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ORIGINAL PAPER

Piagetian object permanence and its development in Eurasian jays (*Garrulus glandarius*)

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Abstract Object permanence in Eurasian jays (*Garrulus glandarius*) was investigated using a complete version of the Uzgiris and Hunt scale 1. Nine hand-raised jays were studied, divided into two groups according to their different developmental stages (experiment 1, older jays: 2–3 months old, $n = 4$; experiment 2, younger jays: 15 days old, $n = 5$). In the first experiment, we investigated whether older jays could achieve piagetian stage 6 of object permanence. Tasks were administered in a fixed sequence (1–15) according to the protocols used in other avian species. The aim of the second experiment was to check whether testing very young jays before their development of "neophobia" could influence the achievement times of piagetian stages. Furthermore, in this experiment tasks were administered randomly to investigate whether the jays' achievement of stage 6 follows a fixed sequence related to the development of specific cognitive abilities. 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. With regard to the achieving order, 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.

Keywords Object permanence · Piaget · Bird · Corvid · Jay

Introduction

"Object permanence" is the notion that objects are separate entities that continue to exist even when they are out of the observer's sight (Piaget 1952, 1954). Research on the ability of animals to form object concepts has emerged primarily in the last 20–30 years, and most of the studies carried out take humans as a starting point (Wynne 2001). However, as reported by several authors (Vauclair 1996; Pepperberg 2002), Piaget's theory that cognitive development is a consequence of internal maturation under the influence of environmental constraints allowed researchers to adapt Piaget's methodology to cross-species comparison (Etienne 1984; Chevalier-Skolnikoff 1989; Pepperberg and Funk 1990; Dumas 1992; Tomasello and Call 1997; Wynne 2001). The apparently simple concept that a hidden object continues to exist even when it is no longer available to sense organs was first investigated in great apes, such as chimpanzees (Mathieu et al. 1976; Wood et al. 1980), bonobos (Minahan et al. 2000), orangutans (de Blois et al. 1998; Call

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2001) and gorillas (Redshaw 1978; Natale et al. 1986), in several species of monkeys (Mathieu et al. 1976; Hauser 2001; Hauser et al. 2001; Neiworth et al. 2003) and then in other mammals like dogs (Gagnon and Doré 1992, 1993, 1994), cats (Dumas and Doré 1989; Goulet et al. 1994) and golden hamsters (Thinus-Blanc and Scardigli 1981). Object permanence was investigated also in birds, though less extensively (i.e. grey parrots, macaws, parakeets and cockatiels: Pepperberg and Kozak 1986; Pepperberg and Funk 1990; Funk 1996; Pepperberg et al. 1997; ring doves: Dumas and Wilkie 1995; pigeons and mynahs: Plowright et al. 1998; domestic chicks: Etienne 1973; Regolin et al. 1994a; 1995; Vallortigara et al. 1998; magpies: Pollok et al. 2000). The results of these studies showed marked differences in terms of times of development and levels of performance achieved. While many psittacine species achieved the complete stage 6 (Pepperberg and Kozak 1986; Pepperberg and Funk 1990; Funk 1996; Pepperberg et al. 1997), the full achievement of stage 6 in a food storing bird like the magpie (*Pica pica*) is uncertain: magpies, 2–4 months old, achieved several tasks of level 6 but they never reached the criterion for task 15 even when re-tested at the age of 1 year (Pollok et al. 2000).

Here we studied object permanence and its development in a corvid species that has peculiar food-storing abilities, the Eurasian jay (*Garrulus glandarius*). Jays store food all year round, but during autumn and winter they store more (mainly acorns), spend more time hiding caches and leave their caches for longer periods before retrieving them than they do during the rest of the year (Bossema 1979; Clayton and Krebs 1995; Keve 1995; Savage 1995; Clayton et al. 1996; Madge and Burn 1999). It has been estimated that a single bird could "plant" as many as 3,000 acorns in 1 month (Wilmore 1977). Jays thus appeared quite different from magpies (the other corvid species for which extensive evidence of object permanence has been collected, see earlier Pollock et al. 2000): magpies appear to hide only few food items and retrieve them shortly after storing them (Wilmore 1977; Birkhead 1991; Pollok et al. 2000). The behavioural strategies used by jays for storing food make them an interesting avian model to be used in the study of object permanence. According to the large amount of data available on food-storing behaviour in several passerine food-storing birds and to the role of cognition in caching (Clayton and Krebs 1995; Shettleworth 1995; Bugnyar and Heinrich 2006), several predictions can be made. As reported by Clayton and Krebs (1994), the achievement of piagetian stage 4 in a food-storing bird should be expected because food storing requires that the bird remembers where food items have been hidden. Jays, however, should perhaps be expected to achieve stage 5 too; 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. Jays have also been described as possessing rather sophisticated cognitive abilities. They can re-cache acorns after several months (Chettleburgh 1952; Bossema 1979) and unlike magpies (Wilmore 1977; Pollok et al. 2000) and other species of food-storing corvids such as ravens (*Corvus corax*), jays frequently re-cache their food items several times, thereby increasing the number of steps and caching sites they need to remember. They use their vocal abilities also in a social context, for example, when they are sighting a particular type of predatory bird. As described for the differential vervet alarm calls by Seyfart et al. (1980), Wilmore (1977) reports that jays, in a group context, give the "hawk alarm" at the sight of a sparrow hawk (*Accipiter nisus*) and an "owl-screech" call when attacking an owl. Jays react to other jays' alarm calls, even when they cannot directly see the danger (Wilmore 1977). Stage 6 competence has been claimed to be associated with the presence of this sort of cognitive ability in other bird species (e.g. Pepperberg and Funk 1990).

