Behavioural Processes 112 (2015) 108–113

Contents lists available at ScienceDirect

Behavioural Processes

journal homepage: www.elsevier.com/locate/behavproc

Object permanence in marine mammals using the violation of expectation procedure

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ARTICLE INFO

Article history:
Available online 2 September 2014

Keywords:
Marine mammals
Dolphins
Sea lions
Object permanence
Violation of expectation

ABSTRACT

Object permanence refers to the ability to process information about objects even when they are not visible. One stage of object permanence, called visible displacement, involves being able to find an object that has been fully hidden from view. Visible displacement has been demonstrated in many animal species, yet very little is known about object permanence in marine mammals. In addition, the methodology for testing visible displacement has sometimes been called into question because alternative explanations could account for subjects' success. The current study investigated visible displacement in Atlantic bottlenose dolphins and California sea lions using a methodology called violation of expectation, in which the animal's fish bucket was placed on a table surrounded on three sides by curtains. A solid screen placed in front of the bucket was then rotated in an arc from front to back. The screen was rotated either 120° (possible event) or 180° (surprising event), appearing as if the bucket disappeared. Both dolphins and sea lions looked significantly longer during the 180°, unexpected, trials than the expected event trials. Results suggest that both dolphins and sea lions pass visible displacement tests without the use of perceptual cues.

This article is part of a Special Issue entitled: Tribute to Tom Zentall.

1. Introduction

Object permanence is defined as the ability to understand that objects continue to exist even when they are out of sight and develops in human children between the ages of 18 and 24 months (Piaget, 1954). Piaget proposed that this ability developed over six stages with each stage becoming increasingly more complex. In the first two stages, babies do not search for objects that move out of their visual field. They will search for partially hidden objects in stage 3. They are able to find fully hidden objects in a single location in stage 4 (also called visible displacement) and objects hidden in multiple locations successively in stage 5. The sixth and final stage involves tracking the motion of an object as it moves once it has been hidden. This final stage is called invisible displacement.

The methodology for testing human infants on stage 4 object permanence tasks is well established. In the traditional method of testing for visible displacement a child is shown a favorite toy and then the toy is hidden underneath a blanket or other occluder (Piaget, 1954). The child with object permanence would lift up or reach under the blanket to retrieve the hidden toy. An alternative test would be to place the object inside one of three boxes and then ask the child in which box the toy is located. Children with object permanence successfully choose the box with the hidden toy inside.

Many animals have been tested and pass visible displacement tests including dogs (Gagnon and Doré, 1992, 1993), cats (Dumas, 1992), parrots (Pepperberg and Funk, 1990), and many monkey species (e.g., Neiworth et al., 2003). Ape species, such as chimpanzees and orangutans have also been studied and successfully pass these visible displacement tests as well (e.g., Call, 2001; Collier-Baker et al., 2006). However, there is little research on object permanence in marine mammals. This is particularly surprising given how similar cetaceans and primates are in terms of cognitive abilities (Marino, 2002).

These studies of object permanence in non-human animals used the more traditional method of testing for visible displacement in which an object is hidden inside or behind an occluder and the subject must correctly identify the location of the hidden object. For example, a trainer would show an animal subject an object and then place that object inside one of multiple opaque containers (Jaakkola et al., 2010) or hold a container while placing an object inside

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http://dx.doi.org/10.1016/j.beproc.2014.08.025
0376-6357/

(Mitchell and Hoban, 2010). A potential problem with this design is that subjects may use associative rules to choose the correct container rather than holding a representation of the object in memory. For example, the subject could choose "the box whose lid was just lifted" or "the container the trainer most recently touched". Collier-Baker et al. (2006) attempted to address the concerns regarding simpler search strategies and found that chimpanzees appeared to solve the task without relying on associative rules. Similarly, Miller et al. (2009) found that adult dogs were able to solve an object permanence task when body position and eye gaze cues had been eliminated. In this experiment with dogs, Miller et al. (2009) prevented the dogs from maintaining eye contact with the container the food had been placed inside by turning the experimental room lights off for a variable delay period. Even after eye contact was broken, when the lights were turned back on, the dogs were able to accurately locate the hidden food at both 0-s and 5-s delays.

An alternative method of testing for visible displacement is known as violation of expectation (VOE) (Baillargeon et al., 1985; Baillargeon, 1986). With this procedure, a child watches an event take place but the ending is changed in such a way as to violate what the child should expect to see. For example, an object is placed behind a flat screen that is then rotated in one of two ways. The expected result is that the screen rotates 120°, as far as the object allows. This is expected because the screen "should" stop when it touches the solid object behind it. The unexpected result is that the screen rotates a full 180° from its original position and lies flat over where the child expects the object to be located. The screen should not be able to rotate through a solid object and thus "should" have stopped before it was able to complete a 180° rotation. Object permanence ability is demonstrated by longer looking times on events in which an expectation is violated than on events in which an expected outcome occurs. This method allows for testing of visible displacement level object permanence without the possibility that participants are solving the task through associative rules such as following the position of the trainer or maintaining eye contact with an object as it is hidden behind an occluder and using that directional eye gaze as a cue for choosing where the hidden object is located.

