToM is especially important for treatment options. For ASC, tDCS treatment of the right TPJ seemed to lessen the deficiencies in ToM. Yet for AN, it was only tested whether tDCS on the DLPFC lessened the symptoms of AN. It would therefore be very interesting to test whether tDCS in AN also lessens symptoms of AN or that it only elevates the symptoms related to a ToM deficit. It could even be that lessening the symptoms related to a ToM deficit has a big impact on the symptoms of AN, but further research is needed to investigate this. The fact that ToM deficiencies were less to none in individuals that recovered from AN gives hope for the success of treatments. However, that research still needs to be investigated further as another research did not find quantitative differences between active AN and neurotypicals in the same frith-happé test. The information about recovered AN individuals suggests that the brain is capable of enough neuroplasticity to turn the deficiencies around. Although, whether this is also true for ASC has yet to be discovered.

In conclusion, both ASC and AN exhibit common traits and neurocognitive dysfunctions, suggesting overlapping mechanisms that contribute to impaired social interactions. The hypoactivity observed in the TPJ in both ASC and AN highlights potential reasons for deficiencies in ToM in both ASC and AN. The promising potential of tDCS interventions, particularly those targeting the right TPJ in ASC, provide a potential way of treatment of ToM deficiencies in AN. While current studies focus on the DLPFC in AN, a shift towards investigating TPJ interventions could unveil novel insights into alleviating ToM-related symptoms. The near-complete recovery of ToM functions in recovered AN individuals offers optimism, highlighting the brain's capacity for neuroplasticity and its potential role in successful interventions. However, caution is warranted in drawing direct parallels between ASC and AN, given their differences in prognosis and treatment options. In addition, more research into implicit opposed to explicit ToM is also needed for more specified diagnosis and treatment options. But who knows if information about ToM deficiencies and treatment in ASC can help lessen the severity of similar difficulties in AN as well.

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