When Do Octopuses Play? Effects of Repeated Testing, Object Type, Age, and Food Deprivation on Object Play in *Octopus vulgaris*

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Studying play behavior in octopuses is an important step toward understanding the phylogenetic origins and function of play as well as the cognitive abilities of invertebrates. Fourteen *Octopus vulgaris* (7 subadults and 7 adults) were presented 2 Lego objects and 2 different food items on 7 consecutive days under 2 different levels of food deprivation. Nine subjects showed play-like behavior with the Lego objects. There was no significant difference in play-like behavior corresponding to food deprivation, age, and sex of the octopuses. The sequence of behaviors, from exploration to play-like behavior, had a significant influence on the establishment of play-like behavior, as it occurred mostly on Days 3–6 of the 7-day experiment. The pattern of development of play-like activities after a period of exploration and habituation in this study agrees with the hypothesis that object play follows object exploration. A homologous origin of this behavioral trait in vertebrates and invertebrates is highly unlikely, as the last common ancestor might not have had the cognitive capacity to possess this trait.

Keywords: octopus, play behavior, invertebrates, cognition

The discovery of playful octopuses (Kuba, Meisel, Byrne, Griebel, & Mather, 2003; Mather & Anderson, 1999) added a new momentum to the discussion on the phylogenetic origin of play behavior, which until recently has typically been considered to be limited to mammals and perhaps birds. (Burghardt, 1984; Fagen, 1981; MacLean, 1985, 1990). Learning more about play in octopuses is an important step in understanding the different evolutionary origins of play behavior.

One of the main problems facing quantitative study of play behavior has been the lack of solid definitions. In his recent book Burghardt (2005) formulated five criteria to formalize the research on this behavior. His criteria (here presented in a shortened version) offer scientists working with different species of animals the opportunity to find a common measure by which to compare their findings. The first criterion is that play behavior is incompletely functional in the context in which it is expressed. The second criterion states that play behavior is spontaneous and voluntarily (done for its own sake). To meet the third criterion, play has to differ from other behavior in being exaggerated, being modified, or occurring precociously. The fourth criterion says that play behavior occurs repeatedly but is not stereotypic. The fifth criterion for play is that it has to be observed in healthy subjects and initiated in stress-free condition. However, there are exceptions to this criterion, as play might either cause stress or danger and can also reduce stress levels.

On the basis of the sequence of behaviors preceding object-play in children, several authors (Burghardt, 1984; Hughes, 1983; Hutt, 1966; Power, 2000) have suggested that there is a transition from exploration to play. The series begins with behaviors focused on learning to manipulate an object, succeeded by more diverse exploration and/or habituation and culminating with play. Hutt (1966, 1970) was the first to state that a child starts exploration of an object asking the question, "What is this object?" and later transforms to the question, "What can I do with this object?" which leads to play. We want to identify this transition between exploration and play in octopuses, which we do using Burghardt's (2005) criteria.

Hall (1998) pointed out the similarities between object play and predatory behavior and hunger is seen by some authors to be one of the key factors for intrinsically motivated exploration (cf. Hall, 1998). For the connection of predatory motivated behavior and object play to be investigated, it is important for the motivation of animals to engage with food or inanimate objects to be manipulated. Much research has been directed toward the general energetic demands of play and how the amount of available energy is crucial for the establishment of play behavior (for a review, see Burghardt, 2005). However, there are few studies on the immediate effect of hunger on play behavior, although see research on juvenile and adult cats (Hall & Bradshaw, 1998; Hall, Bradshaw, & Robinson, 2002). In general, cats were shown to exhibit more object play when hungry. An earlier study (Pellis, 1991) on the effects of hunger on object play and social play in oriental small

clawed otters showed that object play increased before feeding, but social play decreased. After feeding, this effect was reversed, and the otters had a faster increase in social play than in object play. To evaluate the difference between predation and object play for the first time in an invertebrate, tests need to be done on the influence of satiation level and age on play behavior of *Octopus vulgaris* toward food and nonfood objects. We assume that *Octopus vulgaris* can discriminate between food and nonfood objects and treats them accordingly.

