Joint attention: providing bases for social-cognitive and language skills.

Reinoud Bothof [1]
Utrecht University

Elizabeth Batista Pinto Wiese[2]
Utrecht University

Abstract: Joint attention entail the mutual focus of two human beings on either a common object of interest or on each other. When two persons focus on one another, emotional and mental states can be inferred by means of mirror neurons, dispersed over brain regions involved in emotionality and motor coordination. The mirror neuron system is suggested to have an important role in motor synchronization for shared behavioral goals, as well as imitation of articulation and speech gestures. Joint attention bids associated with a common object of interest can accommodate learning, especially by forming proper learning environments for language acquisition in infants. Attention-regulating areas in the prefrontal cortex have a central role in the initiation of joint attention, and a pattern of specialization has to mature in children, as areas responsible for initiation and maintenance of joint attention migrate towards the frontal poles of the brain.
Key-words: Joint attention; mirror neuron system; social cognition; empathy; language development.

Resumo: A atenção conjunta envolve o foco mútuo de dois seres humanos em um objeto de interesse comum ou entre si. Quando duas pessoas focam uma na outra, estados emocionais e mentais podem ser inferidos por meio de neurônios-espelho, distribuídos por regiões do cérebro envolvidas na emocionalidade e coordenação motora. Sugere-se que o sistema de neurônios-espelho possui um importante papel na sincronização motora pra objetivos comportamentais comparti-

1. Graduated student of Roosevelt Academy, International Honors College of Utrecht University, Middelburg, The Netherlands.
2. Professor of Psychology of the Roosevelt Academy, International Honors College of Utrecht University, Middelburg, The Netherlands. Retired professor of IPUSP/PSC, email: *ebatista@usp.br* or *e.wiese@roac.nl*

lhados, bem como para a imitação da articulação e de gestos da fala. Ofertas de atenção conjunta, associadas com um objeto de interesse comum podem acomodar o aprendizado, especialmente pela formação de ambientes de aprendizagem apropriados para a aquisição da linguagem por crianças. As áreas de regulação da atenção no córtex pré-frontal apresentam um papel central na iniciação da atenção conjunta, e um padrão de especialização nas crianças tem de amadurecer, já que as áreas responsáveis pela iniciação e manutenção da atenção conjunta migram em direção aos pólos frontais do cérebro.
Palavras-chave: Atenção conjunta; sistema de neurônios-espelho; cognição social; empatia; desenvolvimento da linguagem.

As humans, we must adjust to society and its ever changing demands, using multiple mechanisms of high complexity to navigate through many social situations and challenging events, often being very successful. Mechanisms that underlie an average human's success in the field of social interactions are comprised of a multitude of social skills and interpersonal capabilities, largely summarized as social cognition.

As newborns, we are equipped with measures to steer through the social world with great prowess and effectiveness, often to the amazement of caregivers and researchers alike. Multiple aspects related to social cognition have their neurological underpinnings in the cooperation of various brain areas, and are shaped through contact with other human beings, from infancy onwards.

This paper will discuss one of the components of social cognition that is necessary to perform well, both on verbal and non-verbal social interactions, namely the capacity of joint attention. Research findings suggest that joint attention is an irreplaceable skill in human development for both social cognition and language acquisition. This paper will discuss the different components of joint attention and their meaning for human social interactions, as well as the neurological underpinnings involved in the establishment of joint attention studied by neuropsychological research.

The relevance of joint attention for social cognition

As children learn and adapt to their surrounding physical and social world, special cognitive capabilities are necessary to promote rapid individual progress in learning the essential skills necessary for coping well with life. One crucial element of social interaction is joint attention. Frith and Frith (2007) defined joint attention as a means of sharing representations of the world, by allocating attention away from an item of interest to one observed by another person. This type of attentional shift is highly advantageous in promoting rapid learning, as the repertoire of experienced events grows exponentially when attending to discoveries made by others.

The same mentioned authors (Frith & Frith, 2007) also suggested that this ability is meant for aligning two perceptual worlds, to match the situational context of different individuals. From this point of view, joint attention is related to empathy, since the sharing of representational worlds benefits and promotes the development and sustenance of empathy: the ability to understand and resonate with the emotional experience of another human being, thus making it possible to share feelings (Purves et al., 2008).

