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Animal behavior

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5th Borsellino College on Neurophysics, ICTP, Sept 2007 Trieste, Italy

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ANIMAL BEHAVIOUR I: SENSORY PERCEPTION

ANIMAL BEHAVIOUR II: COMPLEX COGNITION

SHORT PRACTICAL LAB: COMPARATIVE MORPHOLOGY AND NEUROANATOMY

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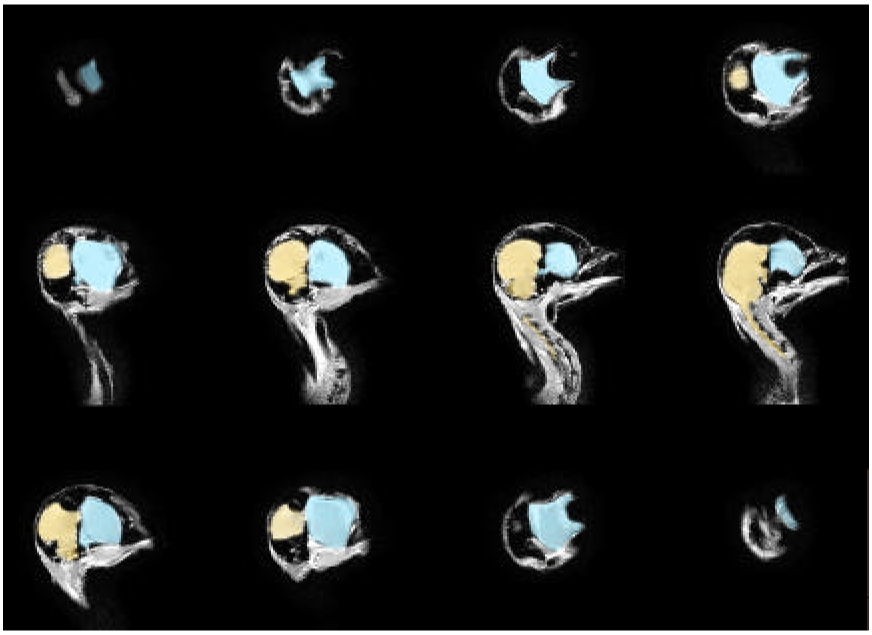

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ABSTRACT

The study of an other mind

1. Physical dimension: sensory perception (5 senses and exotic senses)
2. Simply behaviours
3. Abstract dimension: Complex cognitive behaviours

Mental representations, object discrimination, object permanence, concept of time, sense of number, teory of mind (empathy)

Jakob Von Uexküll –1934

the surrounding world or the environment of an animal
is not the same of its world as perceived and internalized

UMWELT – INNENWELT

Every animal species has its **peculiar perceptual world** that allows it to survive in its environmental niche.

•5 “classic” senses

•Exotic senses

•Sensory integration

Five senses

When we consider sensory perception, we naturally focus on the five “special” senses: vision, hearing, touch, taste, and smell.

It is through these senses that we experienced the world outside our bodies.

Many mammals species that have the “classic” five senses give them different priorities to acquire informations from the environment.

Humans visual mammals

•Humans are one of the few “visual” mammal species. All the other mammals use primarily the sense of smell, to acquire informations from the environment.

Birds as model for cognitive ethology and comparative psychology

Birds on the other hand represent a good model for cognitive ethology and comparative psychology because they are mainly “Visual” animals like human being.

Other senses

We are convinced that we see “what is really out there”.

However our perceptual windows are not as transparent as we think.

Many species of animals have senses that are not available in the common human perceptual world.

Biosonar in Bats and Dolphins, Bird Compasses, Pherormone communications, etc.

It is more difficult for the human beings fully understand these abilities because they don’t belong to our normal perceptual world.

The initial evidence for new sensory modalities came from behavioural experiments: from the observations of what the animals actually *do*.

Biosonar in Bats

It was a subject of scientific investigation since the 18th century although the fact that bats can avoid obstacles in complete darkness by using echoes of call they produce was not understood until the 1940s.

1794 Lazzaro Spallanzani, Italian Zoologist
1795 Baron Georges Cuvier – bats navigation was based on an elaborate sense of touch. His theory was presented without any supporting evidence. It was accepted for more than 100 years as scientific fact
1930-1940 Donald Griffin, undergraduate student at Harvard University proved finally that bats use the sense of hearing.

