

## Theory of Mind: Development, Neurobiology, Related Areas and Neurodevelopmental Disorders

*Zihin Kuramı: Gelişimi, Nörobiyoloji, İlişkili Alanlar ve Nörogelişimsel Bozukluklar*

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### Abstract

Theory of mind is a social cognition skills demonstrated its importance in the last forty years with psychiatric clinical trials. Theory of mind is seen as an effective and necessary skill in the social functioning of human who is a social creature as the ability to recognize the mental states and emotions of others. In the first six years of life, theory of mind has been associated with many fields. Findings related to many neurobiological bases, such as limbic-paralimbic structures, prefrontal cortex, which start with mirror neurons, help this sense of meaning. Areas associated with theory of mind development provide better understanding of theory of mind skills and deficits, the first psychopathology studies have been carried out in children with autism, and the studies about theory of mind skills in the diagnosis of neurodevelopmental disorders are becoming more and more interesting. In this review, theory of mind development, neurobiological basis and related areas will be explained and the relation of theory of mind with psychopathology will be examined.

**Keywords:** Theory of mind, neurobiology, psychopathology, development.

### Öz

Zihin kuramı son kırk yılda yapılan klinik çalışmalarla psikiyatrideki önemi ortaya konulan bir sosyal biliş becerisidir. Zihin kuramı becerisi başkalarının zihinsel durumlarını ve duygularını fark edebilme yeteneği olarak sosyal bir canlı olan insanın sosyal işlevselliğinde etkili ve gerekli bir beceri olarak görülmektedir. Hayatın özellikle ilk altı yılında pek çok ilişkili alanla birlikte temeli atılan bu becerinin, ayna nöronlarla başlayan ve limbik paralimbik yapılar, prefrontal korteks gibi pek çok nörobiyolojik temelle ilgili bulguları bu beceriyi anlamamıza yardımcı olmaktadır. Zihin kuramı gelişimi ile ilişkili alanlar zihin kuramı beceri ve bozulmalarını daha iyi anlamamızı sağlamaktadır. İlk psikopatoloji çalışmaları otizmlili çocuklarda yapılmakla birlikte nörogelişimsel bozukluklar tanı kümesinde zihin kuramı becerileri ile ilgili çalışmalar giderek ilgi çekici olmaktadır. Bu derlemede zihin kuramı gelişimi, nörobiyolojik temeli ve ilişkili olduğu alanlar anlatılacak ve zihin kuramının psikopatoloji ile ilişkisi incelenecektir.

**Anahtar sözcükler:** Zihin kuramı, nörobiyoloji, psikopatoloji, gelişim.

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**THEORY OF MIND (ToM)** is defined as the capability of individuals to differentiate the mental states and emotions of others (Brüne and Brüne-Cohrs 2006). The ability to understand that the beliefs of others may be different from one's own beliefs and that they can behave differently because of this, is necessary for successful social interaction and communication (Youmans 2004). Through the prediction of people's behaviour and the perception of the ability, ToM forms the basis of being able to understand the intentions of others (Rowe et al 2001). Studies related to ToM have shown that ToM skills disorders cause problems in many areas, such as social communication and interaction, concentration, behaviour and prediction. It is thought that skills training for ToM disorders, especially in neurodevelopmental disorders, could be complementary treatment for the difficulties experienced in social functionality. It is important to understand the contribution of this training to the efficacy of treatment. Longitudinal studies based on early intervention to ToM skills, including the period of early childhood, could shed light on the development of new treatment strategies. Therefore, the aim of this review was to examine the relationship of ToM with psychopathology which could explain the neurobiological basis and related areas and ToM development, which could guide treatment goals.

## **Theory of Mind**

The concept of Theory of Mind (ToM) was first used in 1978 by primatologist and psychologist, Premack and Woodruff. It was proposed that chimpanzees could infer the mental states of their own species (Premack and Woodruff 1978, Brüne and Brüne-Cohrs 2006). In the study, chimpanzees were shown video recordings with forms of resolutions to difficulties encountered by adults, and were then shown pictures related to the resolutions of these situations. The chimpanzees selected pictures including an appropriate solution for the subjects observed (Premack and Woodruff 1978).

ToM skills in children were first evaluated by Wimmer and Perner in 1983. To be able to measure the capability of children to perceive the mental state of others, the "unexpected transfer test" was used and the stories they developed within this method. It was shown that from the age of 4 years, children were able to differentiate beliefs and were able to understand the difference between these (Wimmer and Perner 1983). ToM disorders were first identified from a psychopathology aspect in children diagnosed with autism and other common developmental disorders by Baron-Cohen in 1985. ToM was defined as the ability to understand the wishes, beliefs and emotions of others, which is an important skill in interpersonal communication, and these skills were shown to be impaired in autistic children (Baron-Cohen et al. 1985).