Experiment 1 tested whether jays could achieve full stage 6 of object permanence, using the Uzgiris and Hunt (1975) scale 1 tasks. These tasks were originally created by developmental psychologists and they are widely used in comparative psychology studies.

Experiment 2 investigated another issue, namely whether other variables not related with specific cognitive abilities, like "neophobia", would influence the development of the piagetian stages in terms of achievement times. Jays, similar to other species of birds such as sparrows (*Passer* sp.) (Greenberg 1990) and ravens (*Corvus corax*) (Heinrich 1988, 1995, 1999; Heinrich et al. 1995) go through sharply timed behavioural developmental stages. When they first leave the nest, about 3 weeks after hatching, they are fearless and they are free to learn, explore and touch whatever crosses their path. In the wild, during this time, they are usually accompanied by their parents who keep them out of harm's way. When young jays are on their own, at roughly 2 months post-hatching, they enter a stage described as "neophobic", where they are fearful of new objects or unfamiliar situations as happens for other species of corvids (Heinrich 1995, 1999; Heinrich et al. 1995). In experiment 2 (see Table 1), we tested a group of young jays before they reached the "neophobic stage". Furthermore, in experiment 2, we tried to verify whether jays follow a fixed sequence during their achievement of the piagetian stages. During experiment 2, the Uzgiris and Hunt (1975) scale 1 tasks were administered randomly (see also Methods in experiment 2) and few control tasks, like task 16 and the "shell game" were added (see the following text).

Table 1 Experiments 1 and 2: two groups of jays tested at different ages according to the development of the "neophobic stage"

Group-year	Subjects	Age	"Neophobic stage"	Tasks administered
Experiment 1				
Older Jays ($n = 4$—tested during 2002 and 2003)	n. 1 (Ross)	2–3 months old	Fully developed	All 15 tasks of scale 1 of Uzgiris and Hunt (1975)
	n. 2 (Mat)	"	"	
	n. 3 (Russell)	"	"	
	n. 4 (Carlo)	"	"	
Experiment 2				
Younger Jays ($n = 5$—tested during 2004 and 2006)	n. 5 (Violet)	15 days old	Not achieved	All 15 tasks of scale 1 of Uzgiris and Hunt (1975) plus task 16 and task "S", omitting 11 and 12 (Pepperberg et al. 1997)
	n. 6 (Cyan)	"	"	
	n. 7 (Red)	"	"	
	n. 8 (Lola)	"	"	
	n. 9 (Elvis)	"	"	

Experiment 1

The primary goal of experiment 1 was to verify whether older jays, 2–3 months old, could achieve piagetian stage 6 of object permanence.

Methods

Subjects

Four hand-raised Eurasian jays (*Garrulus glandarius*), 2–4 months old, were tested on the entire scale 1 by Uzgiris and Hunt (1975; see also Tasks). Birds were tested individually in physical and visual isolation from their cage-mates twice a week in the summers and autumns of 2002 and 2003. Testing began when jays were already "neophobic".

Housing

Birds were first kept in a cardboard box the size of a jay's nest; few days before fledging, when birds start to move around the nest, they were housed in groups until they were 2 months old. Then, they were housed individually in outdoor aviaries of about 2.5 m $\times$ 2 m $\times$ 3 m. Each aviary was equipped with several perches, a small table and a chair for the experimenter (see Fig. 1). Great attention was paid to the environmental enrichment of the aviary using natural wood perches with leaves and a large variety of fresh fruit positioned all around the aviary. Jays were fed ad libitum with insectivorous bird food, fresh fruit and supplied with vitamin-enriched water.

Apparatus

All the tasks were administered on a table inside the aviary. On the table was an experimental setup made up of a transparent plastic "cake-box" (see Figs. 1 and 2) to prevent the jays from jumping and removing the screens and the hidden objects before the end of the presentation. We used small plastic boxes, pieces of paper and towels as screens (see Fig. 2). We always hid food items (fresh mealworms *Tenebrio molitor*) killed a few minutes before the beginning of the experiment.

Tasks

Jays were tested with the complete scale 1 tasks by Uzgiris and Hunt (1975). The scale 1 has been used in several earlier studies on object permanence in birds (Pepperberg et al. 1997; Pollok et al. 2000); it measures competence levels through the performance on 15 tasks of increasing difficulty. Uzgiris and Hunt (1975) divided their tasks into five subgroups:

1. visual pursuit of slowly moving objects (tasks 1 and 2);
2. search for simply hidden objects (tasks 3–7);
3. search following more complex hiding (tasks 8–9);
4. search following an invisible displacement (tasks 10–13);
5. search following successive invisible displacements (tasks 14–15).

Piagetian stages correlate partially with a specific group of tasks from scale 1 as follows:

- Stage 2 (tasks 1 and 2 of scale 1);
- Stage 3 (task 3 of scale 1);
- Stage 4 (task 4 of scale 1);
- Stage 5 (tasks 5–9 of scale 1);
- Stage 6 (tasks 10–15 of scale 1).

