Student: Luca Vassalli
Matr: 0565642
Email: s0565642@sms.ed.ac.uk
Course: visiting undergraduate Erasmus student
School of Informatics

Introduction to Cognitive Science

Assignment 3: Essay

Neurological and Developmental Substrate of Planning and Language

Pierre Paul Broca was the first scientist who found out the relation between the Brodmann's area 44 and 45 and the human skills of language processing, speech production and comprehension. After several studies about this area, called also Broca's region, it was understood that it is involved not only in the language or communication-related functions but also motor function like hand actions and orofacial gestures.
Nishitani (1) classified the main functions in these group:

- Language and speech
- Perception-action link for communication
- Action understanding
- Imitation
- Forward and inverse models
- Motor and perceptual sequencing
- Hand gestures and their relation to speech

About the “Action understanding” group are interesting the Rizzolatti's (2) study about the 'mirror' neurons. In his research, Rizzolatti found a relation between the monkey brain area F5 and human area 44. In the monkey, area F5 has both a representations of hand and mouth actions, similarly beside the classical speech function of the area 44, Rizzolatti pointed out that it is also related to hand actions. Moreover complex manipulation task activates in the humans this area with other two areas which are the same that are activated in the monkey with the area F5. Furthermore the focus of representation of precision grip is mainly located in area 44 for the humans and in area F5 for the

monkeys.
He observed that some F5 neurons, for this reason named Mirror Neurons, were activated when the monkey watched another individual making an action in front of it, in particular it was observed that the monkey's Mirror Neurons are activated even if the final part of the action is hidden behind a screen. Interestingly, if the monkey knows that nothing is behind the screen its neurons will not be activated, that suggests that these neurons are involved in the "understanding" of actions made by others, in fact if the monkeys is conscious that the action is not real but only simulated, like in the example of the screen above, its Mirror Neurons are not activated. In particular it is interesting that since the action is recognised in another subject, it has to be represented in a symbolic way which is common between the actor and the observer. The understanding of what distinguish an action from an other, actually which steps "count" or are necessary in one action, and the common representation of the action itself are the two fundamental prerequisites of the communication according to Liberman(7). Interestingly the Mirror Neurons are important to recognise action which are in the observer's motor repertoire, so if a monkey says a dog barking, its Mirror Neurons will not be activated since it cannot bark (3), this is another proof of the connection between the understanding and recognition made by the Mirror Neurons and the communication. Since a dog does an action which is not in the observer's repertoire, it is not in his same group of individuals and so, from an evolutionary point of view, no interaction is needed. Rizzolatti underlines like the primitive dialogue between observer and actor, based on the fact that the actor realises the observer has understood the action he is doing and the observer knows that the actor's behaviour is for this reason affected, have yielded enormous benefits of adaptive value for the group of individuals that started to make use of it providing the selective pressure for the extension of these capacities to other groups (6).
Another interesting function of the Broca's region is the "Forward and inverse models" presented by Nishitani. When we are planning an action the forward model is the sequence of perceptions that we should receive,our brain will compare this prediction with the actual perception to understand if the goal was achieved. For example for this reason when we are speaking our auditory cortex is not elicited by the sound of our voice because this is expected but the situation is different if we hear the same sound from an external source, like a tape. The inverse models are based on the feedback that we receive from our perceptions when the plan is carried out. Broca's region is the area of the brain which coordinates these two different informations. Moreover with "Motor and perceptual sequencing" Nishitani refers to rules in action segmentation and sequencing. It means that this region is involved in the division of a sequence of different perceptions, in its singular elements and it is involved in the construction of a motor plan based on more then on step (1).
The fact that the Broca's area is so important not only in speech-related function but also in action planning, action observation, action understanding and imitation strongly suggests the idea that natural language grammar and planned action are related systems (4), and that that linguistic semantics is grounded in the perceptual and motor systems, and therefore reflects characteristics of these systems (5). Furthermore the position of the Broca's region, immediately adjacent to areas involved in motor planning, suggests that in evolutionary and developmental terms, the former are built upon the latter (4). Also Rizzolatti proposed that the development of inter-individual communication to the final stage of speech was based on the mechanism for recognizing actions made by others, which the F5 area is endowed with (6). In a possible scenario of the evolution of the speech from the original oro-facial system of communication, still used by the apes, Rizzolatti point out the importance that both the F5 area and the Broca's region can control oro-laryngeal, oro-facial and brachio-manual movements. So they can link the perception of an action to its understanding and reproduction and for this they have the potential to create some simple "closed systems of communication". According to Rizzolatti the first associated closed system to the oro-facial one was probably the manual gestures which is highly connected with the Broca's region ("Hand gestures and their relation to speech" is presented by Nishitani like one of the main function of this region). The manual gesture was able to increase the expressiveness of the sender allowing for example the transmission of informations about position of objects or other apes. At