ToM has two components; cognitive and emotional. It has been stated that when asked what you feel, emotional ToM is necessary and when asked what you think or believe, cognitive ToM skills are necessary (Brüne and Brüne-Cohrs 2006). These two components of ToM, known as social-cognitive and social-perceptive can be measured with different tests. Social-cognitive ToM is defined as the skill of looking at the behaviour of others and interpreting the underlying mental states and in evaluations, false belief tests are used. Social-perceptive ToM is related to the emotional system rather than language and cognitive skills and is defined as the ability to perceive the mental state of others based on directly observed information and the "Reading the Mind in the Eyes Test"(RMET) is most commonly used to evaluate this. In the understanding

of the mental states of others within social life, both ToM components are used together (Tager-Flusberg and Sullivan 2000).

Various tests have been developed related to ToM. In consideration of the difficulty of advocating ToM as a single skill, evaluation with different components has been studied. These components include first order false belief, second order false belief, and the concepts of metaphor, irony and faux-pas (Bach et al. 2000).

First-order ToM: this is the most simple and first-developed ToM skill, and is defined as the skill of understanding a false belief or thought of another person. First-order ToM skills are evaluated with first order false belief tasks (Bach et al. 2000). In these tasks, a false belief is referred to and it is evaluated whether or not the behaviour of the character is predicted correctly. The past of the person may be examined or their own knowledge related to reality must be blocked in this task and their own understanding must be based on overcoming the false belief of the character. To be able to measure the skill of perception, Wimmer and Perner evaluated ToM skills in 4-year old children for the first time and in the application of the unexpected transfer test, children were seen to be able to transfer a false belief they carried (Youmans 2004). Baron-Cohen et al used the Sally Anne test to assess first-order ToM skills, while other researchers have used similar picture tasks (Wellman et al. 2001).

Second-order ToM: Perner and Wimmer, defined this skill, which develops as a secondary ToM skill, as “belief about belief” or “thought about thought”. This second-order ToM skill is the ability to understand that a third person has a false belief of the beliefs and thoughts of the beliefs and thoughts of another person (Perner and Wimmer 1985, Wellmann et al. 2001). Thus the observer knows whether or not A has a false belief of the false belief of B. To test second-order ToM skills, second-order false belief tasks are used and these tasks are more complex than the first-order false belief tests (Stone et al. 1998). The Dokuz Eylül ToM Scale, which was developed in Turkey and has proven reliability has been recommended for use in studies investigating the relationship between ToM and the symptoms of disorders in various adult psychopathological populations, primarily schizophrenia and autism. One of the picture tasks in this scale evaluates first-order false belief skill, one evaluates second-order false belief skill and the result evaluates empathetic understanding skill.

The perception of metaphor and irony: This is a more complex, fine ToM skill providing a pragmatic understanding and interpretation of the real intention of the speaker by disregarding the concrete and plain meaning of language (Youmans 2004). Pragmatism is accepted as one aspect of the functions of language. The understanding of a statement is based not only on syntax and semantics (Frith and Frith 2003). In the development of language and communication, it is important to be able to read the intentions of others because what is implied is not directly said (Meltzoff 1999). Therefore, in utterances such as irony and metaphor that do not have a plain meaning, it is necessary to have the capacity to go beyond the meaning of the words to understand the statement (Brüne ve Brüne-Cohrs 2006). The relationship has been shown between ToM skills and metaphor and irony, and it has been revealed that although both require ToM, irony requires more complex ToM skills than metaphor (Happe 1993). It has been suggested that while metaphor needs first-order ToM skill, the understanding of irony requires at least second-order ToM skill (Langdon et al. 2002).

The perception of faux-pas: Understanding the making of a faux-pas or gaffe is a

more complex ToM skill in respect of development. A faux-pas occurs when something is said which has been uttered by the speaker without consideration that the listener may not want to hear it, or may be hurt or offended by it. In faux-pas tests, something is said in a conversation between two people, without knowing or realising that it should not be said, and a series of questions are asked about this situation. Both ToM components are used in understanding the faux-pas made; the cognitive component to understand that the person who made the utterance did not know that they should not have said it, and the emotional component for empathetic understanding that the listener will feel offended or unhappy. The perception of faux-pas test is accepted as a good measurement of fine ToM disorders (Baron-Cohen et al. 1999, Bach et al. 2000, Brüne and Brüne-Cohrs 2006).

## Development of Theory of Mind

Examination of development in infancy raises 2 questions on this subject. The first is at what months of different development can the behaviour of infants be seen to be related to the knowledge of people? The second question is how can this behaviour be interpreted (Flavell 1999). A newborn infant is basically aware of time, space and causality. Infants showing normal development start to acquire basic knowledge about the world from the moment of birth. Several ToM researchers have grouped this development as shown below. Thus the structure of the ToM mechanism can be better understood with the knowledge of what occurs at each developmental stage (Leslie 1987, Jarrold et al. 1994, Stone et al. 1998, Flavell 1999, Brüne and Brüne-Cohrs 2006).

### *a. 18 months-3 years*

It is known that infants are born with several skills and predispositions to understand the world and they acquire skills in the early period of life. Throughout the first 2 years of infancy, skills are developed to differentiate different facial expressions and sounds (Flavell 1999). At approximately 6 months, the movements of animate and inanimate objects can be distinguished and at approximately 12 months, the development of shared attention skills starts. It is accepted that ToM is seen for the first time as a developmental stage in this shared attention skill at approximately 18 months.

