Evolution of musical perception and language

SARA INVITTO
RESEARCHER IN GENERAL PSYCHOLOGY

LABORATORY OF HUMAN ANATOMY
AND NEUROSCIENCE
DEPARTMENT OF BIOLOGICAL AND ENVIRONMENTAL SCIENCES AND TECHNOLOGIES
UNIVERSITY OF SALENTO
Music is solidificated geometry. Pitagora

The universe was considered silent until the man has built a receptor capable of transforming radio frequencies in sound frequencies. NASA today transduced the radio emissions of some stars in the sound frequencies which have a sound similar to the songs of some birds.
Music like protolanguage

- We can consider the analysis of the music/sound perception as a precursor to the language and as a protolanguage, which later evolved in a human brain structure with syntactic rules, similar to the spatial and temporal language, but without semantic connotations.
Neuroarchaeology (Malafouris, 2010) examines the concept of metaplasticity to describe the relationship between neural plasticity and cultural changes. This model predicts a linear correlation between genetic patterns, physiology and behavior that underlie the development and evolution of the species.

According to Robert Zatorre (2001, 2005), in the light of the most recent surveys by neuroimaging, the music seems structurally associated with key neuronal functions delegated to the survival of the individual and the species, which are nutrition and sexuality. So it's a skill potentially present in every human being.

We can start from an analysis of biological genes involved in communicative functions. The genes involved in language are the Fox P2 (gene implicated in fertility) and genes NL3 and NL4 (also implicated in autistic syndromes). The impairment of the gene Fox P2 leads to a reduction of the vocal behavior and, in some cases, the premature death. The impairment of NL3 and NL4 in mice decreases social behavior and vocalizations (Fischer and Hammerschmidt, 2011). This implies a strong genetic correlation between vocalization skills, socialization and reproductive capacity. Mediated by RNA interference, which reduces the levels of Fox P2 in brain regions, producing songs with irregular forms.
Vocalization Pathway

- From the point of view of the neuronal pathway of vocalization involves a number of different subsystems, both in birdsong and that in terrestrial mammals, contributing, at different levels and degrees of vocalizations and, in humans, the structural properties of language. Jurgens (Jurgens, 2009) speaks of two pathways control of vocalization: one in the cingulate cortex to the acueductal midbrain, the other in the reticular formation that sends input to the bridge, and motor neurons in the brainstem phonyatory.

The role of the basal ganglia in the control of motor has been studied by Gazzaniga (2004). The dopaminergic pathways, involving the basal ganglia, are fundamental in birds, for learning various forms of hand (Hara, 2007; Jarvis 2004; Haesler et al., 2004).

In a subsequent step of an evolutionary analysis of a phylogenetically ancient species of mammals, i.e., euteri, you can see how the calls of pups unleashing behaviors related to amygdala responses (this also happens even in the species homo). Some references, the ultrasonic vocalizations (UVS) of mice pups (descended from one of the first species of euteri, species appeared about 125 million years ago), singly or in hypothermia, trigger maternal behavior research (Fischer & Hammerschmidt, 2011).

Perceptual Evo

- Into a perceptual level and discriminative instead, we have categories of fish, such as the goldfish (the common goldfish), who can learn to discriminate the sounds, in particular, through a conditioning task (Chase, 2001), discriminate baroque music from blues music. This suggests that there are mechanisms involved in the perception of music with a date that appears with the first vertebrates (500 million years ago).

In the work of Tecumseh Fitch (2006), is analyzed from the evolutionary point of view, the percept music (production and perception) from an interdisciplinary perspective. The study of Tecumseh Fitch is related to the analysis of Tinbergen, according to which the response categories of the percept can be analyzed in four levels: mechanistic, developmental, phylogenetic and functional.

• mechanistic-analysis: some animals sing because they have a complex vocal organ and neural circuits associated with the song that are activated by high hormone levels.

• Analysis of evolution: the song would emerge in an environment full of singing conspecifics, learned.

• Phylogenetic analysis: the class of Aves has a larynx, a structure that makes us think that is the only vocal organ found at the beginning of the evolution of this taxonomic class.

• Functional analysis: the song was born as a reinforcing element of attraction for reproductive and territorial defense.
Exaptation and hearing

- Functions, in a evolutionary level, are constantly changing. This is due to a phenomenon called exaptation (Gould, 1991). Three examples are particularly relevant to the music: the middle ear bones of mammals, who were born to a support function of the jaw, and not for auditory function, cartilage of the larynx of vertebrates, which originated as support function of the gills and not for a sound function and the lungs, which are homologues of the swim bladder of fish, a system of control of the direction and orientation, and that instead in tetrapods are used in the breath and in the vocalization.
Jin Meng, Yuanqing Wang and Chuankui Li (2011) have described the discovery of a complete fossil mammal from the Mesozoic found in China recently: complete enough to present some of the characteristics of transition between the ear of reptiles and that of mammals; features that bridge the gap fossil evolution of the middle ear of mammals.