The importance of joint attention lies in the so-called shared world concept (Frith & Frith, 2007). This model states that two individuals can align their perceptual perspective of the world, thereby creating a common background vital for the exchange of information. As infants master the ability to respond to joint attention bids made by their caregivers, they can expose themselves to rich information sources from the social environment, and can make large improvements in learning new concepts, especially for socially relevant knowledge (Paterson, Heim, Friedman, Choudhury, Benasich, 2006).

Besides opening an information gate between two individu-

als, joint attention can give the means to the person to infer behavioural goals of someone else, and to make predictions of possible actions made by that person. Namely, after coordination of perspectives between two persons, actions can be synchronized to produce complementary behaviour to facilitate social interaction and achieve a common goal with greater ease and effectiveness (Sebanz, Bekkering & Knoblich, 2006). This form of joint attention and joint behavioural effort is mainly mediated by a set of neuronal circuits in the brain, called the mirror neuron system, which will be discussed below.

The neurological mechanisms of joint attention: the mirror neuron system

When two individuals align their gaze, they create a shared context for social interaction. What is interesting is that during this communication environment, both individuals can infer information about each other's mental states from the messages expressed through eye gaze, facial expression, and body movement. Therefore joint attention opens a mutual information gate, in which the individuals involved can have means to understand each other's motivations, goals and even emotions.

Paterson and colleagues (2006) made a distinction between initiating joint attention and responding to joint attention efforts. They posed that different neural circuits underlie these two varieties of joint attention. According to them (Paterson et al., 2006), initiation of joint attention is accompanied by an increase in activity in frontal areas of the brain, such as the dorsolateral prefrontal cortex and medial prefrontal cortex. These two areas are also implied in sharing many other functions, with the dorsolateral cortex playing a main role in executive control systems, attentional control systems, decision making, and working memory (Purves et al.,

2008). The medial prefrontal cortex, often in combination with activation of other functional areas in the limbic system (e.g. amygdala, cingulate cortex), has been related to emotional responses in attention, mentalization, theory of mind and empathetic response generation (Purves et al., 2008).

On the other hand, creating a response to joint attention bids seems to involve parietal networks, mainly involved in attentional domains of functioning. This attentional shift seems to be the result of a synergistic relationship between left and right parietal areas, probably the medial parietal cortices (Paterson et al., 2006).

However, it is important to note that, in joint attention, the frontal regions of the brain play a vital role. Research by Paterson and colleagues (2006) showed that as an infant gets older, brain regions involved in joint attention shift from posterior to more anterior regions of the brain, suggesting a clear form of specialization and maturation of neural structures. Frontal areas are more involved in attentional control, granting the child a higher social competence with respect to joint attention bids. The brain's frontal areas make rapid developmental progress between 8 to 12 months of age, with respect to the development of joint attention capacities (Paterson et al., 2006).

The brain mechanism that underlies the features of social interaction involved in joint attention is called the mirror neuron system. This mechanism is an intricate neuronal system present in the inferior frontal gyrus and in the inferior part of the premotor cortex, the inferior parietal lobule, the superior temporal sulcus and parts of the limbic system: the anterior insula and anterior cingulate cortex (Oberman, Pineda, & Ramachandran, 2008; Gallese, Keyers, & Rizzolatti, 2004).

The mirror neuron system works by connecting the observations of another individual's actions to brain areas responsible for execution of those same actions in the observer. Activation in mir-

ror neurons, especially in the inferior frontal cortex (implied in the representation of motor actions) and the inferior parietal lobule (implied in the representation of body schemata and self), underlies this internal representation of actions, so that it seems as if the observer would be performing the actions him/herself, thereby providing understanding about the meaning and eventual goal of the motor actions of the observed individual. Besides this internal action mirroring, the superior temporal sulcus seems to be related to making predictions about the eventual outcome of an observed action, which further benefits the understanding of an inferred goal (Frith & Frith, 2007). It is important to note the developmental significance of this mechanism, as children are supposed to attain understanding of the behavioural goal of the caregiver, when they form a joint attention connection and receive observational input of the caregiver's actions.