Play is often claimed to have an adaptive (e.g., learning, training) function in juvenile animals (Bekoff & Byers, 1998; Power, 2000). According to these theories, play should be more frequently observed in younger, smaller animals, as proposed by various theories on the importance of play in training and preparing animals for future behaviors (Bekoff & Byers, 1998; Byers & Walker, 1995; Power, 2000). However, this does not take examples of play in adult mammals (Pellis, 2002) and in adult nonavian reptiles into account (Burghardt, 2005). More generally, it has been argued that almost all claims for training effects of play are suspect (see Burghardt, Ward, & Rosscoe, 1996). According to these theories, either there should be more play in juveniles or there should be no difference.

Choosing *Octopus vulgaris* for research on play behavior gives us the opportunity to compare their behavior in our experiment with existing knowledge of this behaviorally and neurophysiologically well-studied animal (Hanlon & Messenger, 1998; Nixon & Young, 2003; Wells, 1978). Previous research on play behavior in octopuses (Kuba et al., 2003; Mather & Anderson, 1999) laid the groundwork for an investigation on the structure of play behavior in octopuses. However, in both earlier studies, the octopuses' acclimatization to the captive environment did not follow a standard protocol, and therefore, the individual time and experience of the octopuses in captivity was different. The amount of interaction between octopuses and humans prior to the experiments could have caused the octopuses to become "tame." This familiarity effect is well known to scientists working with animals and was described several times in the literature (e.g., Bitterman, 1975; Boycott, 1954). An experimenter approaching the animals to introduce an object can be a major bias on the outcome of a study, so the present study specifically minimized the keepers' and experimenters' contact with the octopuses.

The possible existence of play in octopuses raises important evolutionary questions. Given the fact that the ancestral lineages of mollusks and vertebrate split about 1.2 billion years ago (Wray, Levinton, & Shapiro, 1996) the behavior would have to have developed independently of vertebrate play. The structure and function of play, then, could not be tied specifically to vertebrate biology and cognition.

To investigate this, we aimed to do the following in our study: (a) to document the existence of play behavior in a cephalopod mollusk on the basis of levels under controlled conditions, (b) to perform a quantitative analysis on the behavioral changes during the experiment, and (c) to investigate the influence of feeding level, age, and sex on play.

Method

Subjects

Subjects were 14 wild-caught *Octopus vulgaris* (6 females, 8 males) from Naples, Italy. Seven of those were small subadults (Octopuses 1–7)

with mantle lengths ranging from 4–7 cm at the beginning of the experiments. The other 7 subjects were large adults (Octopuses 8–14) with mantle lengths ranging from 11–17 cm at the onset of the experiments (Roper, Sweeney, & Nauen, 1984). The octopuses were either obtained directly from the Statione Zoologica di Napoli or bought from local fishermen. Octopuses were always fresh caught and stayed in the holding tanks of the Statione Zoologica di Napoli for a maximum of 6 days. They were kept either under daylight or on a 12-hr illumination regime of artificial fluorescent light. Until 24 hr prior to departure, subjects had access to crabs ad libitum. Transfer of the octopuses to the lab was done by car and took place over night.

Animal Keeping

Octopuses were held in tanks that were part of a closed circulation system of approximately 4,500 L of artificial sea water with a turnover rate of 24 times per day. Within this system, up to 9 subjects were kept individually in 1.0- × 0.6- × 0.5-m or 1.0- × 0.7- × 0.5-m glass tanks. Water was filtered with protein-skimmers and biological filters. Air stones produced a weak current and additional aeration in each tank. Illumination was provided by artificial light with a daylight emission spectrum from 0800 to 2000. An escape-proof Plexiglas lid was used to cover the tanks. All tanks had a decoration of live rocks and a several-centimeter-thick layer of sand substrate collected either from the Mediterranean or bought locally at specialized pet shops. Environmental enrichment has proven to be very important for a more natural behavior of cephalopods in captivity (Anderson & Wood, 2001). Rather than installing artificial dens, we provided plenty of building materials and rocks so that the octopuses could establish their dens at a place of their choice.