Changes in the subject of aims and wishes start in infants at the age of 18 months. Another stage in the development of ToM skills is the playing of games based on imagination. Between 18 and 24 months, the child can play “pretend” games by separating what is real and what is representative and thus, meta-representation is developed and gradually skills including mental states are acquired (Brüne and Brüne-Cohrs 2006). Language learning accelerates at the beginning of this stage. Therefore, toddlers of 18-24 months discover the difference between reality and pretence, and “pretend play” skills are formed, which are important in the development of ToM skills. This state is conceptualised as “decoupling”, or separation. In this state, a child may use an object in a game of pretend by separating the object from its original identity and giving it a temporary-representative role (e.g, using a brush as a microphone) (Leslie 1987, Frith ve Frith 2003, Brüne and Brüne-Cohrs 2006). It has been said that children understand and interpret information about the mind with two representation skills. Primary representation is the skill of understanding directly related to the external world, for example, thinking that a banana is a banana. Secondary representation, also known as

metarepresentation, is when the child reconsiders the primary representation, and thus a banana can also be thought of as a telephone (Leslie 1987, Jarrold et al. 1994).

To be able to perceive secondary representations, it is important to be able to understand the minds of others. In this same period, the child learns to recognise himself in the mirror (Leslie 1987). Role playing is a form of perceiving and understanding the emotions, thoughts and perspectives of others (Bergen 2002). Despite the assumption of acquiring role-playing skills at an early age, it has been shown that children are not able to understand false belief until the age of 4-5 years. This has been explained as being seen as an action rather than presumed to probably represent the mind (Lillard 1998).

### ***b. 4-5 years “First-order Implied Belief”***

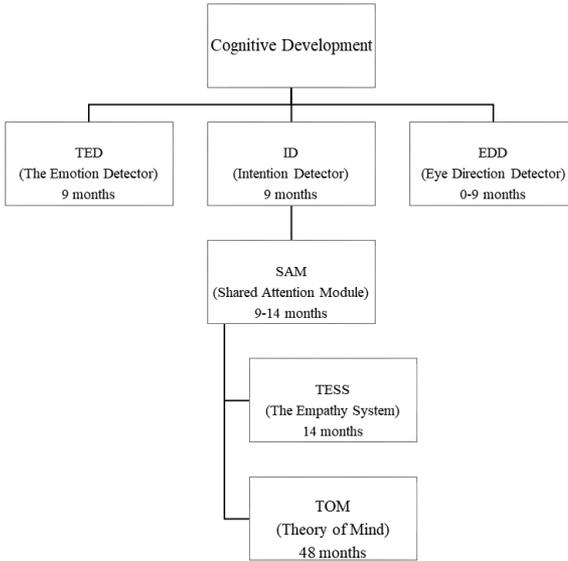
Up to the age of 3-4 years, children cannot differentiate the beliefs of another from their own and they presume that what others know is similar to what they know. At around the age of 3 years, children start to absolutely understand the difference between physical and mental states. Thus, by establishing simple causal relationships, they then start to understand that the beliefs, wishes and emotions of others may be different from their own and that others could have false beliefs. That first-order false belief was understood by children of this age was revealed in a study by Baron-Cohen et al (Stone et al, 1998, Frith and Frith 2003, Brüne and Brüne-Cohrs 2006).

To be able to evaluate first-order implied belief as developed in children, mental conclusions have to be made from observed situations and there has to be behaviour appropriate to that (Premack and Woodruff 1978). As an example of children aged 4-5 years understanding a change in their beliefs, despite removing a pen from a box of sweets, in response to the question of what they first thought when they saw the box, they said, “sweets” (Apperley and Robinson 2001). Studies have shown that 3-year olds cannot understand and differentiate the beliefs of others from their own, whereas children aged 4 years have developed the skill of understanding the beliefs of others (Baron-Cohen et al. 1985).

### ***c. 6 years and older***

From the age of 6 years, children start to think about the content of the mental states of other children. Thus, people can perceive the thoughts and intentions of other people. This shows that second-order ToM skills have developed (Brüne and Brüne-Cohrs 2006). Previous studies have shown that 90% of 5-year olds and all 6-year olds have second-order ToM skills (Baron-Cohen et al. 1985, Perner and Wimmer 1985). The skill of being able to understand metaphor and irony requires the ability to think beyond the actual meaning of the words and it has been shown that children have not developed this skill before the age of 6 years. With the development of second-order ToM skills, metaphor and inference can start to be understood. As the perception of faux-pas is the most complex ToM skill, representing the mental status of the person who has made the faux -pas and the person affected, it is thought that the development of this skill can take until 9-11 years old (Brüne and Brüne-Cohrs 2006). There has been shown to be a gender difference in this respect with girls acquiring the skill at approximately 9 years old and boys at 11 years (Baron-Cohen et al. 1999).