Among the animals that emit sound complex vocalizations are many marine mammals (Payne, McVay, 1971), amphibians, fish, and insects (Alcock, 2005).

The 'songs' animal vocalizations can define simple or complex innate and learned. This definition of singing (based on ethological issues) may coincide almost entirely with that of humans, with the exception that this is separate from speech.
The use of instruments (including percussion of body parts) to produce a sound is universal in the human species and common in primates. The African great apes (chimpanzees and gorillas) use hit with objects parts of the body, trees or other objects, as a sign of socialization, fight and play (Arcadi, Robert and Mugurusi, 2004; Schaller, 1963). The Bimanual Drumming in African great apes, may indicate a strong homology for what concerns the use of musical instruments in humans.
Another category of primate that uses drumming is that of macaques. In a study of Remedios (2009) it is estimated that, in these animals, the sounds activate the temporal cortex. Observing social groups of macaques, we have studied how these animals use objects to produce salient periodic sounds, similar to musical gestures.
The fMRI showed that, in both levels of sound perception is active in both the auditory cortex caudal to the amygdala. Behavioral responses to drumming and vocal sounds, and their neural representation, suggest a common origin of voice and non-voice communications and support the notion of gestural origin of speech and music.
The archaeological human, regarding the use of the first musical instruments, are luckier data on prehistoric anatomy, because the tools built into bone, it was possible to maintain over time. These instruments, especially flutes, date back to about 36,000 years ago (Cross 2003; D'Errico et al., 2003). The oldest flute found in good condition, dating to about 36,800 years ago and has been built with a bone of the wings of a swan. It has 3 holes at a distance of 3-4 cm of space (Fitch, 2000).
It was also found a probable flute (a hollow bone with two holes) dating back to Neanderthal (40,000 years ago). The bone analyzed by radiocarbon, dates back to 43,100 years ago (Kunej & Turk, 2000). The discovery was made in a cave in Slovenia, along with other tools also dating Neanderthal age.

So you might be traced back to the beginning of the music production Neanderthal period (Krings et al, 1997).
Darwin suggested that a primitive system of sound communication-like singing has been a precursor of human language, which was adaptive for human progenitors, and that the music system today exists as a kind of behavioral fossil of this system past.
In a recent work of Snowdon were inserted vocalizations of Tamarin monkeys in some songs. He then compared the behavioral response of monkeys to humans and excerpts of songs composed for the monkeys. The monkeys responded with an increase or decrease arousal to music composed in tones and frequencies of Tamarin. So the affective components in human music may have evolutionary origins in the structure of non-human calls. In addition, the signals animals could be evolved to manage the behavior from the influence of the affective state conditioned by sounds.
Musical /sound perception

- The musical/sound perception actually exists as a precursor language, both at the genetic level, at the level biological and behavioral. How protolanguage social, essential for reproduction, for the management of dominance in groups and affective communication, then it has evolved in a human brain structure with syntactic rules / mathematical, spatial and temporal own linguistic communication. The sound prosodic recognized in the earliest stages of development, which is phylogenetically ontogenetically (even prenatally, there is a recognition melodic / prosodic).
The communicative function of music also affects metacognition as active processes also fundamentally subcortical necessarily driving through a top-down process, the perceptual processing. Its origin comes necessarily in parallel with the birth of the first receptor system capable of transducing the frequencies in perception and thus comes together with the evolution of the living
The first receptor system has been evolutionarily complete was the haptic system, which then originated the photoreceptors. You could also assume, given the presence of drumming in primates and dates vibrational frequencies of music, one of the first receptor channels of music perception has been that haptic, which still has Crossmodal responses during the musical listening (Zatorre 2011).
Then... Language

- Language is one of most important human social behavior.
- It is found in all human societies, probably due to a cerebral organization specializing
- To acquire it you do not need special training, despite its complexity
- Input: the auditory system and visual output: motor system
- Primates do not learn to talk even if raised as a child and/or undergo specific training.
- Only learn a few words. Morphology and position of the larynx are not suitable for producing the sounds of humans, anatomophisiology is different and simpler.
- Some monkeys have learned the rudiments of the language of gestures, more understanding and in production. The spontaneous production of language seems to be the most insurmountable problem for them. As with other functions, in particular, it seems difficult for them to do if these actions do not lead directly to a tangible reward.
Language and Thought

- Language necessary is a performing of thought? Some monkeys perform abstract reasoning without appropriate language. Many people say that the best insights have been designed without words. Einstein's theory of relativity - from mental image of him astride a beam of light looking at a clock (Brancucci A., 2011)