Experimental Procedures

Observations were conducted between December 2002 and September 2003. All octopuses were kept in the lab for 2 weeks prior to the experiment. During this time, feeding of the octopuses and maintenance work in the lab was done with a minimum of contact between octopuses and humans. All sessions took place between 0900 and 2100 and were recorded with a digital video camera (Sony DVX 2000, Saturn, Vienna, Austria). The video camera was positioned in front of the tank, and the octopuses were visually shielded for 30 min prior the experiments with opaque curtains (see Figure 1). The objects were put into the tank at a fixed distance to the subjects by use of one of the three openings (15 cm × 15 cm) in the lid. These openings were used only for the test objects and not for the regular feeding of the octopus. Subjects were presented one item at the time, either the food items clams (*Cardium sp.*) or mussels (*Mytilus sp.*) or two different inanimate objects made of Lego blocks. One was a smooth-surfaced cubic block made of black and white Lego (smooth-surfaced object, 7.7 × 4.3 × 5.7 cm). As octopuses are unable to discriminate colors (Messenger, 2001) the black and white Lego blocks provided maximal contrast. The other was a single-colored (blue) snowflake-like Lego construct (8.2 cm axis length), which maximized the roughness of surface areas. Experiments were carried out either 2 hr after the octopuses were fed (satiated, −2 hr) or 24 hr after feeding (hungry, −24 hr). Observations lasted for 30 min and were done on 7 consecutive days for each of the two food items and nonfood objects. After each week of testing, there was a 2-day break before the next session started. The sequence of the experiments was arranged in restricted random order to provide a time interval of at least 27 days before the octopus received an object again. The octopuses received food ad libitum at least 30 min after the end of the experimental session.

Data Analysis

Data analysis was done with a Sony DVR 1000 digital video recorder (Photo Jaeger, Vienna, Austria), which could freeze on single frames. We
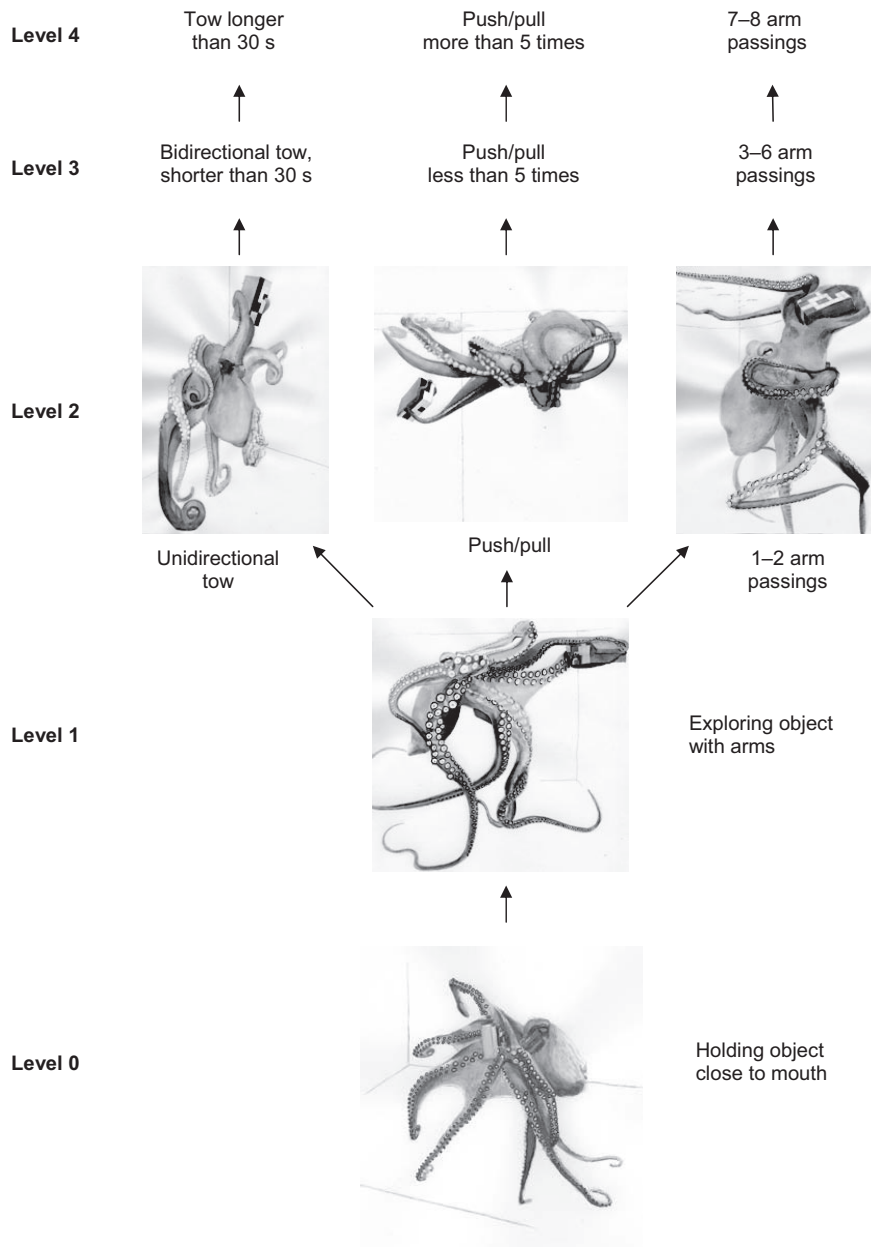
| Level 4 | Tow longer than 30 s | Push/pull more than 5 times | 7–8 arm passings |

