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Neurolinguistics and animal cognitive science

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Abstract. Humans have developed language as one of their most precious resources. Language ensured that reproduction could be more organized and continuative, as proved by the human supremacy on the planet. This evolution has made us different from the other species; language is what sets us apart from the other animals.
Yet, although they cannot speak, the other animal species have a different way to communicate, which we have difficulty to understand and sometimes barely recognize. Evolution, since it did not develop language in animals, might have sharpened other senses and created a particular sensibility, which might have been dulled in humans by the expansion of the neo-cortex[1].
Animals, in fact, possessing a reptilian brain governed by instinct, which is more ancient than the neo-cortex, have characteristics of intuition which are different from those of humans – this might explain, for example, the ability of dogs to predict natural events such as earthquakes before they occur.
In this paper, we have applied the study of neurolinguistics to the analysis of several specific cases, in order to investigate the language of animals, understand its processes and relate with what we, as humans, have lost through evolution.

Key-words. Neurolinguistics, cognitive science, language, ethology.

1. Introduction. In 1872, Charles Darwin published a book entitled *Expression of emotion in man and animals*, where he provided a very accurate description of emotions, analysing their effect on the muscular system, on the face and on the body. Darwin identified six main expressions – happiness, surprise, revulsion, anger, fear, and sadness – which he believed are

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shared by men and animals. He also provided examples of how men and animals communicate these six basic emotions using non-verbal language, such as facial expressions and body movements.

He also demonstrated that some expressive acts (blushing, facial expressions) are innate and hereditary, and similarly to physical organs they are transmissible traits produced by evolution by means of natural selection. In other words, expressions for Darwin are biologically determined, even though culture partially influences them through the customs of the society where the subject is living.

He particularly focused his attention on the link between muscular conformation, character and the expressions conveyed by a human face or an animal's muzzle.

According to the scientific beliefs of the time, which also influenced Darwin, a face's muscular conformation is indicative of a person's most common expressions. So if you frown often, you will particularly develop the muscles in your forehead which are commanded by the movements of your brows. Also with animals, character was seen to be deeply connected to the physical aspect.

A study begun in the early 1960s and interrupted in 1996 because of lack of funds seemed to confirm this observation. The Russian scientist Dimitri Belayaev, who did not believe in genetics, observing the physical differences between dog and wolf speculated that they were due to the selection operated by man in order to obtain better behavioural traits in dogs, such as docility. He thought that the appearance of modern dogs was due to neurochemical and hormonal changes caused by selection.

So he decided to select wild canines, and his choice fell on foxes. His aim was to breed some specimens in order to select them according to their docility.

He chose the least aggressive animals and made them breed. The experiment was carried on for forty generations, finally obtaining a group of domesticated foxes which showed behavioural and physical features which were very different from those of wild foxes. They were very friendly towards humans – they licked the experimenters, sniffed them and appreciated their presence. They tried to attract their attention and wagged their tail to show their feelings. Also they were not afraid of strangers and their appearance was very similar to that of dogs. Changes in ears, tails and colour were noticed, and even the skull and teeth structure had changed.

According to Belayaev, these substantial differences were due to modifications in the glandular system controlling the production of adrenalin, which, like in dogs, was present in smaller amounts.

Coming back to Darwin, we can summarise his observations on the expression of emotions in the three following points:

1) There is heredity in the typical movements of species. They may be movements repeated by ancestors, which had a specific utility at the time, and which are included in the

genetic stock of species even if they are no longer useful (dogs, for example, when they want to sleep on a hard surface like a pavement, circle around the spot where they have chosen to sleep. They do that because their ancestors tried to soften the earth a little before lying down; the gesture is maintained as heritage of a once-useful habit).

2) Another point is antithesis: the answer to a stimulus is automatically a movement. Think of the gesture of scratching oneself; a horse when rubbed down feels itchy, so it will move its teeth as if to scratch itself with its teeth.

3) Lastly, the nervous system has a fundamental function in expressing emotions, producing involuntary responses to stimuli.