ECOLOCATION

Specialized type of acoustic communication in which an animal sends information to itself. It has arisen independently at least five times in mammalian history: microchiropteran bats, shrews, golden hamster, flying lemurs, marine mammals (Odontocetes).

What is like to be a bat? Thomas Nagel

It is impossible to reply but tecnology and cognitive etology can help us to built a clearer picture of their world and their brain, even if we will never ever be able to experience their "Innenwelt".

Furthermore, it is not only a story of sensory perception…

THE DOLPHIN'S SONAR TRANSMITTER

Dolphins have an extremely sensitive sound production and reception systems;

Larynx – just udible calls - Nasal cavity – biosonar transmitter

Impedence problem for the dolphin's sonar produced in the nasal cavity.

Why doesn't it bounce in the dolphin's head?

Dolphins have a unique structure called melon, a large saclike lens made of fat tissue.

THE DOLPHIN'S SONAR RECEIVER

The external ear is absent. The ear canal is not functional. However, like land mammals, inner ear contains the cochlea, but the middle and inner ears of dolphins are not located in the skull at all.

The internal auditory apparatus is encased in a separate bone called the bulla that is joined to the skull via cartilagineous and connective tissues. It is surrounded by "acoustic fat".

Dolphins receive sounds throught the jaw.

They are able to detect the direction of the sound underwater

The jaw is filled by "Acoustic fat".

SOUNDS

The sounds emitted for echolocation are generally very high frequency (110 kHz). The penetration of the sound waves is inversely proportional to frequency and dolphins modulate as necessary.

During normal swimming condition, low frequency sounds are emitted with a range of action of a few km. As soon as there is something that interest them

they increase the frequency and this reduce the range of the “vision” but allow the animal to acquire more details about the object.
Dolphins can detect the presence of a water filled steel ball 7.5 cm in diameter at distances up to 120 meters.

Underwater booms: bottlenose dolphins (*Tursiops truncatus*) are able to shoot their prey with an acustic bomb up to 230 decibel.

Sun compass, Star compass, Magnetic compass

During the day

To find the route using the sun you must know exactly what time is it.

During the night

Position of the stars

Magnetoreception

Polarity compass and inclination compass?

Orientation of the lines relative to the force of gravity

PHERORMONES

“SENSORY INTEGRATION AND THE UNIFIED PERCEPTUAL EVENT”

Cetaceans developed the ecolocation-biosonar ability sense that seems to be more functional for communication than the strategies used by primates.
Integration between different sensory systems (hearing learn from vision). And what about ecolocation?
The exotic systems serve as models of biological sensory systems more generally.
No data about the unification ot these different sensory modalities – the unified perceptual event.

ANIMAL BEHAVIOUR II: COMPLEX COGNITION

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Abstract

THE STUDY AN "OTHER MIND"

It is not just a question of perceptual abilities, i.e. which are the information that a species can obtain from the environment using its senses (more or less exotic).

I. Biological features of the species under study

II. Relationship between perceptual experiences and what is going on the world. It is a more abstract level of perception

The avian model for a comparative study of mind

What researchers think

•Small brains

•Different cortical architecture

•Complete optical decussation

•Visual animals

•Brainy animals

People still do not consider birds as intelligent animals and expressions such as “**bird brain**” or “**dodo**”, or “**dead as a dodo”** are common in numerous European languages.

The bad reputation of the avian brain could stem from the studies of **Ludwig Edinger** (1855-1918), one of the founders of the modern neuroanatomy. He thought that **brain evolution** was **progressive** and not **linear**, from fish to amphibians, to reptiles, to birds and mammals, to primates and finally to humans, ascending from lower to higher intelligence in a chronological series.

Modern birds have evolved a unique, homogeneous body plan. As a group birds show much less variation in size, body form, and weight that do mammals or reptiles.

Forelimb Specialized for flight

Centralized Body Mass

Higly developed Central Nervous System and Vision

Birds developed a sophisticated Central Nervous System necessary to control their bodies in the three-dimensional world they inhabit as flying animals.