| Level 3 | Bidirectional tow, shorter than 30 s | Push/pull less than 5 times | 3–6 arm passings |

| Level 2 | | | |

Unidirectional tow   Push/pull   1–2 arm passings

| Level 1 | | Exploring object with arms |

| Level 0 | | Holding object close to mouth |

Figure 1. Five levels and three different modes of exploration and play by *Octopus vulgaris*.

recorded the start of every contact and its duration for each experimental session. One person analyzed the film material using the following levels criteria, formulated by observer agreement viewing approximately 5% of the tapes (Bakeman & Gottman, 1997). For analysis, tapes were labeled with only a number code and were scored in a random order.

Levels Criteria

To be able to quantify behavioral activity, we designated levels of interaction, starting from more predatory or exploratory contacts to play behavior (see Figure 1) on the basis of findings from our previous study (Kuba et al., 2003). The intensity of each behavior was manifested in a rise in levels (0–4) on a play scale. At Level 3 the octopuses' interactions were classified as *play-like*, following the definition of Burghardt (2005), and at

Level 4 the behavior was classified as *play*. In the captive environment, healthy octopuses soon begin to respond to new objects introduced to their tanks by approaching them. These objects are then either directly engulfed in their interbrachial web or first inspected and probed by one or several arms. A Level 0 contact was a behavior similar to that found when octopuses deal with food objects, surrounding them with their arms and interbrachial web. In contrast to Level 0, a Level 1 contact was an exploratory or predatory interaction with the object in which only distal areas of one or several arms were used. This initial exploration is often followed by a fetching movement to bring the object to the mouth area (Sumbre, Fiorito, Flash, & Hochner, 2005).

Apart from these standard procedures, further modes of interactions with the objects were defined. On the basis of differences documented between exploration and play (see Power, 2000), these modes followed a path of

exploration to play-like behavior and play represented by increasingly diverse and manipulative interactions. The first mode of exploration or play (Level 2a) was a simple unrepeated action in which the octopuses pulled the objects closer or pushed them away, either horizontally or vertically. The behavior was categorized as play-like behavior (Level 3a) if these push/pull actions were repeated in one coherent action. If this sequence was observed more than five times, this was categorized as Level 4a play behavior. The second mode was towing the floating objects on the water surface. Octopuses held the object with one or more arms and then started to move without changing the distance between the object and the body of the octopus. At Level 2b this was a short, unidirectional tow. Once the octopus towed the object in more than one direction, this was classed as Level 3b, and if such an action lasted longer than 30 s and was multidirectional, we recorded it as a Level 4b interaction. The third mode was passing the object from one arm to another. At Level 2c the octopus only passed the object once or twice between arms. If it continued this behavior for up to six arm passings, we assumed this to be a Level 3c interaction, and seven or more such actions were categorized as Level 4c.