We group the 15 tasks of Uzgiris and Hunt (1975) according to the piagetian scale as reported in Table 2.

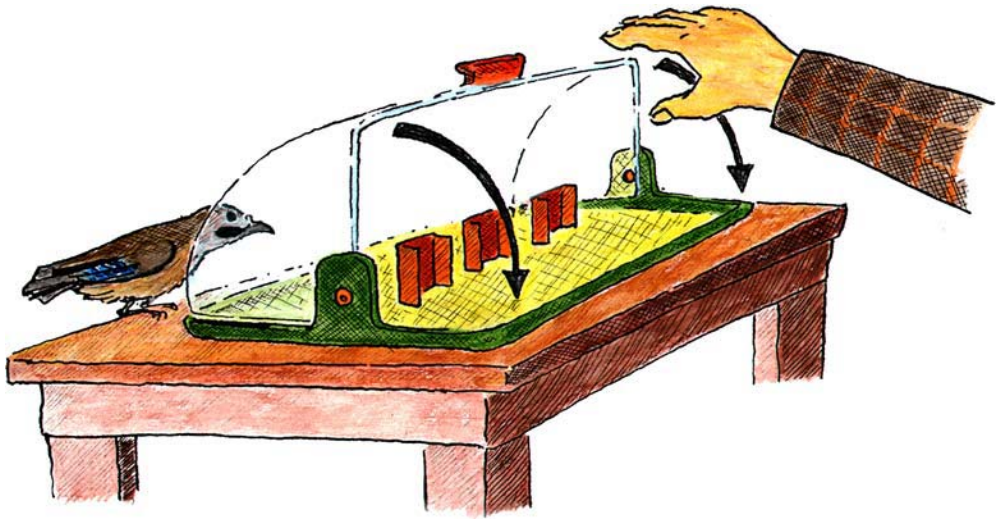

Fig. 1 Schematic drawing of the wooden platform with the experimental setup inside the aviary. The cake-box size is 45 cm × 30 cm × 18 cm

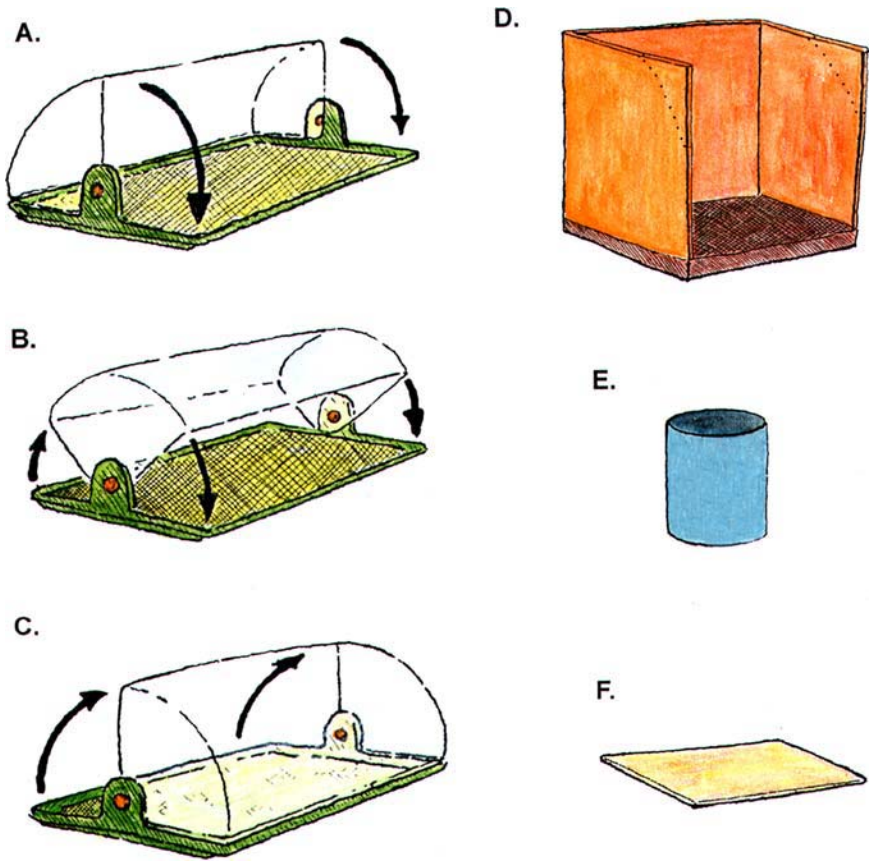

Fig. 2 **A–C** The opening mechanism of the cake box setup; **D** Screens (7 cm × 7 cm, side 2 cm); the *dotted lines* show how the two corners were rounded to reduce neophobia in two subjects, **E** Small plastic box (3 cm × 3 cm diameter) for the successive invisible displacements and **F** Covers (8 cm × 8 cm; task 9 first cover 2 cm × 2 cm, second cover 6 cm × 6 cm, third cover 15 cm × 15 cm)

Procedure

The jays were never moved from their experimental aviary until the end of the tests, to avoid any stress to the animal. Trials were administered by an experimenter inside the aviary. A second experimenter was outside the aviary and video-recorded the test. The tasks were administered alternately by two experimenters during the sessions. Jays were tested only for short periods and sessions were usually 15–20 min long.