The common opionion that birds' brain are simple and that **without a six-layered cortex**, birds could not be intelligent, persisted for many years throughout the 20th century.

The Avian Brain Nomenclature Consortium: the new understanding of avian brain organization

As in mammals, the adult avian pallium comprises about **75%** of the telencephalic volume. It processes information in a similar manner to the mammalian sensory and motor cortices. Bird brains are small simply to reduce the weight of the head. Small does not mean less functional or less intelligent but frequently people associate the small size with poor cognitive abilities.

Certain cognitive abilities which, until not long ago, were attributed only to a **few species of primates**, seem to be widespread not only in mammals but also in the **Class *Aves***.

The comparative studies of minds

Investigations of the **abstract dimension**, i.e. how animals puts together and organizes the experience to understand what is going on in the surrounding world: objects discriminations, object permanence, sense of time, sense of number, tools use

Detour behaviour: to keep in mind a disappeared object.
Mental representantions are essential in the every day life of animals. Where is my mum? Where is my food? Where is the lion? Different habitat, different abilities

An other good paradigm for studying the abstract dimension of the avian mind is given by a test originally used by developmental psychologists, the **problem of object permanence**.

Object permanence is the notion that temporarily not visible objects are separate entities that continue to exist even when they are out of sight of the observer (Piaget, 1952 and 1954).

THE OBJECT PERMANENCE IN EURASIAN JAYS

Scale 1 Uzgiris and Hunt (1975), tasks divided in five subgroups:

a. visual pursuit of slowly moving objects (Tasks 1 and 2);
b. search for simply hidden objects (Tasks 3-7);
c. search following more complex hiding (Task 8-9);
d. search following an invisible displacement (Task 10-13);
e. search following successive invisible displacement (Tasks 14-15).

Subjects: captive colony of **Eurasian Jays** (*Garrulus glandarius*)
Testing twice a week, individual isolation, avoid learning mechanisms

The Piagetian stages correlate partially with a specific group of tasks from Scale 1:

- **Piagetian Stage 2** (Tasks 1 and 2 of Scale 1);
- **Piagetian Stage 3** (Task 3 of Scale 1);
- **Piagetian Stage 4** (Task 4 of Scale 1);
- **Piagetian Stage 5** (Task 5-9 of Scale 1);
- **Piagetian Stage 6** (Task 10-15 of Scale 1).

PREDICTIONS

• **STAGE 4:** it should be expected in a **food-storing** bird because food storing requires that the bird remembers where food items have been hidden.••

STAGE 5: it should be expected. In fact the visible **hidings at different places** fit their food-storing behaviour. It would be adaptive to remember which caching sites contain food and which have already been visited and used.

• **STAGE 6:** it has been claimed to be associated with the presence of **sophisticated cognitive abilities**. Jays can re-cache acorns after several months; use their **vocal abilities** also in a **social context**, for example when they react to other jays' alarm calls, even when they cannot directly see the danger.