this point the association of sounds to gestures allowed them to assume more open, referential character. So if the first sounds were connected always with the same gesture a primitive vocabulary of meaningful sounds could start to develop(6).
In this argument may be interesting to analyse the development stages of the infants, in particular is interesting the Drescher's analysis of the six stages of the first two years of her life also named sensorimotor period, individuated for the first time by Piaget (8). According to this theory, when the infant is born, she has no cognitive structure of the world and reacts only with reflex activity. Then stages after stage she develops better models of reality based on more powerfully expressive logics according to her decreased constrains in the interaction with the world. As Ferell showed, at the beginning the infant's input and output are seriously bounded so she has limited motorical skills, poor visual acuity, poor visual accommodation and short limbs (10). If she had no limitations from the beginning she would be overwhelmed from the complexity of the input received but month after month she develops more powerful representation of the world and she increase also her skills of interacting with the world. For example, in the second stage, she learn to coordinate these reflex activities in the so named primary circular reactions which are used to increase her understanding of the effects of her action on the objects. It is in this stage that the infant starts to have the concept of objects rather than sensory images, but she still applies familiar schemas to inappropriate situation since these schemas were found fortuitously after the generation of a surprising effect.
In the fifth stage, the infant does another step in her development starting to use the so named “tertiary circular reactions”: she starts to apply a series of different schemas to the objects to discover the effect of the actions on them. So now the focus is on the effect of the action on the object rather then on the action itself. The difference with the third stage can be explained better in an example: if the infant has a pet which can produce a sound in the third stage she is surprised to hear a sound shaking it and so after the fortuitous discover she will try to shake also other objects to reproduce the wished effect, in the fifth stage she will try to shake, to drop, to grab, to throw and so on, the object with the goal of simply seeing what happens to the pet. We could think that it is in this stage that the infant finds out the affordances of the objects, in Gibson's terms, and the type raising on them. In fact the infant selects an object and systematically tries all the possible actions to see which ones produce an interesting result so eventually the object is turned in a function over the second order function from its affordances to the their results (4). The Miller's TOTE units building up process is this process of connecting the perception of the object, the Image, with its affordances used in the operational phase of the units(9).
Finally in the last stage of the sensorimotor period the infant can also mentally manipulate the objects learning from simulation instead of from actual experimentation. Interestingly the infant starts to communicate not only desires and commands but also real ideas after the sixth period. This is also connected with the fact that the Broca's region itself matures later then primary sensomotor cortices (1). It was also observed that the frontal region of the brain, implicated in language disorders and associated with the exciting phenomenon of the Mirror Neurons, is also involved in the mastery response inhibition which the motor plans depend on in situations like reaching an object which is blocked by an obstacle, in fact in this case the infant has to suppress the direct relaxation reach. Another interesting fact is that like I said above, when the infant reaches the fifth stage we can use to represent her planning the combinatory operator of type raising. Also the operator of composition is present when she uses a stick to draw an object out of reach closer and the she grasps it. This two combinatory operators have a fundamental rule in planning but they appear also in natural language in a syntactic way (4).
All these signs indicate that language faculties are strictly connected with planning faculties and that the former develops in children from a primitive apparatus. This pre linguistic apparatus uses composition of the affordances of the objects to reach the goals.

References

1. Nobuyuki Nishitani, Martin Schürmann, Katrin Amunts and Riitta Hari “Broca’s Region: From Action to Language”
2. Rizzolatti G, Fogassi L, and Gallese V. “Motor and cognitive functions of the ventral premotor cortex.” Curr Opin Neurobiol
3. Buccino G, Lui F, Canessa N, Patteri I, Lagravinese G, Benuzzi, F, Porro CA, and Rizzolatti G. “Neural circuits involved in the recognition of actions performed by nonconspecifics: an FMRI study.”
4. Mark Steedman “Plans, Affordances, and Combinatory Grammar”
5. Shweta Narayan, Benjamin K. Bergen, Zachary Weinberg “Embodied Verbal Semantics: Evidence from a lexical matching task”
6. Giacomo Rizzolatti and Michael A. Arbib “Language within our grasp”
7. Liberman, A.M. (1993) “Haskins Laboratories Status Report on Speech Research”
8. Drescher, G. “Made-up mind”
9. Miller er al. 1960 Ch.14 “Some Neurophysiological Speculation”
10. Cynthia B. Ferrell and Charles C. Kemp “An Ontogenetic Perspective to Scaling Sensorimotor Intelligence“

Without references and headers this essay is long words.