Criteria and other procedural details

The number of presentations and the performing criteria to complete the trials were those of scale 1 by Uzgiris and Hunt (1975). Tasks were administered as in Pepperberg

Table 2 Experiment 1 (older jays): description of the task and its successful criterion. The 15 tasks of the Uzgiris and Hunt (1975) scale 1 are grouped according to the piagetian scale

Stage 2	*Task 1*. Before starting the test, the object is shaken in order to catch the bird's attention. The object is moved slowly around the bird along a horizontal plane through an arc of 180°.
	Successful criterion: the bird had to follow the object continuously through an arc of 180°.
	Task 2. A moving object disappears from one side of a screen and reappears on the opposite side.
	Successful criterion: the bird looks at the point where the object disappears or, after several presentations, its glance returns to the starting point or to the point of reappearance before the object reappears.
Stage 3	*Task 3*. An object the bird focuses its attention on is partially hidden under a single cover.
	Successful criterion: the hidden object is obtained by pulling it out from under the cover or by taking the object after removing the cover.
Stage 4	*Task 4*. An object the bird focuses its attention on is completely hidden under a single cover.
	Successful criterion: the hidden object is obtained by removing the cover and taking the object.
Stage 5	*Task 5*. Two screens are used. If the bird finds the object that was hidden under one screen (A) during two trials, then the object is subsequently hidden under the second screen (B). The object is hidden in the same way as in the first presentation but twice under the second screen and then twice under the first screen.
	Successful criterion: the bird searches for the object in the place of its final disappearance, for instance, under the second screen during the first presentation. Searching under the first screen would indicate the "A-not-B error".
	Task 6. The object is hidden alternately under each of the two different covers.
	Successful criterion: the bird searches under each cover according to the site of the last hiding of the object.
	Task 7. The object is hidden at random under three different screens.
	Successful criterion: the bird searches under the screen where the object was hidden.
	Task 8. The object is hidden consecutively behind each of the three screens by moving the hand that holds the object from left to right or the other way round, temporarily hiding the object behind each screen and finally hiding the object under the screen where it disappears for the last time. Check that the attention of the bird is constant during the complete presentation.
	Successful criterion: the bird immediately searches behind the last screen where the object last disappeared.
	Task 9. The object is hidden under three superimposed screens. Cover the object with the first screen, then cover the first screen with the second one and finally cover the second screen with the third. Place the screens in a such way that it is not possible to remove all the screens at the same time.
	Successful criterion: the bird obtains the object after removing all the screens.
Stage 6	*Task 10*. The object is placed in a small non-transparent plastic box. Then, the plastic box is moved under a screen and the object is removed from the box and hidden under it. Remove the empty box and show it to the bird.
	Successful criterion: the bird searches inside the box and then searches under the screen or the bird searches immediately under the screen where the box disappeared.
	Task 11. Corresponding to task 5. Object as in task 10. The object is hidden, using the plastic box for the successive invisible displacements, under one of two screens and then it is again hidden under the other screen twice.
	Successful criterion: the bird searches under the screen where the box disappeared.
	Task 12. Corresponding to task 5. Object as in task 10. The object is hidden, using the box for the successive invisible displacements, alternately under two screens.
	Successful criterion: the bird searches immediately under the screen where the box disappeared.
	Task 13. Corresponding to task 5. Object as in task 10. The box is hidden behind one of three screens.
	Successful criterion: as in task 11.
	Task 14. The object is visibly placed in the palm of the experimenter's hand, which is then closed. The hand passes behind two screens (closed) and the object is placed behind the last screen. Then the experimenter shows the empty hand to the bird. Repeat the session in the opposite direction, again leaving the object under the last (first) screen.
	Successful criterion: the bird searches under all the screens in the same order as the experimenter's hand passed behind them and finally finds the object or searches directly behind the last screen.
	Task 15. One object is already hidden under the first screen before beginning the test. Then, a second object is visibly placed in the palm of the experimenter's hand, which is then closed. The hand passes behind two screens (closed) but the second object is placed inside a glove worn by the experimenter, without being seen by the bird. Then, the experimenter shows the empty hand to the bird. The bird is led to believe that the object is under the third screen.
	Successful criterion: the jay searches systematically in reverse order, i.e. final screen, second screen and first screen. This task is administered only to the jays that met the criterion for task 14.

et al. (1997) making sure that the birds that failed never saw where the object had been hidden so that they could not learn by observation. A trial began when the jay approached the experimental setup (the "cake-box") on the table inside the aviary. Then, the object was hidden and any response of the jay was scored. Jays had to respond to nine trials (one session) with no more than two mistakes to move to the successive task. If jays manifested interest in the task but did not approach the experimental setup due to neophobia, after 2 min this response was scored as "trial not attended" and the trial was presented again after 5 min. After three consecutive fearful responses, the session was scored as "session not attended" and the session ended.

Fear responses

The four jays were tested when they had already achieved the neophobic stage. For this reason, great attention was given to reduce the fear of the animals against the experimental setup. The "cake box" was permanently fixed to the small table inside the aviary and the jays were allowed to play every day with the several types of screens used during the tests. Furthermore, we decided to test jays inside the aviary because we noted that, being hand-raised animals, they were afraid when the experimenters were outside.