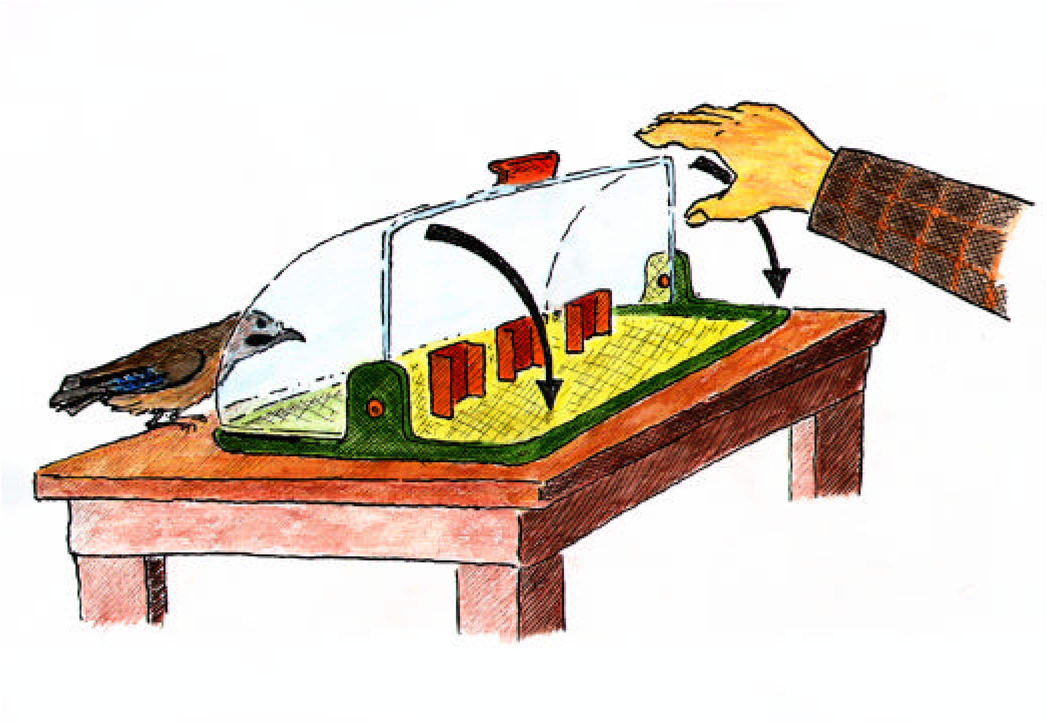
EXPERIMENTAL DESIGN

Experiment 1: the primary goal of experiment 1 was to verify whether four <u>older jays, 2-3 months old</u>, could achieve **piagetian stage 6 of object permanence**. Tasks were administered in a <u>fixed sequence</u>.

Experiment 2: the aim of this experiment was to investigate whether the full achievement of the **stage 6** in jays followed a fixed sequence. Tasks were administered randomly to five of very young jays and few control tasks, like task 16 and the "shell game" were added.

CRITERIA and TRIALS

Twice a week, jays were tested in individual and physical isolation from their cospecifics.A **trial** began when the jay approached the experimental setup on the table inside the aviary.Then the **object** (a mealworm - *Tenebrio molitor*) was hidden under the screens and any response made by the jay was scored.Jays had to respond to **9 trials** (1 session) with no more than **2 errors** to move to the successive task.To avoid the **learning mechanism** of searching where the hand last went, experimenters randomly touched other screens, or the experimental setup after hiding the mealworm.



Control Tasks (exp 2)

•**Task 16**: the experimenter repeat task 14 but hides an item less favoured (biscuit) than that the jay previously observed (mealworm).

•**Task S**: it is a variant of the "Shell game"it; the experimenter visibly hidden an object behind one screen and then screen is visibly exchanged of position with one of the other two screens.

RESULTS

• All jays tested in experiments 1 and 2 fully achieved piagetian stage 6 and no "A not B" errors were observed.

• Performance on visible displacement tasks was better than performance on invisible ones.

• The results of experiment 2 show that "neophobia" affected the response of jays in terms of achievement times; the older jays in experiment 1 took longer to pass all the tasks when compared with the younger, less neophobic, jays in experiment 2.

• Jays followed a fixed sequence of acquisition in experiment 2, even if tasks were administered randomly, with the exception of one subject.The results of these experiments support the idea that piagetian stages of cognitive development exist in avian species and that they progress through relatively fixed sequences.

MEANS-END TASK IN EURASIAN JAYS

contiguity (ON) - continuity (CONNECTED) test

•Features associated with the tools for solving a **means-end problem**

•Distinction between functionally relevant and irrelevant features of a problem

• Functional properties of tools

•Adapted to Jays from the work of Hauser et al. (1999) with cotton-top tamarins (*Saguinus oedipus*)

•ON (contiguity test) Choice between food located **on the surface** of a string of paper and food locate **close to** a string of paper.

•CONNECTED (continuity test) Choice between food located **on a single connected** piece of paper versus food located on a piece of paper that is **separated** from a **second piece** of paper by a horizontal gap of 1,5 cm.

EXPERIMENTAL DESIGN

•Task subministrated in a **plexiglass box**

•The front Plexiglas panel has **two openings** that provide Jays access to a **paper string** where the mean-end problem is set up.

•The tray is divided into two equal halves, setting up a **two alternatives choice** procedures.