The mirror neuron system is especially relevant in the previously described phenomenon, as it does not only contributes to the inference of behavioural goals, but also activates and prepares the muscle groups necessary to perform the same behavioural action in children observing an individual's motions, thus facilitating imitation and behavioural learning (Rizzolatti & Fabbri-Destro, 2008). Sebanz, Bekkering and Knoblich (2006) found that mirror neuron-generated motor activation often occurs during the observation of a performed action, implying the role of this neural system in action prediction and in the appropriate response generation. These predictions hold significance for the establishment of a common ground situation, so often seen during joint attention, because the identification of another individual's action goals seems to promote social interaction between individuals (Sebanz, Bekkering & Knoblich, 2006).

Another part of the mirror neuron system is located in regions of the limbic system, called the anterior insula and the anterior cingulate cortex. The insula has been found to have a substantial

role in perception of chemosensory information (taste perception), but also in mediating disgust and in relaying visceral sensations and motor responses, which are related to interoceptive body states (Gallese, Keysers, & Rizzolatti, 2004). The anterior cingulate cortex has an important role in pain perception, which makes this area, together with the insula, a key region for emotional experience.

The mirror neuron system becomes activated when actions and emotions are experienced in a first but also in a third-person perspective, as if we are experiencing these performances or feelings ourselves (Gallese, Keysers & Rizzolatti, 2004). Thus, when an individual experiences pain or disgust the mirror neuron system is activated in addition to the circuits involved in the processing of these basic perceptions, however only the mirror neuron circuits are activated when the same individual perceives pain or disgust in others, thus offering both understanding of the emotional state of the other, as well as distinction between the receivers of these emotions, as the observer's primary pain/disgust circuits are effectively silent (Ramachandran & Altschuler, 2009). This suggests that whenever a person responds to joint attention bids of someone else, he/she experiences the emotional status of that other person and, therefore, can take the other person's perspective.

Taking another person's perspective with respect to emotional mental state is one of the fundamental elements of empathy, a key component of human social interaction. Therefore it is believed that the mirror neuron system (together with areas in the prefrontal cortex that have shown to be important in the initiation of joint attention) holds a share in the development and expression of empathetic responses towards other individuals.

For instance, Dominey and Dodane (2004) suggested that joint attention mechanisms can be used to interpret emotional messages conveyed by referential cues in eye gaze and body-orientation, and this behaviour is already present in infants ranging

from 12 to 18 months old. Thus, from these findings, a link between shared attention, emotions and feelings, inferences of goals and successful performance in interpersonal situations can be seen, with respect to the involvement of the mirror neuron system.

According to Gentilucci and Dalla Volta (2008), the brain systems that govern hand motor control and vocalization share the same neural circuits (presumably Broca's area). This suggestion was build upon by Rizzolatti and Arbib (1998), who have found evidence of the role of Broca's area in oro-laryngeal, oro-facial and brachio-manual movements' control. In their research, the same authors (Rizzolatti & Arbib, 1998) found that Broca's area holds mechanisms for linking action perception with action production. As fluent speech production is related to movements and gestures, the role of movement imitation becomes apparent when discussing speech acquisition. In fact, hand motor actions are important for the development of speech production, which is already apparent in babbling infants (Gentilucci & Dalla Volta, 2008). Imitation of facial expressions can already be found in infants younger than 1 month of age, and during the next two years of life, more sophisticated speech motor imitation behaviours become apparent (Nishitani & Hari, 2002).

Thus, the role of the mirror neuron system is fundamental as human infants, using perception-action links, mimic and learn facial motor behaviours involved in speech. Therefore, it can be said that Broca's area provides another valuable asset to the mirror neuron system, by promoting understanding of facial movements and hand gestures in speech comprehension. Also this system can be interpreted as necessary (but not sufficient) for the acquisition of facial movement skills, necessary to form spoken language (Nishitani & Hari, 2002).