Visual cues

Although several authors (Wood et al. 1980; Triana and Pasnak 1981; Pepperberg and Kozak 1986; Pepperberg et al. 1997) reject any influence of visual cueing, to avoid face-to-face interaction, the experimenter inside the aviary never looked at the experimental setup during the administration of the 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. Concordance between different experimenters in the video analysis of the tasks was 100%.

Odour cues

As reported by Pepperberg (2002), there are several reasons why odour cues are unlikely to affect experimental results. The relative importance of the olfactory system in the Class *Aves* appears to vary across species and it is well documented only in a few species (Kaplan and Rogers 2001). In fact, the full role of olfaction in avian life has not been established clearly (King and McLelland 1984). Odour for several avian species like psittacids is not important, and birds, when tested, made a similar number of mistakes in object permanence tasks whether the hidden object was food or non-food, and often ate little of the food rewards (Pepperberg and Kozak 1986; Pepperberg and Funk 1990). Actually, Gagnon and Doré (1992) argue that odour cues are unimportant in object permanence tasks even for animals such as dogs that are known for using olfactory information.

In our study, the experimental setup and many of the screens used were always located inside the experimental aviary and jays were frequently fed either close to or on the "cake box". For these reasons, the experimental setup, including the screens, was completely marked with the same olfactory cues, in order to avoid giving any supplementary information to the jays regarding the position of the hidden object. Moreover, the experimenters physically handled screens and covers while hiding the mealworms; thus, all the screens picked up both human and mealworm odours. The jays made holes all around the table and also inside it, where they hid food items, including mealworms and these acted as additional olfactory distractors. Finally, it should also be noted that some of the Uzgiris and Hunt's scale tasks (1975) such as number 15, specifically test for odour cues. In fact, an animal using odour cues would not be "tricked" in these tasks (see following text and see also Pepperberg 2002).

Results and discussion

Figure 3 shows the results and the ages at which older jays in experiment 1 mastered all the tasks of scale 1, while Table 3 gives a detailed description of the sessions to which older jays were exposed before meeting criterion in each of the 15 tasks.

Details are provided later of the 15 trials according to the notes taken during experimental sessions as reported for other avian species (Pepperberg et al. 1997; Pollok et al. 2000).

Visual pursuit

Task 1 (arc) and task 2 (object disappearance) All the jays mastered these two tasks on their first experimental session without any mistakes. All four animals attempted to grab the objects (mealworms) while they were in motion as reported for other avian species tested after independence from parents (Pepperberg and Kozak 1986).

Simple visual displacements

Task 3 (partial hiding) and task 4 (complete hiding) Jays seemed not to have any trouble in solving these two tasks either. At the beginning, some animals showed their fear of the covers, even if they were simply a piece of paper and it took 1-2 min before they started the test.

Task 5 (two sites, visible) All the jays retrieved the hidden food consecutively at sites A and B. However, for

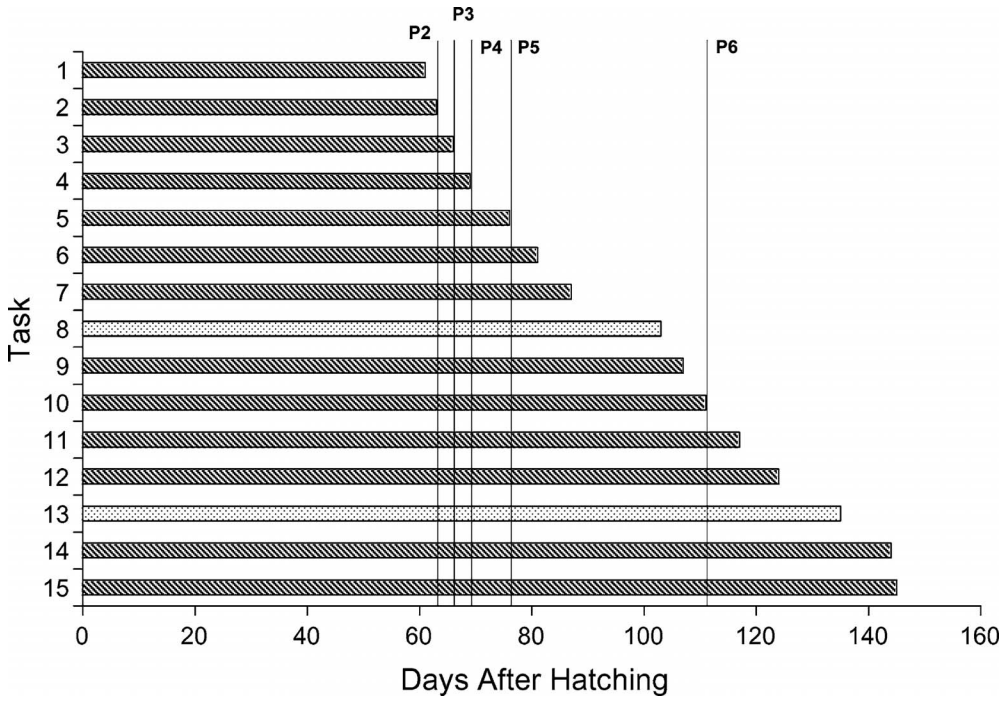

Fig. 3 Experiment 1, older jays: mean age at which the older jays mastered the tasks of scale 1 by Uzgiris and Hunt (1975). The *bar* for task 8 and for task 13 are based on three birds because, Russell and Carlo did not attend to these two tasks due to their neophobia of the cover. Both tasks were re-administered and mastered last, after task 15. *Lines* labelled with P2–P6 show the corresponding piagetian stages

the first time during this test, two covers were introduced contemporaneously inside the experimental setup and the jays were initially afraid of the increased number of covers. In fact, this task shows an increased number of not attended trials compared to task 4 (see Table 3), even if jays did not make any errors when they decided to attend to the test. Contrary to psittacine birds (Pepperberg and Kozak 1986; Pepperberg and Funk 1990; Funk 1996; Pepperberg et al. 1997) and humans (Piaget 1952, original work published in 1936) and similarly to magpies (Pollok et al. 2000), all the birds chose the correct location on all trials and no "A-not-B errors" occurred (see S1 for video clip 1).