Statistical Analysis

We entered raw data into Microsoft Excel files to facilitate data management and then imported the data into SPSS 11 for Mac OSX, which was used for all tests. We used a Wilcoxon signed-ranks test to document differences in latency between the food and nonfood objects, and we used chi-square tests to document significance in differences in play-like behavior concerning age and feeding regimes. We used Kendall's tau-b test to look for significant differences in the number of actions at each behavioral level each day. To determine whether the factor day or other factors (duration of contacts, size, hunger, object) had the most influence on the establishment of play-like behavior, we conducted a binary logistic regression. This test used the dependent variable (presence or absence of Level 3 play behavior) and independent variables (day, size, hunger, amount of contacts, object) to calculate the probability of occurrence of play for each session.

Results

General Results

Healthy, nonsenescent octopuses in captivity react to any stimulus dropped into their tanks by approaching it. Contact was established with food objects within $M = 124$ s, $SD = 35$ s, and inanimate objects were approached within $M = 406$ s, $SD = 67$ s. Latency to approach the stimulus was significantly different for food and nonfood objects (Wilcoxon's $W = 105$, $Z = -4.503$, $p < .001$).

Nine out of the 14 subjects tested showed behavior that we considered Level 3 play-like behavior with inanimate objects following our criteria (see Table 1). One of the 14 octopuses proceeded further and exhibited Level 4a-type play interaction. None of the subjects showed any interaction other than eating, exploring, or ignoring (only Level 0 and Level 1 interactions) toward food items, and after the subjects ate the bivalves, they ignored the remaining shells. Two additional adult subjects (Octopuses 10 and 13) showed out-of-context play-like behavior as they grasped the object with one or several arms and jetted water at it without letting it go. Following our scheme, these behaviors were scored as Level 3d interactions; these observations were included in the calculations on play behavior. Therefore, 7 subjects attained Level 3 play-like behavior according our levels criteria, and 2 did so through a seperate behavior.

The Effect of Age and Hunger on Play

Four of the subjects exhibiting play-like behavior were small subadults (Octopuses 1, 2, 3, and 4), and 5 were adults (Octopuses 8, 9, 10, 11, 13). This difference in the number of subadult versus adult subjects attaining play-like behavior was not significant, $\chi^2(1, N = 9) = 0.143$, ns. Comparing the total number of play-like interactions among the two different feeding regimes (-2 hr or -24 hr), and the two different objects (smooth: 13, snowflake: 8), we found no significant differences, $\chi^2(3, N = 21) = 1.400$, ns.

Changes in Behavior Over Time

The number of Level 0 contacts decreased over days, and the number of contacts of higher levels (3 and 4) of play-like or play behavior increased from the 3rd day on and was lower again on the 7th day (see Table 2). This difference between days was significant (Kendell's $T = 3.1$, $N = 9$, $p = .002$).

As there were no significant differences in the number of play-like contacts across age and feeding level of the subjects, data were pooled across these variables. A binary logistic regression (collapsed across conditions) with the dependent variables (pres-

Table 1
Total Number of Observed Behaviors Following the Classification Schema of the Levels Criteria

| Level | Octopus | | | | | | | | | | | | | |
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0	31	149	37	53	41	54	59	13	41	81	33	11	25	22
1	128	99	120	116	142	68	210	64	128	159	174	27	187	145
2a	1	3	11	8	2	4	13	5	7	15	28	4	24	14
2b	18	7	2	4	5	1	3	7	5	8	12	6	7	1
2c	3	2	0	1	0	3	5	0	5	11	5	0	2	1
3a	0	1	0	0	1	0	0	1	4	0	2	0	0	0
3b	3	0	1	0	0	0	0	0	0	0	1	0	0	0
3c	0	0	0	0	0	0	0	3	1	0	0	0	0	0
3d	0	0	0	0	0	0	0	0	0	1	0	0	1	0
4a	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Sex	F	M	M	F	F	M	M	F	F	F	M	F	M	M

Note. Octopuses 1–7 were subadults, and Octopuses 8–14 were adults. F = female; M = male.

