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LOOKING AT PLAY IN *OCTOPUS VULGARIS*

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ABSTRACT

Prior to the demonstration of play behavior in turtles and birds it was thought to be limited to mammals. To more effectively understand the context facilitating playful behavior and its subsequent evolution as a prominent, perhaps even critical, trait in animal life it is necessary to investigate it in different phyla. Aristoteles and Plinius were the first to describe a behavior that could be called exploration in octopuses. Octopuses' talents for manipulating objects have been studied in various learning experiments over the last several decades. However, it was not until 1999 that Mather and Anderson demonstrated object play in cephalopods.

The main purpose of this study was to set up definitions to characterize exploration and play behaviors in octopuses. We tested seven *Octopus vulgaris* in their reactions to two different objects. Each object was given to the octopuses for one hour a day for eight days in a row. Octopuses showed individual variation in their interaction with these objects ranging from ignoring them or making infrequent contacts with them to possessive behavior and playful interactions.

INTRODUCTION

Some of the earliest references to play in the western tradition are by Plato, who argued that play is the best possible teaching method. Plato claimed that play was the best way to learn and to do philosophy even for adults.

The idea that play is functional was rejected in the early 20th century by authors like Patrick (1916) or Schlosberg (1947), who asserted that play is "useless in the eye of the beholder". Attitudes towards play changed again in the later part of the 20th century when many authors (e.g. Fagan 1981, Smith 1982) began to once more regard play as a functional and motivated behavior (Einon 1983).

At this time play was seen to be a trait unique to mammals. Authors like MacLean (1985, 1990) claimed that play behavior is one of three "signature behaviors" separating mammals from other vertebrates. He also concluded that play behavior is linked to the development of the limbic system and therefore to mammalian brain development.

However, these views failed to take into account reports on avian play listed in Fagan (1981). In 1996 Burghardt and co-workers reported play behavior in a Nile soft-shelled turtle. This finding stretched the "phylogenetic boundaries" of play further. Three years later Burghardt (1999) reported studies on play behavior in fish, adding another non-mammalian vertebrate group to the list of playful animals. In the same year Mather and Anderson (1999) first reported play behavior in an invertebrate. The discovery of playful octopuses (*Octopus dofleini,* now: *Enteroctopus dofleini*) added a new facet to the dispute on the phylogenetic origin of play.

The theory that play is a trait exclusive to mammals or even vertebrates therefore faces serious challenge. In turn this opens up further questions: if play is not linked to the evolution of vertebrate cognitive systems how does this change our theories on this controversial topic?

Choosing *Octopus vulgaris* for research on exploratory and play behavior gives us the opportunity to add research on this behaviorally and neurophysiologically well studied animal (Hanlon & Messenger 1996, Wells 1978) to the debate on the origin of play. Testing the playfulness of this cephalopod will be the first step in a series of studies and experiments to take a non-mammalian perspective on functional development of play-behavior. Besides the wealth of ethological, physiological and morphological data, the lifestyle and learning capacities of *O. vulgaris* make this species a perfect subject for experiments on exploration and interaction with novel objects.

According to Fagan (1981) three different types of play are recognized by biologists:

1. Social rough-and-tumble play

This type of play constitutes a broad variety of interactions and behaviors of more or less social animals. Octopuses with their solitary lifestyle and opportunistic cannibalism cannot be expected to have this type of play.

2. Locomotor exercise

Perhaps the most familiar locomotor play is the gamboling of lambs or the leaps and kicks of young horses (Einon 1983). Octopuses might show this kind of play, however one of the difficulties in demonstrating locomotor play in cephalopods is their alien way of movement. We need more data on the basis of the movements of octopuses to look for variable aspects of this behavior.

3. Object play

The only agreed-upon characteristic of object play is that at least one object, one animal and one scientist are necessary to observe this behavior. The scope of object play is very wide, ranging from octopuses (Mather & Anderson 1999) to reptiles (Burghardt 1996) to mammals (for a review see Bekoff & Byers 1998) and humans (e.g. Einon 1983). This study will focus on the documentation of object play in *O. vulgaris*.

Hughes (1983) defined the transition from exploration to play as a series of behaviors leading from learning to manipulation of an object to play followed by more diverse exploration and/or habituation (Fig. 1).