Starting from these premises, Paul Ekman and Wallace Friesen carried out an intercultural research in 1967-1992, establishing that human facial expressions are universal and remain unchanged throughout the world, even in very isolated areas (Ekman & Friesen 1992).

Expressions have a neurocultural structuring: innate neuronal stimuli, genetically inherited, produce adaptive responses which are ascribable to the six families of emotions defined by Darwin. These responses can be voluntarily controlled in culturally-appropriate ways by techniques of masking, intensifying, un-intensifying, and neutralising, i.e. showing a "poker face". Nevertheless, as expressions are produced by two muscular circuits, one of which is involuntary, even when trying to conceal an emotion, its spontaneous facial expression will appear for 1/25 of a second – this is called a "micro expression".

Emotion can be defined as an intense mental state, either positive or negative, arising in an automatic way in the nervous system. Ekman and Friesen tried to established how many emotions can be considered "primary", in that they cannot be broken down to simpler emotions. Orval Hobart Mowrer had stated they were only two: pleasure and pain, but, during forty years of research, Ekman and Friesen showed that basic emotions, shared by every culture, are in fact seven, one more than Darwin's (surprise, fear, anger, revulsion, sadness, happiness, disdain).

Animals communicate – this much has been proved, even if the debate is still open about how we can define language. Clive Wynne, for example, claims that the referential language used by animals, which refers to the external world, cannot be defined a real language because it is without syntax, so it does not have the ability to express elaborate concepts (Wynne 2006). The philosopher Noam Chomsky, analysing the nature of language, came to the conclusion that language is the most quintessentially human tool and that it enabled the rapid expansion of humans, since it facilitates the transmission of personal knowledge useful to the progress of the species.

Regarding animal communication, there are several examples in nature of animals using communication tools. For instance, chimpanzees have three different alarm shouts: one when the predator comes creeping, another when it arrives running and the third if it arrives flying, and the community members answer using three different ways of escaping or defending.

2. Methodology. In order to analyse animal communication and expressions, ten chicks were observed for two weeks starting from their birth in a breeder, recording progresses daily.

Chicks were kept in freedom and they had only a lamp in order to imitate the warmth of a brooding hen.

3. Results. Even if growing isolated, without their mother, chicks did not need parental imitation to learn behaviours which are inborn in young birds and transmitted as hereditary characters – among them, expressions and strategies.

Very early, from the second day, chicks began to let out different kinds of cheeping sounds to express a sense of well-being or if they were annoyed by something. Starting from day five they could independently elaborate strategies typical of their species (for example scratching to find the best seeds) and personal strategies such as running up and jumping on their siblings when they were blocking the way to food.

Moreover, they immediately showed a tendency to stay in a group in order to give one another warmth and protection; from day three, when one of them was absent, they noticed its absence and emitted a particular cheeping sound to recompose the group – which suggests that they have a sense for numbers and language.

4. Discussion. The communication of animals, like that of humans, can be influenced by the social group or the environment. Bees, for instance, communicate dancing – they waggle their abdomen to indicate to the other members of the colony where to find water or pollen. Just as with human languages, the meaning of this gesture is not universal: in northern Europe a waggle means 50 metres, in Italy 20 metres, and in Egypt 10 metres.

Konrad Lorenz, a Viennese scientist who is considered the “father of ethology”, the science which studies animal behaviour, excluded *a priori* Darwinian classifications and classifying theories and in 1937 developed the “imprinting” theory, which hypothesised the existence of an instinctive pattern of learning which is typical of a species and is not dependent on individual experience.

Lorenz arrived at these conclusions when he placed some wild goose eggs in an incubator until they hatched. In the absence of the goose, the goslings took the scientist for their mother, following him everywhere and crying when he was not there. This led to the discovery of filial imprinting, which implies the existence of a temporary behaviour connected to the information a gosling receives from the external world during the first 36 hours of life – during this time its nervous system is able to “imprint” the image of the parent or whoever is recognized as such. But the fact that this parent might not be the gosling’s natural mother does not impede the process of learning to which the animal is genetically disposed. The cuckoo, for instance, although it is raised by other species of birds, invariably looks for a mate of its own species.