Table 2

The Difference in Numbers and Classification of Contacts Over 7 Days for Octopuses Reaching Level 3 Play-Like/Play Behavior

Level	Day						
	1	2	3	4	5	6	7
0	133	93	92	95	94	82	54
1	264	220	257	302	287	239	210
2	32	27	41	44	58	38	23
3	2	0	5	3	4	6	0
4	0	0	0	0	1	0	0

Note. The number of low-level contacts decreased over time, and the number of higher level contacts reached a peak on Day 6.

ence or absence of play behavior) and independent variables (day, size, hunger, amount of contacts, object) was used to calculate the influences on play-like behavior. This logistic regression, $\chi^2(4, N = 385) = 391.671$, $p > .001$, Nagelkerke $R^2 = .851$, showed that play-like interaction with objects was positively correlated to the factor day ($p > .001$) and to the number of occurrences of Level 2 behavior ($p > .001$). Neither feeding nor the age of the octopuses had a significant influence on the probability of play in this model.

Further Observations

One unusual set of behaviors occurred in an adult female octopus (Octopus 9). This subject had been fed a large snail of the family *Buccinoidea* on the day before a week of testing started. The snail was eaten, but some of the snail's body remained inside the shell. Its decay caused the production of gases inside, which resulted in the shell becoming positively buoyant during one session. The octopus approached the shell without previous chemo-tactile exploration and started to push it down in a series of interactions that we would describe as a Level 3a-type contact.

Discussion

Nine out of the 14 octopuses tested showed Level 3 play-like behavior directed toward inanimate Lego objects; only 1 of these 9 octopuses also proceeded to a Level 4 play behavior. The behaviors documented in this study agree with the five play criteria formulated by Burghardt (2005). The detailed analysis of the changes in behavior over days revealed a pattern of interactions starting with exploration followed by habituation, which can then lead to play-like interactions. Feeding level of the octopuses, age, and sex did not influence the amount and existence of play-like behavior.

Do octopuses have the cognitive complexity to show play behavior? Yes they do. Learning processes including complex learning have been demonstrated in several species of the genus *Octopus* (Boal, 1996; Hanlon & Messenger, 1998; Nixon & Young, 2003). Another very important point is the curiosity of *Octopus vulgaris* (Byrne, Kuba, & Griebel, 2002), which has given rise to speculations about their intelligence ever since Aristotle first reported it. Recently, authors have also reported the existence of personalities in octopuses (Sinn, Perrin, Anderson, & Mather, 2001), further indicators of complex behavior. In addition, Power

(2000) claimed that animals that use objects as tools are also more likely to engage in object play. Aristotle was the first to report the use of objects in their shelter construction (see Figure 2), and Mather (1994) documented tool use by octopuses in such den construction. Through extensive manipulation of an object, the octopus could acquire the information about whether the object is suitable for this purpose, and such manipulation to retrieve information might then lead to object play as proposed by various authors (see Power, 2000, for a review).

The pattern of development of play-like activities after a period of exploration and habituation in this study is consistent with our hypothesis that object play may arise following diversified exploration (Einon, 1983; Hughes, 1983; Power, 2000). This sequence of behavior also matches that found in earlier studies by Mather and Anderson (1999) and Kuba et al. (2003) on object exploration and play behavior. The presence of this sequence in invertebrates suggests that there might be a common principle for how animals and humans interact playfully with objects.

Although hunger affected the motivational basis of object play in cats (Hall, 1998; Hall & Bradshaw, 1998; Hall et al., 2002) and changed the frequency of object play and social play in otters (Pellis, 1991), in our present study feeding time had no significant influence on play behavior. This difference may come from the fact that prey-like stimuli were used in vertebrate object-play experiments (Hall, 1998; Hall & Bradshaw, 1998; Hall et al., 2002), whereas we used objects with no biological significance. We used nonfood objects because of concerns that the discrimi-

Figure 2. Adult male *Octopus vulgaris* sitting in his den constructed out of a flowerpot and several stones and pieces of broken flowerpots. The octopus used larger flat pieces of clayware to block the remaining opening when threatened.