We accept the view that object-play derives from exploration (Hughes 1983). But the major difficulty in

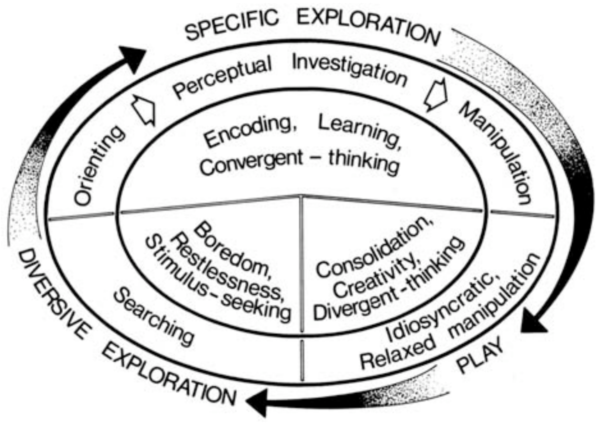

Fig. 1 The exploration-play cycle (Hughes 1983)

analyzing play behavior is that solid definitions of play are missing. This tends to be difficult even when we deal with animals seemingly familiar to us, as some mammals are. Things get worse when we watch eight arms attached to a sack-like body with two eyes. "I watch my dog and see that he or she is playing" has been for a long time the state of the art definition, even for scientists working on this topic. Mitchell (1990) said that "Play is the hobgoblin of animal behavior, mischievously tempting us to succeed in what, judging from the number of failed attempts, seems a futile task: defining play".

Burghardt (1999) formulated 5 criteria to formalize the research on play behavior. His criteria were the first to offer scientists working with different species of animals the opportunity to find a common terminology to compare their findings.

These criteria are central to our study, and we list them here in a shortened version:

1. Play behavior is incompletely functional in the context in which it is expressed.

2. This behavior is spontaneous and pleasurable ("done for its own sake").

3. Play differs from other behavior in being exaggerated or modified.

4. Play is repeatedly observed in a non stereotypic manner.

5. Play is observed in healthy subjects and in stress free condition.

Following these criteria the formulation of an octopus-specific definition, as well as a basic description of octopuses play behavior were the main issues of this study.

MATERIALS AND METHODS

Seven *Octopus vulgaris* were collected in the Mediterranean by the Statione Zoologica di Napoli (Naples, Italy). The octopuses were held individually in 1.0 x 0.6 x 0.5 m glass tanks at the Vivarium of the Konrad Lorenz Institute for Evolution and Cognition Research. The tanks were part of two closed circulation systems of 1700 l and 2700 l artificial sea water, with a turnover rate of 24 times per day. The tank water was filtered using protein-skimmers and biological filters. Additional aeration in each tank produced a weak current. Water temperature was kept at about 16°C in winter and 22°C in summer.

Animals were kept under a day-night cycle from 8 a.m. to 8 p.m. including a 30 min twilight phase at dawn and dusk. Illumination during the day was provided by artificial light (neon light bars with a daylight emission spectrum). As Dickel and co-workers (2000) showed that an enriched environment in cuttlefish has a positive effect on growth and learning tasks, the octopuses were provided a semi-natural environment. The tanks contained a sandy bottom, many small rocks and some large rocks with epigrowth, which provided building materials for dens and shelter. An escape-proof plexiglass lid was used to cover the tanks. The animals were fed live and dead shrimp, mussels, crabs and fish.

Two objects were used for this study. One was a 8.5 cm long opaque plastic bottle with a diameter of 3.5 cm. This bottle was positively buoyant and attached to a stone with a fishing line to keep it hovering about 10 cm above the bottom. The second object was a positively buoyant, smooth surfaced, red- and white-colored lego® block with rectangular dimensions of 11 x 5 x 7 cm. The same object was provided for 8 days in a row for 1 h each day, resulting in 8 h of film for each object/animal. Feeding took place right after each experimental session except for 4 animals, which had one additional test series 30 min after feeding to test the effect of satiation on play behavior.

All sessions took place between 4 p.m. and 9 p.m. and were recorded with a digital video camera (Sony DVX 1000). Each tank was shielded from visual inputs by a dark curtain (Fig. 2). Data were processed in the SPSS 10.0 computer program.