Lorenz's theory of imprinting has been recently applied by an Italian, Bino Jacopo Gentili, to the communication between humans and horses, in order to have a more scientifically-based approach to horse-training. Gentili, who has called his own technique "equoethology", has analysed the structure of a horse's nervous system, which presents few connections between the left and right hemispheres of the brain. In his study of the relationship between humans and horses, Gentili has also observed that horses are herbivores, with the genetic and behavioural makeup of a prey. As predators, we do not often realize this when we approach them.

As we have seen, animals have complex cognitive and communicative systems which can be studied and explained in several ways.

5. Working with cognitive science: an historical example. Interaction between man and animals sometimes produces effects which are difficult to explain, as in the case of Clever Hans and the Horses of Elberfeld.

These events took place in Berlin starting at the end of the 19th century. Baron Wilhelm Von Osten, a teacher of mathematics, was convinced that human beings had not fully understood the intellectual potential of animals and was determined to demonstrate it. At first he tried educating a cat, which showed annoyance at his efforts, then he tried with a bear, but it was too aggressive. Finally Von Osten bought a Russian-bred Arabian horse, paying little money because of a small physical defect, and it turned out to be an extraordinary animal.

The horse, called Hans, amazed Germany and the other European countries, quickly becoming an attraction and earning the appellative of "Clever Hans". It was apparently able to sum, subtract, multiply, divide, calculate fractions, beat time, follow the calendar, change musical keys, as well as read and understand German. Hans answered pointing out or beating on a plank with its hoof – for instance, to the question "How much is 2 + 2?", it answered by tapping its hoof four times.

On 11 and 12 September 1904, a commission of psychologists, zoologists, veterinarians, physiologists and teachers were asked to evaluate Hans's cognitive skills, because the German Ministry of Education wanted to clarify the nature of Hans's answers which were 90% correct. The commission declared that the intelligence and skills of the horse were real because it answered without using any trick.

The commission, at this point, passed on the evaluation to psychologist Oskar Pfungst, who submitted the horse to numerous tests. In particular, he envisaged a double blind trial, where a person told Hans a number and the horse had to repeat it to another person who did not know it – in this case the percentage of correct answers fell appreciably. So Pfungst inferred that the horse responded to involuntary cues that people give if they know the answer. In order to prove this, he submitted himself to the same tests, trying to guess a solution thought up by human subjects by observing them while he was beating his fist on a table. Pfungst concluded that the horse did not have a sense for mathematics, but an ability to read the changes in the questioner's posture and facial expressions – such as movements of expectation when the number of hoof taps was approaching the correct answer, and a release of tension when the horse made the final tap. But Pfungst never explained how the horse was also able to correct the eventual mistakes made by the questioners.

Von Osten never accepted Pfungst's conclusions, claiming that the psychologist had transformed Hans into a circus horse, trained to respond to gestures (and indeed, after these experiments, Hans had started to move its head counting every movement of the questioners). Accusing Pfungst to have deceived him, Von Osten angrily sold Hans to his friend Karl Krall, a rich jewellery manufacturer form the city of Elberfeld.

Krall continued to train Hans, as Von Osten had done before; in addition, he acquired several other horses which he also set out to educate, and which became known as the "Clever horses of Elberfeld". One of them specialised in arithmetic (it tapped one hoof for units and the other for tens). Wanting to disprove Pfgunst's theory, Krall also made his horses answer the questions blindfolded, with no detrimental effect on their performances.

No one ever doubted Krall's good faith – even his worst detractors recognized his intellectual honesty, which was proved by the fact that he never asked for money, having means of his own, and that he did not like to exhibit his "class of quadrupeds", as he used to say.