If you can’t explain it simply, you don’t understand it well enough.
– Albert Einstein
The Wada test, named after Canadian neurologist and epileptologist Juhn Atsushi Wada, also known as the "intracarotid sodium amobarbital procedure" (ISAP), is used to establish cerebral language and memory representation of each hemisphere.
The test is conducted with the patient awake. Essentially, a barbiturate (which is usually sodium amobarbital) is introduced into one of the internal carotid arteries via a cannula or intra-arterial catheter from the femoral artery. The drug is injected into one hemisphere at a time. The effect is to shut down any language and/or memory function in that hemisphere in order to evaluate the other hemisphere ("half of the brain"). Then the patient is engaged in a series of language and memory related tests. The memory is evaluated by showing a series of items or pictures to the patient so that within a few minutes as soon as the effect of the medication is dissipated, the ability to recall can be tested.

J. Wada (1949)

There is currently great variability in the processes used to administer the test, and so it is difficult to compare results from one patient to the other.
Speech and language

- Speech is the vocalized form of human communication. It is based upon the syntactic combination of lexicals and names that are drawn from very large (usually about 10,000 different words) vocabularies. Each spoken word is created out of the phonetic combination of a limited set of vowel and consonant speech sound units. These vocabularies, the syntax which structures them, and their set of speech sound units differ, creating the existence of many thousands of different types of mutually unintelligible human languages. Most human speakers (polyglots) are able to communicate in two or more of them (Tucker, 1999)
There are a lot of evidence on the abilities of prelinguistic infants to perceive speech. Young infant have a highly developed and sophisticated system for the perception of speech. In addition to being able to discriminate fine differences in the speech signal, they are able to form a categorical representation of speech and the multiplicity of cue that signal a single phonetic contrast (Eimas et al., 1983).
A consideration of the infant data in conjunction with findings from adult listeners tested with a variety of experimental procedure leads to the hypothesis that the processing of speech in infants (and adults) is performed on a nonsegmented, continuous speech signal and the categorical representations resulting from this processing have a syllabic structure. For the prelinguistic infant, this syllabic structures are modified by linguistic experience, however, and come to reflect the syllabic structures of the parental language and to provide a basis for the construction of phonological and lexical system.

To better understand how infants process complex auditory input, this study investigated whether 11-month-old infants perceive the pitch (melodic) or the phonetic (lyric) components within songs as more salient, and whether melody facilitates phonetic recognition.

Using a preferential looking paradigm, uni-dimensional and multi-dimensional songs were tested; either the pitch or syllable order of the stimuli varied. As a group, infants detected a change in pitch order in a 4-note sequence when the syllables were redundant.
(experiment 1), but did not detect the identical pitch change with variegated syllables (experiment 2). Infants were better able to detect a change in syllable order in a sung sequence (experiment 1) than the identical syllable change in a spoken sequence (experiment 1).
These results suggest that by 11 months, infants cannot “ignore” phonetic information in the context of perceptually salient pitch variation.

Moreover, the increased phonetic recognition in song contexts mirrors findings that demonstrate advantages of infant-directed speech. Findings are discussed in terms of how stimulus complexity interacts with the perception of sung speech in infancy.

Native sounds: ERP in Infant

- Brain electrophysiological responses from 10- to 13-month-old Mexican infants while listening to native and foreign CV-syllable contrasts differing in Voice Onset Time (VOT). All infants showed normal auditory event-related potential (ERP) components. Our analyses showed ERP evidence that Mexican infants are capable of discriminating their native sounds as well as the acoustically salient (aspiration) foreign contrast.
The study showed that experience with native language influences VOT perception in Spanish learning infants. The acoustic salience of aspiration is perceived by both Spanish and English learning infants, but exposure provides additional phonetic status to this native-language feature for English learning infants.
It is now known that neural localization for language is very much a relative, rather than an all-or-nothing matter (Dronkers et al. 2000, Dick et al. 2001, Martin 2003). Not only is language processing widely distributed over the brain, but traditionally language-specific areas of cortex are implicated in a variety of non-linguistic tasks as well.

Broca's area, for instance, ‘lights up’ on MEG scans (magnetoencephalography, a method for measuring changes in the magnetic properties of the brain due to electrical activity) when subjects hear a discordant musical sequence in much the same way as it does when they hear an ungrammatical utterance. (Maess et al. 2001; a special issue of Nature Neuroscience, 6(7), July 2003, explores the implications of this finding.)

cortical activation while the subject thinks the verbs

- PET neuroimaging is based on an assumption that areas of high radioactivity are associated with brain activity. What is actually measured indirectly is the flow of blood to different parts of the brain, which is, in general, believed to be correlated, and has been measured using the tracer oxygen-15. In the Fig. on the right you can see the cortical activation during a task while a subject think verbs which describe the nouns presented by the experimenter.
Egyptians reported speech loss after blow to head 3000 years ago.