In the mental reading model that demonstrated the development of ToM, Baron-Cohen focussed on ‘empathy’. This is defined as thinking about another person’s feelings and responding with appropriate emotional content. “Mental reading” has been defined as the skill of interpreting the mental status of oneself and of other people. This model aimed to explain ToM ontogenesis by neurocognitive differentiation of children with and without autism. ToM development is explained with the empathy model formed in 2004.



**Figure 1: Baron-Cohen (2004) empathy model**

It is known that infants can show emotional states in the first 3 months of life. Before the development of shared attention at 9-14 months, 3 infant mechanisms are formed. The Emotion Detector mechanism refers to the ability to differentiate emotions between 0-9 months. The Intention Detector mechanism refers to the understanding of basic intentions of behaviour between 0-9 months and the Eye Direction Detector mechanism refers to the eyes being able to look in different directions. With the formation of the Shared Attention mechanism in the 14th month, the empathy system starts to have great importance in the understanding of emotions and behaviour. Therefore, as discussed above, the ToM mechanism is developed at approximately 48 months (Baron-Cohen 2005).

## ToM Neurobiology

As the importance has been understood of the relationships and psychiatric states of normal individuals, so there has been an increase in studies related to the neural bases in the brain of ToM skills. The first step was the discovery of mirror neurons and the idea that a neural network could be formed from these neurons. Although these neurons were first explained in primates, functional observational studies have shown that they are present in the human brain. Mirror neurons have been seen to have a function

in the identification of the movements of others. A behaviour made by another that has previously been made oneself activates the mirror neurons. Thus, they contribute to the understanding of the intentions and behaviours of others. These specific regions have been seen to be activated in primates during specific hand and mouth movements and when another primate has made the same action. It is thought that these activated regions in humans are in the inferior frontal lobe and the ventrolateral part of the premotor area, especially during hand movements (Rizzolatti et al. 1999, Drubach 2008).

Studies have generally shown results prioritising the frontal, temporal and parietal cortices in ToM. A previous MRI study showed that the right hemisphere was active and had an important role in the identification and understanding of facial expressions and mimic gestures, in other words, in empathy. The left hemisphere has been shown to be active when it is wished to make the same facial expressions (Leslie et al. 2004).

Functional, observational studies of ToM have provided consistent results related to this skill and its components. Although observational studies have been made with healthy volunteers, lesion studies and research made on a neurogenic group have been helpful in the understanding of the neurobiological basis of ToM skills. Using stories and attribution tasks in the evaluation of ToM skills, activation has been determined in the posterior singulate, superior temporal sulcus, medial prefrontal cortex (MPC) and bilateral temporal lobe regions on positron emission tomography (PET) imaging (Fletcher et al. 1995, Brunet et al. 2000). When the skill of perceiving the mental state of another has been examined with fMRI, the importance of activation of the anterior singular cortex (ASC) and the MPC has been shown (Vogeley et al. 2001, Gallagher et al. 2000). In an fMRI study that examined the neural mechanism of eye contact while listening to another person, the regions of the brain related to ToM (temporoparietal junction, posterior STS, MPC) and the dorsolateral prefrontal cortex were shown to play a role in the visual cortical areas in eye contact (cuneus, calcar sulcus) rather than mouth fixations (Jiang et al. 2016).

Patients with bilateral orbital frontal cortex damage, have been shown to have lower performance in the understanding and interpretation of faux-pas compared to patients with left dorsolateral frontal cortex damage (Stone et al. 1998). When the ToM functions are examined in patients who develop brain lesions later, it has been shown that these patients had normal ToM skills before the disease and therefore ToM skills could be damaged secondarily (Stuss et al. 2001). Patients with prefrontal damage have been shown to have lower performance in understanding irony than patients with posterior damage (Shamay-Tsoory et al. 2005).

The results of 9 observational studies were consistent in reporting a strong relationship between the anterior parasingulate cortex (approximately corresponding to the Brodmann area 9/32), STS and bilateral temporal poles and ToM skills. However, it has been emphasised that these are not the only regions related to the mental processes (Gallagher et al. 2000). In a recent meta-analysis, changes were seen in the thickness, volume and surface area of the posterior STS at the temporoparietal junction, mid-frontal gyrus, fusiform surface area, inferior frontal gyrus, amygdala, insula and the singulate cortex in a patient group with autism spectrum disorder (ASD). It has been stated that these regions, which have often been emphasised in ToM studies could be basic neuro-imaging markers for ASD (Patriquin et al. 2016).

As a result of neurobiological studies, it has been recommended that ToM neuro-anatomy is examined under two headings: a) specific and common areas of the brain representing the mental state of self and others; b) the integration of anatomic and functional connections. The right posterior parietal system, especially the inferior parietal lobe, has been observed to be active in representing the mental state of the self only, without activation during the representation of the mental states of others. Several studies have suggested that the STS is specific in the representation of the mental states of others in both primates and humans. Common brain areas that function in the representation of the mental states of oneself and others have been shown to be the limbic and paralimbic structures (amygdala, orbitofrontal cortex, ventral MPC, and ASC) and the prefrontal cortex (dorsal MPC and inferolateral frontal cortex) (Abu-Akel and Abushua'leh 2004).