Like every class of children, among his horses some were more careless (they sometimes inverted the figures, 42 became 24, but they corrected themselves when rebuked), and others more careful. Curiously, a little Shetland pony would tap the result of the calculation, then if it turned towards the reward but did not receive it, it would repeat the calculation correcting it. There was even a blind horse, Berto, which was able to solve some simple mathematical problems, possibly reading other non-visual signals.

In 1912, William Mckenzie, a biologist and psychologist, and Roberto Assaggioli, a Venetian psychiatrist, travelled to Elberfeld to verify the horses' skills. Having spent some time watching the animals and not having found any explanation, they had to concede that Krall had succeeded in developing the animals' cognitive abilities.

By this time, Pfungst's explanations were considered insufficient to explain the performance of the horses of Elberfeld. Numerous other intellectuals tested the horses, among them the 1911 Nobel prize for Literature, the Belgian playwright Maurice Maeterlinck. They usually concluded that Krall had managed to "humanise the horses' brain". World War I put an end to those studies, but a lot of people kept on believing in the validity of Krall's methods.

6. Conclusion. These facts are of difficult interpretation. Despite the obvious problems in reconstructing the events, also because of lack of sources, nevertheless we can put forward some general hypotheses on the development of language and cognition in animals.

6.1. Genetic and evolutionary hypothesis. Numerous experiments have proved that animals possess a genetic sense for numbers, a mathematical instinct through which they understand the difference between small and large quantities.

A well-known 17th-century story tells of a crow which could count up to five.

"A farmer wanted to kill a crow which had made its nest in the watchtower of his estate. But when he came near the tower, the bird flew away, far from the range of his gun. Then when the farmer went away it came back to the tower.

So the farmer asked a neighbour for help. The two men entered the tower, and only one went out, but they didn't deceive the crow which came back to its nest only when the second farmer had gone out. So three men entered, then four and afterwards five without succeeding in their aim. Every time the crow waited for all the farmers to go out before coming back to its nest.

Eventually, six men entered the tower; the crow waited until five men had gone out, then it came back to the tower and the sixth farmer killed it".

This story shows the crow could count up to five (but no more than five) in an innate way.

Otto Koehler, a well-known German ethologist working in the first half of the 20th century, was one of the earliest experts on the mathematical skills of animals. A crow, called Jacob, was the protagonist of one of his most famous experiments.

The bird was put in front of several boxes which had different numbers of dots painted on the lids. It was rewarded when it opened the box with a number of dots on the lid equal to those drawn on a piece of cardboard which had been previously shown to it. Koehler found that Jacob was able to count till six, one more than the "crow of the tower", possibly because of evolution. Interestingly, the dots on the lids were different in shape and disposition compared to the ones on the cardboard. Koehler proved birds are able to compare two ensembles and to remember a number of objects shown in different times.

Stanislas Dehaene, a mathematician specialised in cognitive psychology who studied numbers and mathematical representations, stated: "Our brain, as the one of the crow, has been provided with a intuitive representation of quantities since time immemorial". According to Deheane, animals are able to count even if in a different way from men, in more approximate and "faint" way.

The theory that a "sense of numbers" is innate in animals seems to be proved by the observations of ethologists who have demonstrated that squirrels go straight to the tree branch with the largest number of acorns, showing they are able to distinguish between different number quantities. Also, in a herd of wild horses, the herd leader always notices if a member of the group is absent, that is notices the variation in quantity, and looks for the stray animal. So it is not surprising if some clever horses were able to answer simple questions like: "How many hats are there in a hall?" or "How many hearts are drawn on that piece of paper?"

6.2. Behavioural (adaptive) hypothesis. We can also hypothesise that the horses had learnt to give answers in order to obtain a reward, since the trainers, both Krall and Von Osten, did not punish their mistakes but only rewarded the correct answers. Recent studies by Bino Gentili's team at the Imprinting Horse Center near Rome have shown that the cortical areas of a horse's brain are separated and scarcely communicate with each other, a quality present in all herbivores. That means that the vision of an image can only happen, alternately, from the right or the left eye. The separation of the cortical areas also influences behaviour: in fact, being herbivorous, a horse is naturally a prey, and does not possess the ability to develop strategies in order to obtain food (as, for instance, in a cat). While a carnivore is compelled to hunt, for a herbivore it is enough to graze. It is possible, then, that Hans and the Elberfeld horses could have learnt they obtained carrots, walks and delicacies when they gave some answers.