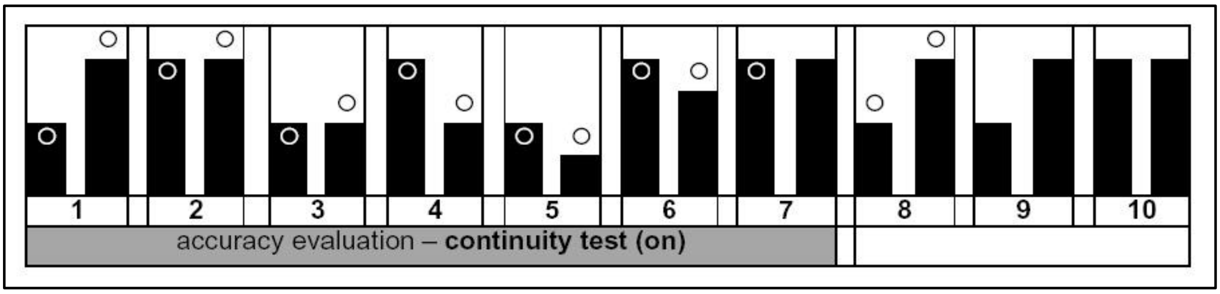
•On each side of the tray is a potentially **useful object** (means) and a potentially **piece of food** (end).

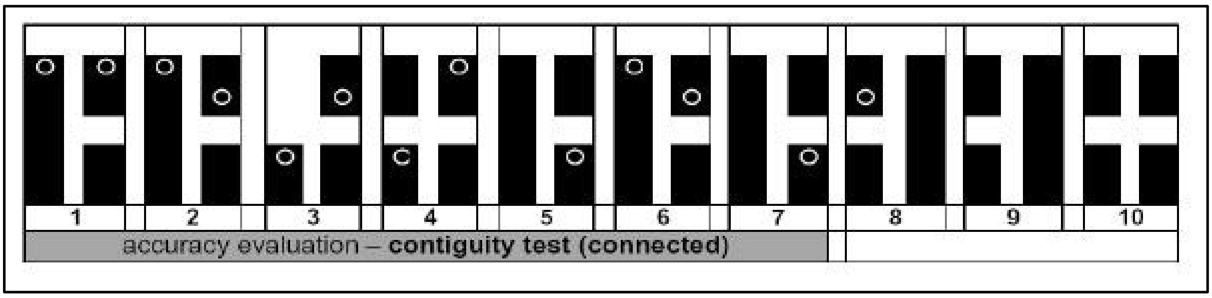
•<u>No preliminary training</u>

•**1-7**: 7 unique trials with only a single correct choice on each trial,

• **8**: 1 trial, the food is unattainable

• **9-10**: 2 trials only the strings without the food (evaluation of inhibition)





RESULTS

ON (contiguity)		Accuracy	
	Russell	Carlo	Taz
1st session	**79%**	**57%**	**79%**
3rd session	-	**61%**	**71%**
CONNECTED (continuity)		**Accuracy**	
1st session	-	**78,6%**	**78,6%**
3rd session	-	**83,3%**	**85,7%**

DISCUSSION

- Cognitive abilities are **widespread** among the **Class Aves** and are not confined only to a few avian "species", which are historically known to be "intelligent", such as parrot.

- These sophisticated cognitive proficiencies are carried out by the **nuclear pallial in birds** and the mammalian six-layered cortical architecture is not the only neuroarchitectural solution for the generation of complex cognitive behaviour.

- **Comparative studies** on corvids' and primates' cognition could set the basis for a better understanding of brain functions and mental evolution.

- The avian nuclear pallial architecture is a source of great surprises and question marks. Paradoxally, **pain stimulation** in birds activates the **nidopallium** (neurochemically and functionally similar to the mammalian prefrontal cortex) and not the amygdaloid complex (similar to the mammalian amygdala and partially to the limbic system (Murphy 2007).

- Is this a lack of avian neuroanatomical knowledge or this phenomena hide a different pathway for avian emotions?

Analogy, great risks but sometimes great results...

- mPET imaging of Hispaniolan parrots (*Amazona ventralis*) after experimentally inducted arthritic conditions (Murphy 2005 and 2007)

"**Bird brain**" should not be an insult any more than "**squirrel or dog brain**" is.