The role of joint attention in language development

According to Purves and colleagues (2008), the matter of language lateralization in the two hemispheres of the brain can be seen as such: the left hemisphere mediates the ability to comprehend and produce speech, while the right hemisphere has the propensity of giving emotional value to the comprehension and production of speech (Purves et al, 2008). This lateralization is evident in practically all right-handed people, where brain specialization for the production and comprehension of language is mostly found in the left hemisphere; in left-handed people, it is more common to find language lateralization either in the right hemisphere, or subdivided over both hemispheres (Anderson, 2005). However, approximately half of all left-handed persons still have language production/comprehension areas contained in the left hemisphere (Anderson, 2005). Nevertheless, it is important to note that the higher cognitive faculty related to language relies on a dispersed neural system, consisting of multiple neural networks that interact to generate the different components (e.g. articulation, verbal memory, understanding of meaning, and many others) on which language is build. These networks are present in both hemispheres, but are involved in different specializations of approximately the same language processing mechanisms (Purves et al., 2008). Thus, one cannot speak of true hemispheric localization related to language, but merely of dispersed specializations that take place bilaterally or unilaterally (within one hemisphere) in the brain.

It is important to note, however, that language associated networks do not store information about the production and comprehension of speech in the form of words (or actions), but rather in the form of meaningful activation patterns within these networks. These activation patterns are then translated into the understanding of concepts (objects – nouns, or actions – verbs) by forming communication-relevant associations with attended environmental

stimuli. Joint attentional skills have been found to be highly important in the acquisition of these associations, and offer means for the expression and understanding of the language spoken in the child's social surroundings (Paterson et al., 2006).

As can be seen in previous sections, the foundations of joint attention lie in the coordination of visual attention between two individuals, and are already being established in infancy. For joint attention to be effective the infant must first acquire the ability to shift his/her visual attention away from an object to the caregiver. The ability to do so makes its scene in the first 6-12 months of life and is consolidated around the 18th month (Mundy & Gomes, 1998). The ability to respond to joint attention bids and the skill to initiate joint attention are predictive measures of early language development (Paterson et al., 2006), as these social skills provide the necessary means to communicate at an early age. Mundy and Gomes (1998) found that taking initiative in joint attention is a significant predictor of developments in expressive language and responding to joint attention is related to developments in receptive language, during the second year of life. Responding to joint attention bids is related to higher achievements in both receptive and expressional language acquisition between 24 and 30 months of age (Dominey & Dodane, 2004).

Another related finding is that the tendency to either initiate or respond to joint attention can explain some individual differences in early language acquisition (Mundy & Gomes, 1998). According to Dominey and Dodane (2004), the initiation of joint attention by caregivers is paired with the use of child-directed speech, to draw the attention of the infant to relevant aspects of the speech, as well as relevant aspects of the situation. Responses to joint attention bids become present in the infant's repertoire of social skills after 6 months of age if the conditions are favourable, as the child's development allows the focus on the social world to shift from dyadic to triadic interactions (Dominey & Dodane, 2004).

The transition of child-object/child-caregiver relations to child-caregiver-object relations makes it possible for the child to direct his/her gaze at an object that is the focus of attention of another individual. This type of attentional triad will facilitate the infant's language acquisition, as social interactions with caregivers are based on object-related events they help the child to identify the goals of the caregiver's use of language in those instances (Dominey & Dodane, 2004). By drawing the child's attention to the object and associating it with language, the child's word-object mapping can develop greater accuracy.

Conclusion

Since humans are social beings, intricate systems to promote competence in social interactions are very important to increase the individual's chance of survival and adjustment. Other members of society provide vast sources of information that may benefit the individual enormously, as experience can be transmitted preventing some trial-and-error effort. The shared world that is created when two people establish joint attention is therefore one of the most important ways to promote early and thorough learning.

To summarize, the mechanism of joint attention is subdivided into initiating and responding to joint attention bids, with different brain neural circuits supporting development and expression of these skills. Joint attention creates a shared contextual world that promotes unidirectional or multidirectional learning for the individuals involved. The activation of the brain's mirror neuron system is necessary for the establishment of this shared context, as it functions in such a way that makes it possible for the observing individual to understand the observed emotional experience and predict goals of another human being. This neuron system is therefore pivotal in modelling learning and imitation, as well as in

perspective taking and empathy.

There is evidence that in infants the competence in responding to joint attention bids is related to better language acquisition of both expressive and receptive language. Therefore the development of joint attention proficiency seems to lead directly to higher individual skills in social interaction.

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