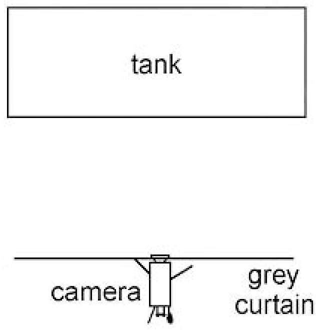

Fig. 2 Experimental set-up

RESULTS

All contacts between the octopuses and the objects were recorded and analyzed. We designated "levels" of play as differing from initial more predatory-style contact (see Fig. 3). The intensity of each behavioral mode is represented by 5 different levels (0 – 4). A level 0 contact was a behavior similar to that found when animals deal with food objects like clams or oysters. When octopuses encounter one of these bivalves they put their web over and around it and try to open it by pulling with their arms (Fig. 4a, b). This process takes 1-2 h usually but can last 24h or more (Nixon 1979) and usually results in opening and eating the bivalve (see Fig. 4a, b).

A level 1 contact was an exploratory interaction with the object where only one or several arms were used without bringing the object in contact with the mouth region. At level 2 a more diverse handling and or manipulating of the object was observed. At this point we distinguished between 3 different "modes" of exploratory and play-like interactions, which are depicted in three different branches in our graph (Fig. 3). At level 3 interactions of the animals started to appear very much like play as defined by Burghardt (1999). The last intensity level (4) is defined as play behavior because it conforms fully to Burghardt´s play criteria. These 3 modes of exploration and later play either became more intense in a sequence or animals changed from one mode of action to another.

The first mode of behavior at level 2 or higher was a simple unrepeated action where the animals pulled the objects closer or pushed them away. This behavior resembles to some extent a vertebrate playing with a ball or similar object. The behavior was categorized

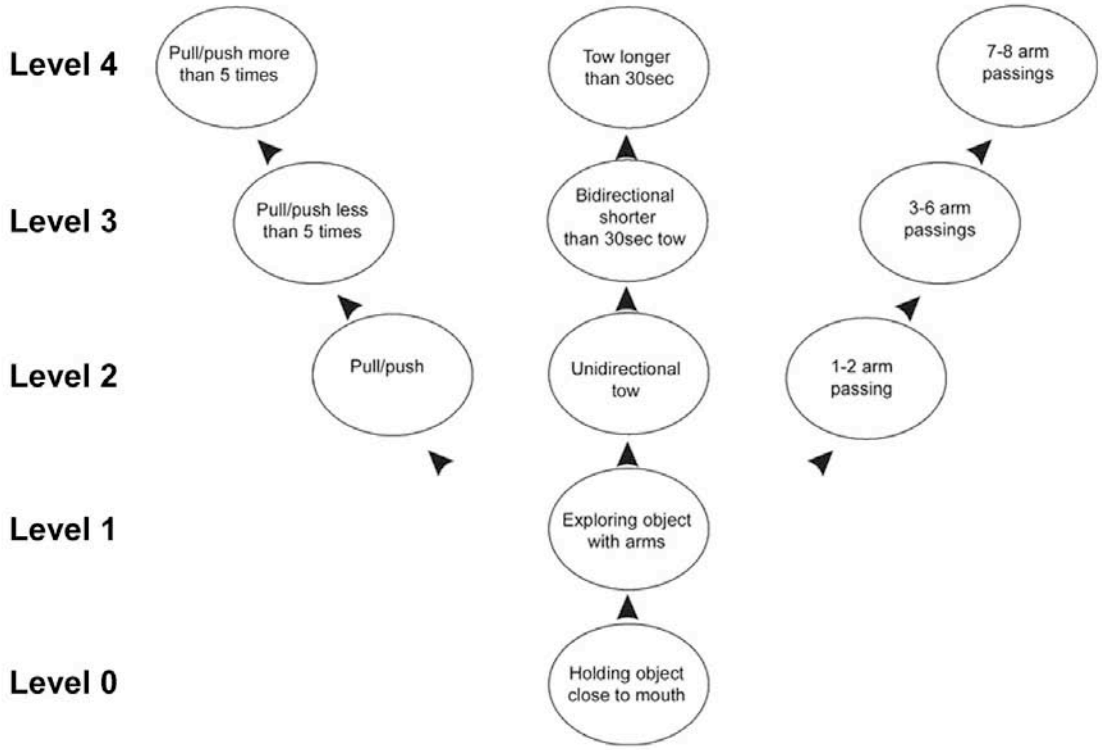

Fig. 3 Five levels and three different modes of exploration and play for *O. vulgaris*