Task 6 (two sites, alternating visible) and task 7 (three sites, alternating visible) Analysing the number of not attended trials (see Table 3) during task 6, jays appeared to have got used to the increased number of screens, but as soon as a third screen appeared in task 7, the number of not attended trials rose again, showing that an increase in the number of screens (from two to three) was a source of fear for the animals. Furthermore, there was also an increase in the number of errors in both tasks during the first one or two trials, even though all the jays immediately mastered the subsequent trials when they paid attention to the test. It is difficult to evaluate whether the increased errors were due to the higher cognitive development required by the task or simply related to "neophobia" which is fully developed at this age.

Successive visible displacements

Task 8 (three sites, successive visible) During this task, ground covers were substituted for the first time with small vertical screens, as per the experimental protocol. One jay, Russel, did not attend to six sessions of task 8 and to four trials of the mastered session. We realised that this was due to fear of the sharp corners of the screens. Fear responses disappeared by presenting the animal with a new set of screens with the corners rounded; however, we decided to submit the task again after task 15 to reduce habituation (see Fig. 3). All the other jays mastered the task making very few errors.

Task 9 (superimposed covers) Jays had no problems mastering the task of searching under three superimposed covers. After the first session, the birds sometimes tried to reach the object as quickly as possible by removing more than one screen at the same time. This response was not scored as a mistake, but in order to abolish such behaviour of multiple displacement of the covers adhesive tape was used to fix the first and smallest cover onto the bottom of the "cake box". This simple method forced jays to remove only one cover at a time (see S2 for video clip 2).

Invisible displacements

Task 10 (complete hiding, invisible) Jays mastered this task with no errors. One animal, during the first trials, searched inside the box and then went to search under the cover where

Table 3 Experiment 1 (older jays): number of presented, not attended and attended sessions to which older jays were exposed before meeting criterion in each of the 15 tasks

Task of Scale 1	Piagetian stage	Subjects	Total number of sessions	Sessions not attended (zero trials each)	Attended sessions (nine trials each)	Trials not attended, last session	Errors last session	Performance
1	2	Ross	1	0	1	0	0	Criterion
		Mat	1	0	1	0	0	”
		Carlo	1	0	1	0	0	”
		Russell	1	0	1	0	0	”
2	2	Ross	1	0	1	0	0	Criterion
		Mat	1	0	1	0	0	”
		Carlo	2	0	1	0	0	”
		Russell	1	0	1	0	0	”
3	3	Ross	1	0	1	0	0	Criterion
		Mat	1	0	1	0	0	”
		Carlo	1	0	1	0	0	”
		Russell	1	0	1	0	0	”
4	4	Ross	1	0	1	0	0	Criterion
		Mat	2	1	1	1	0	”
		Carlo	2	1	1	1	0	”
		Russell	2	0	2	0	0	”
5	5	Ross	1	0	1	0	0	Criterion
		Mat	3	2	1	2	0	”
		Carlo	2	1	1	1	0	”
		Russell	2	1	1	1	0	”
6	5	Ross	1	0	1	1	1	Criterion
		Mat	1	0	1	0	1	”
		Carlo	1	0	1	0	0	”
		Russell	2	1	1	1	1	”
7	5	Ross	1	0	1	0	0	Criterion
		Mat	3	0	3	3	1	”
		Carlo	2	1	1	2	1	”
		Russell	1	0	1	0	1	”
8	5	Ross	1	0	1	1	1	Criterion
		Mat	1	0	1	2	0	”
		Carlo	3	1	2	1	0	”
		Russell	7[a]	6	1	4	0	”
9	5	Ross	1	0	1	0	0	Criterion
		Mat	2	1	1	1	0	”
		Carlo	1	0	1	1	0	”
		Russell	1	0	1	0	1	”
10	6	Ross	1	0	1	0	0	Criterion
		Mat	1	0	1	0	0	”
		Carlo	1	0	1	0	0	”
		Russell	1	0	1	0	0	”
11	6	Ross	3	0	3	3	2	Criterion
		Mat	2	0	2	1	0	”
		Carlo	2	1	1	2	1	”
		Russell	1	0	1	0	1	”
12	6	Ross	1	0	1	0	2	Criterion
		Mat	3	0	3	2	1	”
		Carlo	2	1	1	0	1	”
		Russell	1	0	1	0	2	”
13	6	Ross	3	1	2	5	1	Criterion
		Mat	1	0	1	0	1	”
		Carlo	6[a]	5	1	4	1	”
		Russell	2	1	1	1	2	”

Table 3 Continued

Task of Scale 1	Piagetian stage	Subjects	Total number of sessions	Sessions not attended (zero trials each)	Attended sessions (nine trials each)	Trials not attended, last session	Errors last session	Performance
14	6	Ross	2	1	1	0	0	Criterion
		Mat	1	0	1	1	1	”
		Carlo	3	1	2	1	0	”
		Russell	3	2	1	3	0	”
15	6	Ross	2	1	1	0	0	Criterion
		Mat	1	0	1	0	0	”
		Carlo	1	0	1	0	0	”
		Russell	3	2	1	0	0	”

For the last session, the number of trials not attended and the number of errors that jays made before passing to the next task are also reported

[a]Task mastered as the last task after task 15, jays were fearful of the screens/covers

the box had disappeared. All the other jays immediately searched under the cover.