## **ToM and Related Areas**

### ***a. ToM and Shared Attention***

Shared attention can be stated as the cognitive capacity of the child to look at the place looked at by another person (e.g. mother) and by giving attention to the object looked at by the mother or by directing the mother to the object by indicating the object to which the child has given attention, a three-way representation is formed with coordination between the mother and the object. This cognitive capacity assists in the development of communicative and other social-cognitive skills (Stone et al 1998, Flavell 1999, Brüne and Brüne-Cohrs 2006).

Infants recognise faces at 2-4 months and shared attention skills start to develop at approximately 6 months and a specific object or event can be given as the shared attention with the social collaborator. Infants can start to follow eyes or fingers at between 9 and 12 months of age (Mundy et al. 2006). It is accepted that ToM manifests developmentally for the first time at around the age of 18 months in this shared attention skill. Before the age of 18 months, while infants may be able to understand "Mummy's seen a toy", at the age of 18 months they start to understand "Mummy's seen the toy that I can see". As shared attention can refer to the attention given by different people to different things at the same time, it reflects the reality that the attention of someone can be directed (Baron-Cohen 1989, Stone et al.1998).

A previous study examined the effects on ToM skills at 4 years of age by evaluating the attention and intentional movements of infants at 6 months, and these were found to be of significant importance in the understanding of language and false belief. A basic correlation was found between shared attention and ToM skills (Sodian and Kristen-Antonow 2015).

### ***b. ToM and Pretend Play***

Pretend play, which is necessary to represent reality, is an important component of ToM. It starts to be seen first at around the age of 2 years (e.g. using a stick as a car) (Leslie 1994). It has been classified in two forms. The first is as pretend play only from the age of 12-18 months, when one object is used to represent another object (Leslie 1987). The second form is as social pretend play, which is the same basic transformations enacted with others and this starts around the age of 3 years (Dore et al. 2015). A

previous study reported that the playing of pretend games at the age of 2 years 9 months predicted the false belief skill seen at age 3-4 years (Youngblade and Dunn 1995). Games of pretend can strengthen language skills with the skill of representing reality with pretence. The combination of pretend play and ToM skills is important to be able to focus on the mental states of others and correctly interpret behaviours and these two skills can be mutually supportive (Weisberg 2015). In a previous study, the pretend game skills of young children and the relationship with ToM skills was examined. There was observed to be a positive relationship between pretend play skills and ToM skills when the management of the game was examined and themselves compared to the behaviour of others in the shaping of the game by observing the behaviour of others (Shuqum 2002).

### *c. ToM and Language Development*

The use of language in providing communication is defined as pragmatic. Pragmatic skills are necessary for transforming thoughts into words, when interpreting a word heard and for all kinds of social knowledge and interaction such as responding to a person, telling a lie, being sincere, inferring and gossiping. In a study which examined the relationship between ToM development and language development, language skills were seen to have an effect on predicting the future ToM performance (Astington and Jenkins 1999). A study of pre-school children found that children with low language points experienced more difficulties when explaining their own emotions or states compared to other situations (Hensler 2000).

In literature, language and ToM false belief skills have been examined in children with specific speech disorders and those showing normal development. Children with low language points were found to display low performance in ToM false belief skills (Colle et al. 2007). The effect on ToM and mental understanding of the words used in communication by the mothers of children aged 3-4 years was examined and a positive relationship was determined between the language used and the mental understanding and false belief skills (Howard et al. 2008). As a result of a meta-analysis of 104 studies, a two-way significant relationship was established between language and ToM. According to this, language skill affects future ToM skills and ToM skills affect future language skill. However, the causality role of language on ToM was found to be stronger (Milligan et al. 2007).

### *d. ToM and Social Behaviour*

The first emergence of ToM development starts with social awareness and communication with others (Hale and Tager-Flusberg 2005). A person showing normal development uses a natural evaluation system before a behaviour to assess how this behaviour will be interpreted by the other person. The extent that this skill is used by a person has a positive or negative effect on their conformity to society. Therefore, supportive skill training programs can be applied to individuals seen to have behavioural problems or who experience difficulties conforming to the rules of society, to help predict what other people may think and what the next steps will be.

In a study which examined the relationship between ToM and social ability in friendships, ToM tests were applied to children aged 3-5 years old. It was concluded that ToM skills could predict social behaviours in both boys and girls. A correlation was

determined between shyness and low ToM points in boys (Walker 2005). A significant relationship has also been revealed between low ToM performance and behavioural problems (Sharp 2008).

### *e. ToM and Executive Functions*

The relationship between Executive Functions (EF) and ToM includes inhibition contributing to ToM and /or general mental skills or working memory processes (Carlson et al. 2002). The term Executive Functions covers the implementation of targeted flexible behaviours (e.g. planning, inhibition control, attention span, working memory) (Ozonoff et al. 1991). In general, 3 approaches to the relationship between ToM and EF have emerged. According to the first theory, the two skills are two separate skills independent of each other, as a modular form of neurobiological development (Saxe et al. 2004). According to the second approach, success in expressive language skills requires the use of both EF and ToM skills together. To be able to establish a cause and effect relationship directed at the event or state, both these two skills are necessary and they are complex, interlinked mental processes (Zelazo et al. 2002).