Fig. 4a An octopus feeding on a clam by pulling apart the two halves of the shell

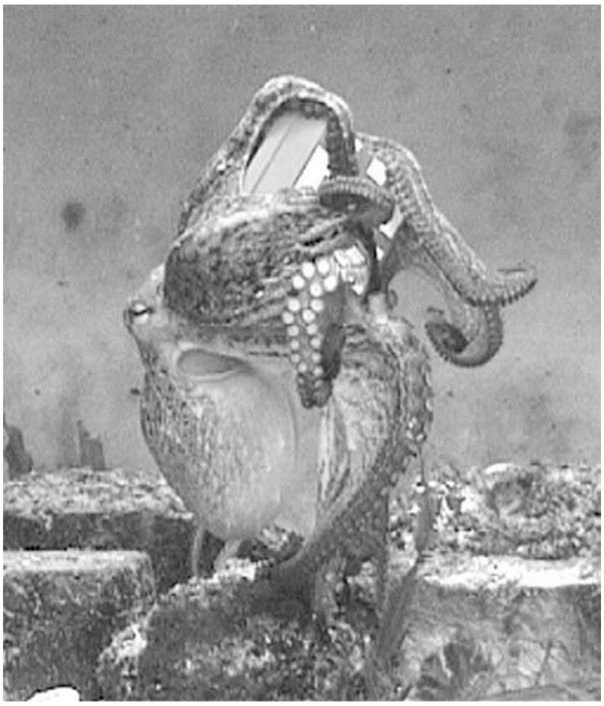

Fig. 4b An octopus interacting with the lego® block. The animal is pulling the positively buoyant object towards the bottom

one level higher if these push/pull actions were repeated in one coherent action. If this sequence was observed more than five times in a row this would be categorized as level 4.

The second mode was towing the objects. Animals held the object with one or more arms and then started to move. At level 2 this resulted in a short and unidirectional tow. Once the animal towed the object in more than one direction, we classified this as level 3. If such an action lasted longer than 30 sec and was multidirectional or in a circle we recorded it as level 4 interaction.

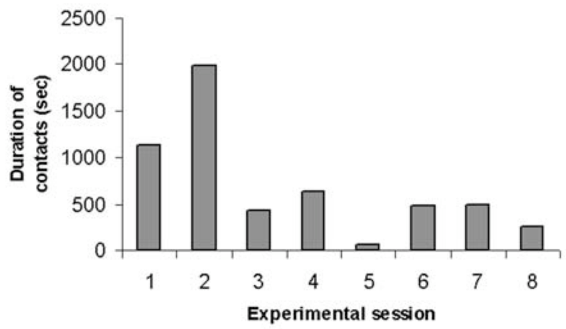

Fig. 5a Exemplary graph showing the duration of contacts with the lego® block for the octopus "Dorian" for each experimental session 1/2 h after feeding

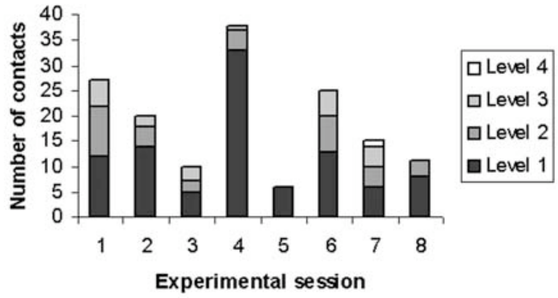

Fig. 5b Exemplary graph showing the number of different levels of interaction by "Dorian" for each experimental session 1/2 h after feeding

The third mode was passing the object from one arm to another. At level 2 the animal had only passed the object once or twice between different arms. If it continued this behavior for up to 6 arm passings we classed this as a level 3 interaction whereas 7 or more such actions where categorized as level 4.

During most observations, the first few hours (of the series of 8 h) had a high number of contacts of levels 0 -2 with the majority of contacts being of level 0 or 1 (level 0 & 1: 74 % of contacts). This was followed by a period of fewer contacts. After that, octopuses increased the number of contacts with the objects and the diversity of behaviors, the amount of level 0 or 1 contacts decreased (level 0 & 1: 64 % of contacts). Figs 5a, b show one series, after being fed, by an octopus called "Dorian". Most level 3 interactions and one level 4 interaction took place in experimental hours 6 and 7.

