Role of mirror neuron system (mns) in autism

Mirror neuron system (MNS) plays an important role in the specific behavioral features of people with autism. In this paper the central aspects, such as neuropathology, etiology and prevalence, of autism and related disorders will be discussed. In addition the Empathizing-Systemizing (E-S) theory and Theory of Mind (ToM), two theories linking the autistic brain with the specific behavior of the disease, will be discussed. The next two chapters are dedicated to the MNS and the consequences of its dysfunction in autism. Important are the two main functions facilitated by the MNS: imitation and action understanding. Several studies show that dysfunction of the MNS in autism, might be a reason why these abilities are underdeveloped in autistic individuals.

Autism was first described in 1943 by the Austrian-American psychiatrist Leo Kanner. He noted 11 cases in which kids weren’t able to relate in usual ways to people and showed unusual responses to the environment including stereotyped motor mannerisms, resistance to change and reduced communicative skills. The condition of these kids was termed Autistic disturbances of affective contact. Nowadays stricter definitions of the disorder have been proposed and clinical indications have been set up for diagnosis. 1

Autism is defined by several clinical manifestations, including qualitative impairment in social interaction, qualitative impairment in verbal and non-verbal communication and restricted repetitive and stereotyped patterns of behavior, interests and activities. 2 These characteristics of the neurological disorder begin before the age of three, although it is not always recognized at this age.

Autism, along with Asperger syndrome and PDD-NOS, belongs to the family of pervasive developmental disorders (PDD). This family includes a broad range of disorders associated with underdevelopment of social and communicative skills particularly. These deficiencies may be caused by mental retardation (Rett's syndrome) but that's not always the case. Cases of Autism and PDD-NOS are not always linked with mental retardation and Asperger syndrome is even associated with normal level of intelligence. This shows that the members of the PDD family are very heterogeneous in their behavioral manifestations, degree of affectedness and etiology. This heterogeneity has lead to the term Autism Spectrum Disorders (ASD). ASD refers to the fact that several neural developmental disorders (Autsim, Asperger syndrome, PDD-NOS) are linked to each other in various ways, which makes it difficult to develop clear-cut diagnostic boundaries. This linkage is highlighted in family members of patients whom mostly do not meet the criteria for a clinical diagnosis but do show (in lesser extent) some of the manifestations present in the patient. 1

Figure 1: Specific behavior observed in persons with autism due to social and communicative impairment and restricted repetitive and stereotyped patterns of behavior, interests and activities. 1: Difficulty in mingling with others. 2: Inappropriate laughing or giggling. 3: Little or no eye contact. 4: Apparent insensitivity to pain. 5: Prefers to be alone; aloof manner 6: Spins objects. 7: Inappropriate attachment to objects. 8: Noticeable physical overactivity or extreme underactivity. 9: Unresponsive to normal teaching methods. 10: Insistence on sameness; resists changes in routine. 11: No real fear of dangers. 12: Sustained odd play. 13: Echolia (repeating words or

phrases in place of normal language). 14: May not want cuddling or act cuddly. 15: Not responsive to verbal cues; acts as deaf. 16: Difficulty in expressing needs; uses gestures or pointing instead of words. 17: Tantrums – displays extreme distress for no apparent reason. 18: Uneven gross/fine motor skill (may not want to kick ball but stack blocks). 3

There are, as mentioned above, four main characteristics of autistic disorders (including the age of onset). First there is qualitative impairment of social interaction. Young children learn their communicative and social cognitive skills by interaction with caregivers. Autistic kids often pay little attention to the smiling face or highly intonated voice of their caregiver and have more interest in the inanimate environment. This will cause a delay in the development of social interaction and also impedes the kid to get attached to a person. The social skills of patients could get better during time but even then the complexity of social interaction (e. g. showing emotions, empathy) will make it hard for the autistic person to have a normal, animated conversation. 1

Another manifestation of autism is qualitative impairment in verbal and nonverbal communication and play. Around 20-30% of patients with autism never speak. There is also no attempt to engage in communication or to compensate the inability to speak by nonverbal communication. These individuals for example do not make eye contact. When autistic persons do speak, their language has often typical features. They often speak with a monotonic voice and might say things not meant for communication (i. e. non-reciprocal communication). They can show echolalia as well, which makes them repeat what is said to them or what they hear in their

environment (e. g. from the radio). Next to that the social uses of language, such as humor and irony, is difficult to understand for patients with autism. Another feature typically seen in individuals with autism is pronoun reversal. 1

A third characteristic is a markedly restricted repertoire of activities and interests. This is expressed by several stereotyped movements, including toe walking, finger flicking and body rocking. Another way in which this characteristic emerges is the interest of the individual in repetitive activities such as collecting certain objects or repeating certain words or numbers.