In the third approach, there is said to be a functional relationship between EF and ToM skills. The skill of forming mental representations forms the basis of self observation and control skills (Perner et al. 2002, Hill 2004). In a previous longitudinal study of the developmental relationship between ToM and EF in children aged 2-4 years, a significant relationship was determined between ToM and EF in children aged 3-4 years. EF skills at 2 years were found to predict ToM performance at 3 years, and the EF skills at 3 years predicted the ToM skills at 4 years. However, the ToM performances at 2 and 3 years of age were not found to be significantly predictive of EF skills at 4 years (Muller et al. 2012). Self-observation as a part of EF is a precursor and fundamental component of self-understanding. This precursor is necessary for ToM development. Impaired EF causes deficiencies in ToM skills. Functional dependence between EF and ToM is prominent and in the relationship between these two skills, if there is an impairment in one, it can lead to an impairment in the other (Perner and Lang 1999).

## **ToM and Psychopathology**

It can be said that individuals who show impairments in ToM do not perceive the mental state of themselves or others or have problems in applying the mental states perceived. In the absence of this skill, problems are seen related to lack of empathy, non-response to social stimuli and independent living skills, and therefore, healthy relationships cannot be established. False assumptions of other people's intentions or a lack of understanding of their own mental state may be seen at the base of various neuronal structural or functional disorders (Brüne 2001, Abu-Akel 2003).

ToM was first shown in the psychopathological field as an inability to represent the mental state in autistic children, and subsequently many studies were conducted related to ASD and ToM. It has been accepted in studies that an impairment in the cognitive mechanism of ToM, which is important for core symptoms of the disease, causes impairments in areas such as communication and social interaction (Baron-Cohen et al. 1985, Baron-Cohen and Swettenham 1997, Brüne and Brüne-Cohrs 2006).

Many studies have been conducted that have clinically examined ToM skills in an extremely broad spectrum including those with schizophrenia, bipolar disorder, anorexia nervosa, bulimia nervosa, antisocial personality disorder, borderline personality disorder, paranoid personality disorder, schizotypal disorders, attention deficit and hyperactivity disorder, behavioural disorder, social anxiety disorder, and those who are deaf or have reduced hearing (Baez et al 2014, Hezel and McNally 2014, Peterson 2015, Bora et al. 2016, Hamatani et al. 2016, Sedgwick et al. 2017). While some of these studies have obtained results showing a relationship between disease and symptoms, others have found no significant relationship. Studies of autism have been conducted more on paediatric groups, whereas in adult patient groups the focus has been on schizophrenia in particular, bipolar disorders and first degree relationships. The data of studies related to these two patient groups are presented below.

In a meta-analysis which examined the mental functions of patients with ASD, a first episode of schizophrenia and long-term schizophrenia, the ToM skills of the ASD group were found to be lower than those of the schizophrenia group. In addition, mental state terms were seen to be used less by the long-term schizophrenia patients than by those with a first episode of schizophrenia. Thus, when the different stages of schizophrenia are taken into consideration, performance differences can be said to have been determined between ASD and schizophrenia (Bliksted et al. 2016). Suggestions and eye functions were examined in a meta-analysis of 36 studies that evaluated the ToM skills of schizophrenia patients and healthy control subjects. Although ToM skills were less impaired in patients in remission, the ToM skills of schizophrenia patients both in remission and not in remission were found to be significantly impaired. In contrast, mental area impairments in patients in remission have been observed to contribute to impairments in ToM skills (Bora et al, 2009). In a study which examined the ToM skills of schizophrenia patients and their healthy parents, impairment was shown in first and second-order ToM functions, independently of intelligence and cognitive inhibition. The healthy relatives of the patients were seen to have impairments only in second-order ToM functions. It has been emphasised that endophenotype could be a candidate for psychosis spectrum disorders in ToM deficiencies (Pentarakı et al. 2012, Ay et al. 2016).

In another meta-analysis, a comparative examination was made of social cognition in bipolar disorder (BD) and in schizophrenia. The schizophrenia patients showed significantly lower performance than the BD patients in both facial recognition and in ToM skills. Neurocognitive impairments were found to contribute to ToM impairments, although social cognition was not seen to be significantly severely impaired by neurocognition in either group (Bora and Pantelis 2016). In another study of patients diagnosed with autistic BD, with and without a history of psychotic symptoms, the ToM performances were similar and both groups demonstrated a significantly lower performance than that of the control group. It was reported that ToM impairments were not a marker of psychosis and this status could be seen in BD patients with no history of psychotic symptoms (Lahera et al. 2008).