Interacting with the bottle on string with pull/push actions were by far the most common of level 2 or higher. Although 4 out of 7 animals had up to 4 repeated push/pull interactions, none went on to level 4. If they were not fed for 24 hours prior to the experiment, all animals often had level 0 contacts for extended time periods. In some cases, animals tried to tear apart the lego® block in the same way they try to open a bivalve.

We repeated the experiments with four animals who were fed 30 min before the experimental hours. Two of these 4 animals showed a significant difference in the way they handled the object. Total time of contacts was significantly longer if the animals did not receive food for 24 h (Wilcoxon U-test, $p > 0.001$, $u = 7890$, $w = 17343$). Yet the number of level 0 contacts was significantly higher if the animals were not feed for 24h prior to the experiment (Wilcoxon U-test, $p > 0.001$, $u = 4898$, $w = 16774$). The number of level 2 - 4 interactions was also higher after feeding for these two animals.

Beside exploratory and playful actions, another interesting behavior was found. Three of the seven animals showed possessive behavior. They tried to take or actually succeeded to take the positively buoyant bottle on string to their dens. These three animals had a lower diversity of interactions with the object than those just approaching and exploring the object. Two of the three animals that took the bottle on the string to their dens also tried to take possession of the smooth surfaced lego® block by dragging this big and positively buoyant object downwards closer to their dens. Although this action involved considerable effort for them, one animal tried to hold the object below the water surface for more than 40 min.

DISCUSSION

Why should octopuses play? Do they have the necessary requisites to show such a complex behavior? One of the best arguments in favor of a playful octopus is their ability to learn (for reviews see Mather 1995, Hanlon & Messenger 1996). Being able to learn during ontogeny is one of the key traits facilitating a behavior as complex and diverse as play behavior. Another very important point is the curiosity found in *O. vulgaris*. This behavior led to speculations about their intelligence ever since Aristotle first reported it. More recently, authors also demonstrated the existence of personalities in octopuses (Sinn *et al.* 2000, Mather & Anderson 1993) another indicator of complex behavior.

Coleoid cephalopods probably developed their cognitive abilities during competitive evolution with vertebrates as they had lost their protective shells (Packard 1972). Play could, therefore, be a by-product of a highly developed brain. Play would then be a common principle of cognitive evolution rather than some form of "intellectual nobility" as it was seen by many of the mammalocentric ethologists.

Although "full" play, according to our definitions (level 4), was only demonstrated once in these observations, the multitude of play-like interactions (level 3) found throughout the trials is promising evidence that *O. vulgaris* exhibits play behavior.

Our attempts to establish a more formal way to categorize exploration and play may provide a tool for further studies on this topic. The five different categories of interaction with an object that we described in this study are a comprehensive description of the most frequent behaviors displayed by our experimental subjects in contact with objects. The trend observed, that octopuses show more interaction in the beginning of the 8 days period, then decrease their interest considerably and in the end increase it again, follows the theories formulated by Hutt (1970). Hutt claimed that a child starts exploration of an object asking the question "What does this object do?" and later transforms it to the question "What can I do with this object?" which leads to play.

Two animals took possession of the bottle on string and took it to their dens. They also tried to do the same with the floating lego® block. Despite the difference of the two objects in shape, texture, visual contrast, and location (one close to the bottom, the other floating), the way the animals interacted with them remained the same. These animals showed less exploratory and play-like behavior than the others, as the possession of the object was the dominant action for them. Whether there is a conflict for octopuses between possessive behavior or play clearly is worthy of further investigations.

O. vulgaris play and play-like behavior differed considerably from that reported for *O. dofleini* (Mather & Anderson 1999). *O. vulgaris* is a very active (Meisel *et al.* 2003), curious and agile species, spending most of the time during the experiments wandering around. In contrast to this the nocturnal cold water species *O. dofleini* is less agile and interacts with the object when the object approaches it (see Anderson & Wood 2001). This difference in duration and mode of play between the two species is not surprising – different mammalian species also show different types and amounts of play (Pellis 1993). Such evidence reminds us of the tremendous scope that investigation of play behavior in cephalopods can have, now we have begun to look at it.

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