nation between object play and feeding behavior might have been difficult. The clear difference in how the octopuses treated food and nonfood objects is important, as this gives further experimental evidence of discrimination in exploratory behavior in octopuses. The play-like behavior with the Lego objects was clearly not misplaced predation by an animal unable to discriminate prey from nonprey. Future studies should focus on testing more prey-like objects, such as positively buoyant snail shells, in octopuses and more nonfood objects in mammals. There was no difference in play by younger versus older octopuses. This should not be the case if one assumes an adaptive significance of play-like behavior as practice for later in ontogeny (Bekoff & Byers, 1998; Burghardt, 2005). Still, play behavior might have a training value for the future life of an octopus. Following the ideas of Spinka, Newberry, and Bekoff (2001) the "training for the unexpected" hypothesis can also be applied to adult animals. Building on the framework of preparation theories, they claimed that play helps mammals to be better prepared for unexpected events. Given that octopuses live in a fast-changing environment, this could be an important benefit for them.

A different theory on the foundation of play behavior can be more helpful in the understanding of why the amount of play behavior was not different in our study. Burghardt (1984, 2004) formulated the surplus resource theory (SRT; Burghardt, 1984), in which he claimed that primary process play is most likely to occur when behaviorally complex animals have ample resources (Burghardt, 2004, 2005). In our study, even the octopuses, which were not fed for 24 hr prior to the experiments, were receiving food ad libitum and therefore were not constrained by a potential lack of food. The captive environment also eliminates the threat of predation for smaller animals. Therefore SRT is the most likely explanation for play in octopuses. Play is most likely to occur when behaviorally complex animals have resources of time along with adequate nutrition that can facilitate performing behavior that may not be immediately functional. SRT would point out that an octopus has the ability to engage in a wide variety of behaviors, must capture and ingest a wide range of challenging prey, and so forth, and this sets the stage for the evolutionary origins of play more than learning per se. In this case, play might have additional functions not easily tested. Darwish, Korányi, Nyakas, and Ferencz (2001a) showed that old rats given novel objects had reduced anxiety levels and that in young and adult rats, play behavior dampened the stress response as measured by the corticosterone level (Darwish, Korányi, Nyakas, and Ferencz, 2001b). In their case, play had a general function to create bolder animals with an increased behavioral flexibility. Play could therefore be a by-product of a complex nervous system heavily dependent on learning, as is the case in octopuses (Hanlon & Messenger, 1998).

Octopus vulgaris play and play-like behavior differed considerably from that reported for *Octopus dofleini* (Mather & Anderson, 1999), which used water jets from their funnels and not their arms to manipulate objects. This difference in mode of play between the two species is not surprising—different mammalian species also show different types and amounts of play (Pellis, 1993). Apart from ecological differences, *Octopus vulgaris* is also a very active, curious, and agile species (Hanlon & Messenger, 1998; Wells, 1978), spending most of the time during the observational period moving around in its tank. *Octopus dofleini*, on the other hand, is a nocturnal cold-water species (Anderson & Wood, 2001) and was

therefore less active, and it interacted with the object only when it approached the octopus.

The documentation of play behavior in invertebrates means that we have to reconsider our theories on the evolution of play. The ancestral lineages of mollusks and vertebrates split about 1.2 billion years ago (Wray et al., 1996). Play has not been documented in the intermediate taxa and is sparse in lower vertebrates (Burghardt, 2005). The only other reports of potential play in protostomes are found in crustaceans and insects and are based on anecdotal evidence (Burghardt, 2005). Therefore, a homologous origin of this behavioral trait is highly unlikely, because the last common ancestor might not have had the cognitive capacity to possess this trait. Also, as play behavior varies greatly within and between vertebrate classes, so does the even greater variation within protostomes support the conclusion that play evolved multiple times throughout the evolution of animals. This highlights the importance of further investigation of play-like behavior in cephalopods, now that we have begun to investigate it. To broaden the scope of comparative research on the simplest manifestations of play-like behavior, further studies should deal with play-like behavior in other species of cephalopods and the investigation of play and exploration in lower aquatic vertebrates.

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