One application of the violation of expectation procedure was to demonstrate that human children were able to solve visible displacement tasks at an earlier age than was proposed by Piaget (Baillargeon, 1987). While Piaget suggested that children did not develop object permanence ability until approximately 12–18 months of age, several studies using the violation of expectation procedure have demonstrated that infants as young as 3.5 months of age demonstrate visible displacement (Baillargeon and DeVos, 1991). The current study does not use this methodology to establish an age at which object permanence develops in animals. Rather, the use of this procedure in the current study is to investigate visible displacement ability with trainer cues about object location being eliminated.

In the studies of object permanence using the violation of expectation test, looking time is the measure of behavior. Investigators propose that infants, and non-human animal subjects, will look longer at an unexpected or surprising event than they will look at an expected event. In some studies, looking time is measured by individual observers who record, by depressing a button connected to a computer, when they believe the infant is looking at the screen. At times there are two independent observers recording looking time simultaneously. Recording continues until the infant looks away for 2 consecutive seconds after looking at the event for at least 6 consecutive seconds or looked at the event for 60 consecutive seconds without looking away (Baillargeon and DeVos, 1991). The total number of time before an infant looks away or how long to continue the trial if the infant does not look away varies by study (e.g., Bogarz et al., 2000). Pattison et al. (2010) used a similar looking time procedure when testing dogs. The time began when a curtain revealed the testing apparatus and stopped when the subject had looked away for 2 consecutive seconds.

In the studies using looking time as a measure previously mentioned (Baillargeon and DeVos, 1991; Bogarz et al., 2000; Pattison et al., 2010), carefully controlled laboratory rooms were used for the study. In the current experiment, research subjects were tested in ocean pools at a public dolphin swim-with facility. Animals were tested with other animals present in the pools as well as guests of the facilities walking past. Thus, the animals were unable to maintain complete focus on the testing apparatus. For this reason, looking time was measured as a proportion of trial time rather than consecutive looking time before looking away for a predetermined amount of time.

Both dolphins and sea lions have excellent vision, both in-air and underwater. Pepper et al. (1972) and Dral (1972) independently determined that bottlenose dolphins see comparably well in-air and underwater. Herman et al. (1975) tested visual acuity using different spatial frequencies both in-air and underwater. Dolphins were trained to push one paddle if they perceived a spatial frequency grating and a different paddle if they perceived a solidly colored target. Dolphins performed similarly in-air and underwater with the primary difference being the distance of the target for the best acuity. Underwater, the best resolution was approximately 1 m while in-air the best resolution increased to approximately 2.5 m. Schusterman (1972) used a similar procedure with spatial frequency gratings to test California sea lions and found good visual acuity at close, mid-range, and long distances. All subjects in the current study were tested with their heads (or whole body) in air; however, their ability to see the apparatus was not hindered by being out of the water.

The current study tested visible displacement in Atlantic bottlenose dolphins (*Tursiops truncatus*) and California sea lions (*Zalophus californianus*). There have been only two prior studies of object permanence in dolphins (Jaakkola et al., 2010; Mitchell and Hoban, 2010). Jaakkola et al. (2010) tested several stages of object permanence including visible displacement, transposition, and invisible displacement. All animals were trained with partially hidden objects inside container before proceeding to test trials. The authors addressed the potential for order effects by having some animals tested on visible displacement before invisible and vice versa. The authors suggest that failure on invisible displacement tests might have been the result of the dolphins paying attention to the box the trainer was attentive to and thus, they did not attend to object movement. It is therefore possible that trainer attention and manipulation of one container held the animal's attention and affected performance on visible displacement trials as well. In Mitchell and Hoban's (2010) study, the trainer held the object (a fish) directly over one of the containers and dropped it in on some trials and picked up the bowl and put the fish in it before placing the bowl back in the water on other trials. Trainer manipulation of the container could have accounted for the dolphin and whale subjects searching the container to retrieve the fish rather than object permanence ability. While dolphins did pass visible displacement tests in the aforementioned studies, neither have eliminated the possibility that the trainer's interaction with the opaque container was responsible for the subject's choice of that container. Previous testing with dogs also suggests that the subjects were relying on visual cues to solve visible displacement tests rather than object permanence ability (i.e., Collier-Baker et al., 2004; Fiset and LeBlanc, 2007).

Although it is likely that bottlenose dolphins do have the ability to pass visible displacement tasks, the current study would provide convergent evidence using a procedure that eliminates associative rule explanations. Further, there have been no prior studies of object permanence in pinnipeds. The current