This urge for steadiness and sameness makes it hard for autistic persons to tolerate change and variation in their daily routine and to deal with stress. 1

At last the age of onset is always before three years. 1

In 2006 the prevalence of autism spectrum disorder was estimated around 1 percent worldwide4, with two to four times more affected males than females5. An increase in the prevalence of autism and related conditions has been observed worldwide. The adoption of broader definitions of autism and greater awareness among clinicians and parents are most likely the main reasons for this growth. 1

The etiology of autism is not always known. In most cases individuals develop autism without an identifiable cause and are diagnosed with idiopathic or non-syndromic autism. About 70% of these patients don’t show any physical abnormalities and are said to have essential autism. The other 30% of the patients can suffer from dysmorphic features such as

microcephaly (i. e. an abnormally small circumference of the head) and structural brain malformation. 5

Autism is associated with a range of other disorders and impairments. In 5-10% of cases, Individuals with Autism are also diagnosed with disorders such as Rett syndrome, Down syndrome, Fragile X syndrome and tuberous sclerosis. Epilepsy is suffered by 33% of the patients and 44, 6% of children diagnosed with autism were reported to have intellectual impairment, defined by an intelligence quotient (IQ) score less than 70. 5

The phenotypic heterogeneity in autism patients is a major challenge in research. Individuals with autism seem to have a unique combination of symptoms and show very divergent behavior. This makes it hard for researchers to find a common cause or treatment for the syndrome. A lot of research is done to clear up the genetic background of autism. The different features of autism suggest that a set of different genes is involved with the disease. 2 Alterations in gene sequence could have an impact on the function of several parts of the brain. With use of Magnetic Resonance Imaging (MRI) major types of pathology have been detected which, most possibly, contribute to the behavioural features of Autism patients. The abnormal brain patterns found include an abnormal acceleration of brain growth in early childhood, minicolumn (local network that contains elements for redundancy and plasticity)

pathology, curtailed neuronal development and brain structure-specific delays of neuronal growth. 2 How these brain pathologies lead to the changes in the behavior described in autistic individuals is still not known. A

(new) theory is proposed by Baron-Cohen to explain the connection between the autistic brain and the correspondent behavior of an autistic individual. This theory is called the Empathizing-Systemizing (E-S) Theory. It is based on the E-S model, which states that the social and cognitive skills of a person are based on an Empathizing Quotient (EQ) and a Systemizing Quotient (SQ). People with autism are said to have an extreme Systemizing brain and thus show little empathy. 6

The E-S theory is closely related to another theory namely the theory of mind (ToM). This theory is an innate mechanism by which a person can interpret and attribute mental states to oneself and others and to understand that another person could have other intentions, desires and beliefs. It makes it possible for people to see the world through another person’s eyes. It has been hypothized that a theory of mind deficit, so-called mind-blindness, is one of the main causes of the impairments in social interaction. It has been proposed that children with autism fail to employ a theory of mind, which makes it difficult for them to see things from another person’s perspective. 7

The Mirror Neuron System

Mirror neurons were first discovered in a specific region of the premotor cortex of monkeys, the F5 area. These special type of neurons appeared to discharge when monkeys did a particular action as well as when they just observed another individual doing the same action. It didn’t matter if the other individual was a human or a monkey or if the subject was rewarded afterwards: responses were equally. 8

Figure 2: A piece of food is grasped by the experimenter (upper panel left), the tray is moved to the monkey and the monkey grasps the food (upper panel right). Activation of neurons in F5 area both during observation of the experimenter’s grasping movements, and while the same action is performed by the monkey (Lower panels). 9

After the discovery of these visuomotor neurons in monkeys, research was done to find evidence for existence of the same neurons in human. By the use of neuropsychological and brain-imaging experiments some results were found that could indicate the existence of a Mirror Neuron System (MNS) in human. 8

First evidence for the MNS in humans was found using electroencephalography (EEG). With this technique was demonstrated that the mu rhythm, which is present during motor rest and disappears during motor activation and somatosensory stimulation9, disappeared during both execution and observation of hand actions10 This shows that not only by executing a task, but also by observing of someone else doing a task, motor neurons are stimulated. Although motor neurons of the observer are stimulated, no movement is made. The mechanism that prevents this unnecessary movement is still unknown. One of the possibilities might be the existence of regulatory mirror neurons or ‘ super mirror neurons’. 11