Task 11, task 12 and task 13 (complex complete hiding, invisible) These tasks required the use of two or three covers/screens at the same time to obtain a complex complete invisible displacement of the objects. For this task too, as for tasks 6 and 7, the increasing number of screens generated fear in the jays. The birds responded with a less cooperative behaviour (the number of not attended tasks increased) and the number of errors was also higher. One jay, Carlo, did not attend to five sessions of task 13 and to four trials of the mastered session because it was too fearful of the sharp corners of the screens. We rounded the corners and we submitted the last task again after task 15, following the same protocol used for another jay previously (see task 8). Jays mastered tasks 11, 12 and 13 with a higher number of errors compared to the other tasks (see S3 for video clip 3).

Task 14 (three sites, invisible) This task was easily mastered by all the jays. One of the few errors made (see Table 3) was that of searching under the first screen of disappearance during the first presentation. During the following trials, the jays went directly to the correct position (see S4 for video clip 4).

Task 15 (trick) All the birds achieved the successful criterion by systematically searching in reverse order from the final screen to the first one. They were led to believe that the object was hidden behind the last screen, whereas it had already been placed under the first one (see S5 for video clip 5). From the point of view of general behaviour, it is interesting to note that during this task the jays performed a close and detailed inspection of each screen before moving on to the next one.

Comparisons using paired-sample *t*-tests were conducted for tasks with similar methods across visible and invisible displacement testing. Performance on visible displacement tasks was predicted to be better than performance on invisible displacement tasks. A significant difference was found between the accuracy in visible (tasks 3–9) and invisible displacements (tasks 10–15) [$t = 3.77, df = 3, p = 0.03$] with a lower number of errors in visible displacements with random locations than in invisible displacements with random locations. Other comparisons did not show any differences in the number of errors between similar tasks with visible or invisible displacements including tasks 4 and 10 [$t = 1$, $df = 3$, $p = 0.39$], tasks 5 and 11 [$t = 2.6$, $df = 3$, $p = 0.08$], tasks 7 and 13 [$t = 0.3, df = 3, p = 0.78$] and tasks 8 and 14 [$t = 1.73, df = 3, p = 0.18$].

Experiment 2

The aim of this experiment was to check whether testing very young jays before the development of “neophobia” could influence the times needed to achieve the piagetian stages. Moreover, in this second experiment, tasks were administered randomly to investigate whether the full achievement of the stage 6 in jays followed a fixed sequence.

Methods

Subjects

Five hand-raised 15-day-old jays were tested before the development of “neophobia”, starting when they were 15 days old. The apparatus was the same as in experiment 1 (see Figs. 1 and 2).

Tasks

The jays in experiment 2, like the four jays in experiment 1, were tested with the complete scale 1 tasks by Uzgiris

and Hunt (1975), with the exception of tasks 11 and 12 (see Table 4). We omitted two of the easier tasks of invisible displacement in experiment 2, for two main reasons. First of all we decided to administer the jays two additional tasks (see following text) and due to the precocial development of "neophobia", which usually appears when birds are 2 months old, there was not enough time for them to master 17 tasks (15 tasks of scale 1 plus two control tasks) within their 2 months of life. Simply reducing the interval between one experimental session and the next was not considered a good solution because it might increase the risk of learning and habituation to the tasks that we wanted to avoid. Second, we wanted to check whether by reducing the number of complex invisible displacements, jays could, all the same, succeed in the more complex invisible displacements of tasks 14 and 15, following the protocol used by other authors (e.g. Pepperberg et al. 1997). Following previous studies (Pepperberg et al. 1997), we also administered few control tasks to this group of jays as follows:

Task 16: The experimenter repeats task 14 but hides a less favoured item (biscuit/raisin) than the one the jay had previously observed (mealworm/pine seed). The Uzgiris and Hunt scale 1 does not test representational memory which is why we added this task.

Task S: It is a variant of the "Shell game" and it is comparable to those of Doré et al. (1996), Pepperberg et al. (1997) and Sophian (1985). The experimenter visibly hides an object behind one screen and then the position of the screen is visibly exchanged with one of the other two screens (see S6 for video clip 6).

Housing and procedure

Administration of the tasks began when the birds were still very young, about 15 days old. For this reason, we initially tested individual jays in an "experimental nest", by separating the focal animal from the others with an opaque barrier for a short time to avoid any stress owing to the lack of social contact. As soon as the birds were 20 days old and began to walk all around the nest in the cardboard box, we moved them into the experimental aviary. Compared to the aviary used for the jays in experiment 1, the aviary used in experiment 2 allowed us to visually isolate the experimental subject from the others by simply moving them into a second compartment.