The faux-pas test and REMT were applied in a study that compared patients with unipolar depression with and without psychotic symptoms. In both groups, there was seen to be significant impairment in the ToM skills that included social cognition and social perception, and this impairment was seen to be significantly greater in the group

with depression of a psychotic nature. A relationship was determined between ToM performances and disease symptom scores (Wang et al. 2008). In another study that evaluated unipolar depression patients in respect of ToM skills, patients were followed up for 1 year and significantly more relapses were observed in the depression patients with second-order false belief impairment compared to those without. It was emphasised that depression patients with second-order ToM impairment could be a high-risk group for recurrence (Inoue et al. 2006).

ToM skills have been researched in brain disease and in neurodegenerative diseases. It has been shown that ToM skills are impaired in Alzheimer's disease, dementia, frontal lobe lesions, frontotemporal dementia, Parkinson's disease and Huntington's disease. These studies have been found to contribute to the understanding of the brain areas related to ToM (Brüne and Brüne-Cohrs 2006).

### ***Neurodevelopmental Disorders***

Clinical evidence has been seen to be significantly conflicting in respect of social functionality impairment in ADHD and ASD. While there may be many potential clinical and psychosocial determinants for these problems, the ability to be aware of the emotions of others and other social cognitive skills have been found to contribute to the symptoms related to ASD diagnosis. While there is a clear relationship with social cognitive disorders of ADHD including facial recognition and prosodic perception, although the relationship between ToM and reduced empathy is rare, there is some evidence available (Uekermann et al. 2010). It is not clear whether or not impaired recognition of emotions in ADHD can be compared with ASD in respect of the severity of ToM impairments. It is important to investigate whether abnormalities are independent of social cognitive impairments in ADHD or whether they are secondary to neurocognitive skill abnormalities that affect social cognitive functions in neuropsychiatric patients (Taylor et al. 2013).

Conduct disorders (CD), which are a significant comorbidity in ADHD, have been found to be significantly correlated to personality disorders, and it has been considered that this could be related to social cognitive impairment (Cadesky et al. 2000). While some children have healthy social lives despite difficulties in school performance, it is noticeable that others cannot establish communication with their peers and other individuals. This second group may have a reduced capacity to understand social reciprocity and social clues. These features are seen to be similar to the social interaction problems of the core symptoms of Pervasive Developmental Disorder (PDD), as defined in DSM-IV. Deficiencies in perceiving the behaviours of others and giving appropriate social responses are characterised by inappropriate social behaviour in many children diagnosed with ADHD. The inappropriate aspect of social behaviour may be related phenomenologically and etiologically to PDD in some ADHD children (Nijmeijer et al. 2008).

Although some behaviours causing social disorders in ADHD may be related to diagnostic criteria defined by DSM (e.g. interrupting), this is not sufficient to explain all inappropriate behaviours observed in ADHD. Furthermore, a disorder showing high rates of comorbidity and conduct disorder is another important indicator of social disorder (Nijmeijer et al, 2008). In a previous study, ADHD, CD, ADHD+CD patient groups and healthy control groups were compared in respect of the interpretation of

emotional clues in sound recordings and pictures of facial expressions. The children with ADHD and CD showed significantly lower performance than the healthy control group. While the ADHD group generally made random errors, the CD group showed a tendency to misinterpret the emotion of fear. Contrary to what was expected, the ADHD+CD group showed a better performance than the groups with ADHD only or CD only (Cadesky et al. 2000).

In addition to other neurocognitive problems such as impulse control, attention and working memory, interpersonal problems of conflict such as inability to regulate emotions, and rejection by parents, siblings, peers and teachers, are seen clinically in ADHD (Barkley 1997, Shaw et al. 2007). Social dysfunction is accepted as one of the most weakening aspects of ADHD (Nijmeijer et al. 2008). In a study of children diagnosed with ADHD, social functionality was impaired in 22% and this was found to be significantly higher than in the control group. Social function impairment is seen as very important in respect of the short and long-term prognosis of children diagnosed with ADHD (Greene et al. 1996).

In a meta-analysis of 47 pediatric and adult studies, ADHD and ASD patient groups and healthy control groups were compared in respect of the recognition of emotions and ToM skills. The ADHD group showed significant impairment in emotion recognition and ToM skills compared to the control group. These social cognitive impairments were seen to be less severe in adults. After checking the effect of IQ, the ADHD group was seen to have a significantly greater ToM skills impairment than the control group and significantly less than the ASD group. The most severe impairment was found in the recognition of fear and anger. Difficulties in recognising these two emotions in other people can be interpreted as contributing to conduct and interpersonal problems in ADHD. The impairment in social cognition, especially in ToM skills, was found to be significantly greater in ASD compared to ADHD. Structural abnormalities in the brain, specific to ASD, may contribute to the differences in social cognition between ASD and ADHD. In ADHD studies that have excluded comorbid ASD, social cognition impairments have again been determined as significant. In a meta-analysis, no significant correlation was determined between social cognition impairments in ADHD and those with a behavioural disorder comorbidity. Findings showed that age played a significant role in these changes and there could be a developmental delay in ADHD. That individuals with ADHD may be able to catch up with those without ADHD in respect of social cognition performance with increasing age supports this view (Bora and Pantelis 2016).