After this first evidence for the existence of a MNS in humans, more clues were found using other techniques such as Transcranial Magnetic Stimulation (TMS) and functional Magnetic Insoncance Imaging (fMRI). These studies showed that during action observation, cortical areas of the brain

involved in motor control were activated. 9 Activation was particularly observed in posterior inferior frontal gyrus (IFG), also known as pars opercularis, and adjacent ventral premotor cortex (PMC). In addition mirror neurons were found in the rostral part of the inferior parietal lobule. Activation was also found in the superior temporal sulcus (STS), which is believed to be the region responsible for visual input to the MNS (figure 3). 11

Figure 3: Schematic overview of the neural circuitry for imitation. Visual input enters via the posterior superior temporal sulcus (STS). Visual information is passed on to the rostral inferior parietal lobule(IPL) (orange arrow). The red arrow represents the information flow from the parieral lobule to the ventral MNS, i. e the ventral premotor cortex (PMC) and inferior frontal gyrus (IFG), concerned with the goal of action. Efference copies of moter imitative commands that are sent back to the STS are represented by black arrows. This allows matching between the senory predictions of imitative motor plans and the visual description of the observed action. 11

Based on these findings, two hypotheses have been proposed that give the possible function of mirror neurons. The first hypothesis states that mirror-neuron activity mediates imitation 12 Humans are one of the few species that can learn by imitation. Studies show that 12-month-old infants can imitate facial and hand gestures and by this mechanism learn these movements themselves. 13 Next to that the infants were also able to predict the action of goals by other people. This introduces the second hypothesis that says that mirror neurons are the basis of action understanding. 9 For people to interact with each other, they must be able to understand the

actions of another person. So action understanding plays a key role in the organization of social behavior of humans. An interesting experiment has been done by Umilta et al, showing that mirror neurons became activated even when visual stimuli were hidden. 14

So different studies show that most likely both hypotheses are true, although there is still some discussion by which mechanism the mirror neurons execute these functions. 9

Autism and the Mirror Neuron System

Recently it has been proposed that dysfunction of the mirror neuron system could have an influence on the development of autism. 15 Defects of these neurons early in development are believed to interfere with the development of normal social actions such as imitation, theory of mind and language. 11

Several studies are done to test this hypothesis. Testing the IQ of children with autism shows a negative relationship between the activity of the mirror neurons and the scores of the children on the social subscales. This means that a higher activity in de mirror neuron system is accompanied with a high score on the social domain. This gives one of the first indications of a link between the dysfunction of the MNS and the development autism. 11

One of the functions that is thought to be impaired by the dysfunction of the MNS is imitation. Imitation is one of the most important mechanism by which young children learn their social and communicative skills. Different experiments demonstrated that children with autism have difficulties performing imitation. 17

Studies using fMRI supported the hypothesis by showing a reduced MNS activity in children with autism during imitation and observation of facial emotional expression. These results all suggest that mirror neurons play indeed an important role in imitation and early dysfunction of MNS may be at the core of the social limitations observed in children with autism. 16

Rizzolatti and Arbib have proposed that the part of the monkey brain which contains mirror neurons dealing with hand actions, has evolved to subserve speech in humans. 17 This would suggest that hand gestures and mouth gestures are linked in humans. A defect in this specific part of the MNS could result in an inability to speak, like some of the persons with autism do. However, to date no research is done to prove this possibility.

Another possible effect of mirror neuron dysfunction could be underdevelopment of ToM. It has been demonstrated that children with autism have difficulties perceiving the world from another person’s eyes, suggesting that they have a reduced ToM. However, a study showing a correlation between the dysfunction of the MNS and ToM has still to be done. 15

Conclusion

Although the discovery of mirror neuron system is just recently done, already a lot of research is dedicated to this interesting part of the brain. The specific neurons first found in monkeys, are most probably also an important part of the human brain forming a basis for functions such as imitation and action understanding. In autistic persons, who show to have difficulties with these abilities, reduced activity of mirror neurons has been found. This would

suggest that the MNS is a key factor that influences the degree of social and communicative impairments in these individuals. Still a lot of research has to be done to find strong evidence for the dysfunction of the MNS and its relationship with reduced speech, social interaction skills and theory of mind.

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