Moreover, Miklósi and Soproni's studies (2006) proved that horses answer to signals made by people they know. If a familiar person points out food to them, they will eat peacefully; if there is a new person, they will be suspicious and eat less. So the fact that the "horses of Elberfeld", almost always performed in the presence of their owner and in familiar places, with familiar objects, seems to support this hypothesis.

In Gentili's opinion, the particular brain structure of horses leads them to have a very high capacity for memorisation, allowing them to remember very long series of simple cause-effect associations in a way that is unthinkable for the human brain. This could explain their more or less correct answers to very complex computations: a simple training of the extraordinary equine memory.

A horse, indeed, more than other animals, knows its environment by memory, as a kind of map: a new element entering its field of view is compared with this internal map, then the animal deduces if the new element is dangerous or not. In short, horses live in the past, comparing it with the present.

6.3. Cognitive hypothesis. If horses had really learnt what they had been taught, developing a "human-like" thought, as defined by Maeterlink, then it would have been a case of cognitive learning.

This hypothesis could be confirmed by the findings of Irene Pepperberg of Brandeis University, in

Massachussets, who for 27 years studied an African gray parrot named Alex. The bird had developed the ability to associate a large number of words and concepts, was able to count, knew materials and, more surprisingly, used correctly the concept of zero, which children only acquire at age 3 or 4, when they begin to use the pronoun "none" in absence of a quantity to count. This result had been obtained by encouraging a sense of competition in the parrot: Pepperberg asked simple numerical questions which her researchers answered correctly, receiving a reward of biscuits and almonds. Alex quickly understood that he had to attempt an answer to obtain his prize; also, he was taught to understand the link between words and actions, so when he was tired, he usually said he wanted to go back to the cage and was immediately taken there.

There is the possibility that, through a similar trick, the "clever horses" had learnt, in a rudimentary way, the link between words and reality.

6.4. Perceptive hypothesis. We cannot neglect the hypothesis that horses, in the absence of language, have developed a different set of senses from humans, which allow them to "sense" special frames of mind or situations, so they know how to behave.

Ethologists have listed several situations which can only be explained by the existence of a particular sensibility in animals: some very rowdy horses are inclined to scare those who are afraid of them, as if they could feel their fear; at the end of a working day, they hurry up, because they know they are coming back home; if they are affectionate to their owner and he (or she) cannot lift their working collar, they can wear it by themselves, making it slide from the snout to the neck.

Rupert Sheldrake, an English biologist and philosopher, suggests that animals possess a sixth sense which has not yet been explained by science. Hundreds of accounts have indeed been reported on their special sensibility, which leads them to be nervous the day before a veterinarian visit, or to understand, hours ahead of time, when their owner is coming home. Without knowing, they are able to "sense" events, in the same way as dogs are able to "sense" a forthcoming earthquake.

6.5.Mixed hypothesis. Finally, we must emphasise that one hypothesis does not exclude the others. The cognitive science of animals would do well to consider the association or interaction of all the previous hypotheses.

These theories highlight how difficult it is to establish accurate rules on the communication of humans and animals, which is so different because of evolution.

Yet at the same time, they show that the neuronal functions governing the communication of animals could easily be investigated by neuroscience.

[1] According to Paul MacLean's model of the evolution of the vertebrate brain (MacLean 1990), the animal brain developed in three phases: the oldest part, the reptilian brain, rules instincts and self-conservation; the second part, the limbic system or paleomammalian brain, developed in order to manage life in a community; finally the neo-cortex or neomammalian brain, typical of humans, is the intelligence created by encephalisation, i.e. the widening of the encephalon caused by a growth in brain dimensions due to evolution.

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