Children diagnosed with ADHD using and not using methylphenidate were applied with faux-pas and ToM tests in two separate sessions and the stimulants were shown to improve social cognition skills in the ADHD group (Maoz et al. 2013). In another study, children diagnosed with ADHD who were not taking any medication were administered face and emotion recognition tests and these tests were then repeated after starting treatment with methylphenidate and atomoxetine. In the first evaluation, the ADHD group showed a significantly lower performance than the control group and the hyperactivity/impulsivity group showed a lower performance than the inattentive group. Following treatment, a significant improvement was seen in both the methylphenidate and atomoxetine treatment groups (Demirci and Erdogan 2016). However, another meta-analysis which evaluated ToM skills did not show any diffe-

rence between ADHD groups (Shuai et al. 2011). In recent familial and genetic studies, evidence has been presented that ASD, neurodevelopmental disorders, schizophrenia and BD partially overlap with ADHD (Cross-Disorder Group of the Psychiatric Genomics Consortium 2013). It is noticeable that all these psychiatric disorders are significantly related to social impairment and social function impairments.

In a meta-analysis that compared ToM skills in children with autism, children with mental retardation (MR) and children showing normal development, a significant difference was determined in the ToM skills of children with autism and children with MR. Similarly, a significant difference was found between the autism group and the normally developing group and between the MR group and the normally developing group. These findings confirm that ToM skills impairment could be characteristic for autism but may not only be present in autism and could be seen in different patient groups such as those with MR. Although there was a significant difference between autism groups with and without high functioning, there was not seen to be a significant controller (Yormiya et al. 1998).

Studies of children with specific learning disorder (SLD) have shown that 75% of these children are rejected by their peers (Wilmshurst 2008). Children who experience difficulties in the area of social emotions can be more childish and intolerant of criticism. Their social competition and communication skills are weak and they have difficulties in understanding non-verbal clues and interpreting gestures and facial expressions. These problems have a negative effect on self-confidence, and the skills of establishing and maintaining social relationships and these can accompany a secondary comorbid psychiatric table (Kavale and Mosert 2004). When it is taken into consideration that learning disorders are often seen and difficulties are experienced in the social area, there can be seen to have been few ToM studies.

EF and ToM performances were examined in 375 children diagnosed with ADHD (55 with comorbid CD and 39 with comorbid SLD) and a control group of 125 healthy children. The results showed that EF was more impaired in the ADHD group, and after control of the comorbidity, this impairment continued, a more severe impairment was seen in planning and working memory in ADHD combined type and working memory and ToM skills were seen to be impaired in ADHD hyperactivity/impulsivity type. The impairment in EF was increased in the SLD comorbid group but this comorbidity was not seen to affect ToM skills (Shuai et al. 2011). In a study which compared ToM skills in children aged 7-9 years, diagnosed with SLD, a significant difference was seen in the ToM tests, both in total and in the subscales, of the SLD group compared to the control group. In addition, a significant relationship was found between the total points obtained in the WISC-R test and the ToM test performances (second-order false belief, implied meaning, faux-pas) (Özen 2015).

Recognition of emotions and social communication processes were examined in a study of children with learning difficulties and the children were found to have difficulty in maintaining social communication, perceiving complex emotions and differentiating conflicting emotional states (Bauminger et al. 2005). Children diagnosed with dyslexia or non-verbal learning difficulty (NVLD) were compared with a control group in respect of pragmatic language skills and ToM performances. The dyslexia group were seen to have a significantly low performance in pragmatic language skills and low performance, but not to a significant order, in ToM skills compared to the control

group. The SLD group generally showed a better performance than the dyslexia group, but a significantly worse performance than that of the control group was reported in the metaphor task (Cardillo et al. 2017).

## Conclusion

Following the first studies conducted on primates in 1978, ToM has become an area of interest in both patient groups and healthy populations. Simple and complex ToM tests have been developed for the evaluation of the mind as an area of social cognition and have been applied to both paediatric and adult groups. Developmentally, there has been shown to be a relationship with many areas such as shared attention, pretend play, language development and EF. It has been shown that children of 3 years old cannot understand and differentiate their own beliefs from those of others, whereas at the age of 4 years, children have developed the skill of understanding the beliefs of others. The first step related to ToM neurobiology was the discovery of mirror neurons by Rizzolatti et al and the idea that these neurons could form a neuronal network. There has been shown to be a strong relationship between ToM skills and the anterior paracingulate cortex, the superior temporal sulcus and the bilateral temporal poles. Clinical studies have been conducted in many psychopathology areas such as autism, schizophrenia and BD. Due to the high combination of neurodevelopmental disorders, attention has been drawn to studies related to ToM skills in patients diagnosed with different neurodevelopmental disorders such as ASD together with ADHD, MR and learning disorders and their clinical relationships.

In recent years there has been a focus of importance on understanding whether or not ToM impairments have a predictive value for relapse, recurrence or response to treatment in psychopathological patient groups. Thus, the research investigating in which diagnostic groups ToM skills training could be successful is important. In particular longitudinal studies in early childhood, based on ToM skills and early intervention could shed light on the development of important treatment strategies.

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