Broca (1861) finds damage to left inferior frontal region (Broca’s area) of a language impaired patient, in postmortem analysis.

In language disorders:

- 90-95% of cases, damage is to the left hemisphere.
- 5-10% of cases, to the right hemisphere.
Damage to the language network near the left frontal area of the brain usually results in Broca aphasia, which is also called nonfluent aphasia. People with this disorder struggle to get words out, speak in very short sentences and leave out words. A person might say "Want food" or "Walk park today." Although the sentences aren't complete, a listener can usually understand the meaning. A person with Broca aphasia may comprehend what other people say to some degree. People with this type of aphasia are often aware of their own difficulty in communicating and may get frustrated with these limitations. Additionally, people with Broca aphasia may also have right-sided paralysis or weakness.
Wernicke aphasia is the result of damage to the language network in the middle left side of the brain. It's often called fluent aphasia. People with this form of aphasia may speak fluently in long, complex sentences that don't make sense or include unrecognizable, incorrect or unnecessary words. They usually don't comprehend spoken language well and often don't realize that others can't understand what they're saying.
Three overt naming fMRIs in a chronic nonfluent aphasia patient treated with 1 Hz rTMS to suppress R posterior Pars Triangularis: pre-rTMS (9 Yr. poststroke), and at 3 and 16 Mo. post-rTMS (11 Yr. poststroke).

Note increased L perilesional and L SMA activation (white arrow) on fMRI at 16 Mo. post-rTMS (best naming score, 58%).

Wernicke’s Aphasia

- Comprehension impaired
- Fluent speech
- Neologisms
- Speech appears to have no information content “fluent nonsense”
- empty speech (i.e. failure to convey ideas, while unaware of problem)
- Even simple sentences not well understood
- Associated with left temporal lobe damage
- Paraphasic (wrong word use in phrases)
- Logorrhea (excessive talking, reduced meaning)
- Severe reading and writing problems
- Musical production partially impaired (in musicians)
- Lesion of areas 22 and surrounding regions
Global aphasia and other syndromes

- Global aphasia results from extensive damage to the brain’s language networks. People with global aphasia have severe disabilities with expression and comprehension.

- Figure on the right: The pathways implicated in syndromes are shown in red with the causal lesion in yellow. Carl Wernicke is linked to both conduction aphasia and associative agnosia. Hugo Liepmann is linked to apraxia. Jules Déjérine is linked to pure alexia without agraphia. These images are overlaid on a contemporary 3-dimensional reconstruction of fibre connections between parietal and frontal lobes in the left hemisphere derived from a single brain from D. Catani and D. ffytche. The rises and falls of disconnection syndromes, pp 2224–2239 (in Brain, a journal of neurology, Oct 2005)
Geschwind Model

Motor words Comprehension

Speech motor output

Concepts

Arcuate Fasciculus

Auditory word Comprehension

Association Cortex

Posterior Temporal Cortex

Ventral prefrontal cortex

Auditory input
Geschwind Model: Wernicke’s Aphasia

Motor words Comprehension

Concepts

Auditory word Comprehension

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Concepts

Association Cortex

Posterior Temporal Cortex

Auditory word Comprehension

Arcuate Fasciculus

Speech motor output

Ventral prefrontal cortex

Motor word Comprehension

Auditory input
Geschwind Model: Conduction Aphasia

- Concepts
- Motor words Comprehension
- Auditory word Comprehension
- Ventral prefrontal cortex
- Association Cortex
- Posterior Temporal Cortex
- Arcuate Fasciculus
- Speech motor output
- Auditory input
A man who suffers from a local cerebral impairment that defect of language is to pronounce words wrong. .. No one argues that the assertion clinical impairment 'is the cause' of the defect of language. But strictly speaking, it is simply impossible that the impaired brain can produce any verbal expression wrong, because the brain does not compromise the brain
conclusions

- ... the expressions wrong place during the activities of non-impaired healthy ... but the positive manifestations are due indirectly, or rather allowed. Chritchley and Chritchley 1998

- Hughlings-Jackson: Language is a dynamic process that involves integrated function of the entire brain: Holistic view of brain function – Localization is impossible
conclusions

- Human language is an extremely complex structure that involves all levels: biological, genetic and behavioral.
- Many cortical areas are involved (even subcortical) all these structures are necessary to occur properly.
- Language (identifications and memorizations of semantic sounds) develops since the prenatal period (v.Tomatis, 1945)
- The language is unique and complex because it is the base of the relational and affective system.