Criteria and trials

The performing criteria to complete the trials were those of scale 1 by Uzgiris and Hunt (1975), but with this group of jays we reduced the number of trials for each task and also modified the task sequence in order to investigate whether the development of the object permanence in jays follows the same achieving sequence as for other species. In comparison with experiment 1, the jays had to respond to six presentations (instead of nine) with no more than two mistakes to move on to the following task. Young jays (see Fig. 1) were tested every 2–3 days according to their willingness to cooperate with the experimenters. After they passed one task, the sequence of the following tasks was chosen randomly from among the remaining tasks in the Uzgiris and Hunt scale 1 (1975). During each experimental day, at least two randomly chosen tasks were presented; if the jay failed to master them, then the next task in the sequential order was presented. Jays were allowed to master more than one session successfully for each testing day with a maximum of three (see Table 4). During the first presentation when jays were 15 days old, only task 1 for a motor development limit was presented. At this age, birds are not able to move properly and they do not have the motor coordination to master the other tasks.

Results and discussion

Three jays achieved all the stages of scale 1, including the stage 6 competence, in a very short time, before reaching the age of 50 days (see Fig. 4). Furthermore, two of them also mastered task 16 and task "S". The other two jays did not attend to the experiment after task 3. Development of the "neophobic stage" in these subjects began earlier when compared to the other birds and for this reason the jays no longer interacted with the experimenters.

Comparisons using paired-sample *t*-tests were conducted for tasks with similar methods across visible and invisible displacement testing. Performance on visible displacement tasks was predicted to be better than performance on invisible displacement tasks. A significant difference was found between the accuracy in visible (tasks 3–9) and invisible displacements (tasks 10–15) [$t = 4.15, df = 2, p = 0.05$] with a lower number of errors in visible displacements with random locations than in invisible displacements with random locations. The difference between the accuracy in visible (tasks 3–9) and invisible displacements (tasks 10–15) is more clear when taking into account the performances of all the jays that completed the 15 tasks ($n = 4$ experiment 1, $n = 3$ experiment 2, total $n = 7$; $t = 4.17, df = 6, p = 0.005$). Testing jays at an early stage of development, before they entered the "neophobic stage", affected the piagetian stages in terms of achievement times. A significant difference in the total number of sessions ("attended" and "not attended") required to pass the 15 tasks was found between the two groups of jays [$t = 4.22, df = 5, p = 0.008$], with a higher number of sessions for the older jays which was probably related to neophobia. The difference is, in fact, in the number of sessions "not attended" between the jays in experiment 1 that had already achieved "neophobia" in comparison with the younger

Table 4 Experiment 2 (younger jays): development of object permanence and its relation to the general behaviour development before the complete achievement of the "neophobic stage"

Age (days old)	Jay	Random sequence tasks	Sequence task	Tasks passed	Piagetian stage	Results	General behaviour development
15	Violet	–	1	1	–	Criterion	Jays start to move all around the nest and on day 20 also in the aviary.
	Cyan	–	1	1	–	Criterion	
	Red	–	1	1	–	Criterion	
	Lola	–	1	1	–	Criterion	
	Elvis	–	1	1	–	Criterion	
26	Violet	5, 10	2	2	Stage 2	Criterion	Jays start to peck at food and objects but they are not able to feed themselves.
	Cyan	5, 10	2	2	Stage 2	Criterion	
	Red	5, 10	2	2	Stage 2	Criterion	
	Lola	5, 10	2	2	Stage 2	Criterion	
	Elvis	5, 10	2	2	Stage 2	Criterion	
28	Violet	6, 13	3	None	–	Criterion not met	Jays call the experimenters repeating sounds at low volumes. Pilfering behaviour appears for the first time, before the appearance of food-caching.
	Cyan	6, 13	3	None	–	Criterion not met	
	Red	6, 13	3	None	–	Criterion not met	
	Lola	6, 13	3	None	–	Criterion not met	
	Elvis	6, 13	3	3	Stage 3	Criterion	
31	Violet	6, 13	3	3	Stage 3	Criterion	There is an evident hierarchy for the first time. "Violet" is the dominant one, "Cyan" is in the middle and "Red" is the more subordinate one. At this time, hierarchy reflects the cognitive development (the ability to master the tasks): the dominant one is the best while the subordinate one is the worst at solving the tests.
	Cyan	6, 13	3	3	Stage 3	Criterion	
	Red	6, 13	3	3	Stage 3	Criterion	
	Lola	6, 13	3	3	Stage 3	Criterion	
	Elvis	8, 10	4		Stage 4	Criterion	
35	Violet	8, 10	4	4	Stage 4	Criterion	"Violet" is the first to begin to repeat word-like sounds. The other young jays follow with the same behaviour the day after. "Red" and "Lola" stop cooperating with experimenters and their fear increases.
	Cyan	8, 10	4	None	–	Criterion not met	
	Red	8, 10	4	None	–	*Not Attended*	
	Lola	8, 10	4	None	–	*Not Attended*	
	Elvis	13, 9	5	None	–	Criterion not met	
38	Violet	13, 9; 10, 14; 9, 13	5, 6, 7	5, 6, 7	Stage 5—partial	Criterion	"Food-storing" behaviour appears although it is still incomplete. At this time, Jays store only food; with non-food items they simply play. Jay "Elvis" solves one of the random sequence tasks by moving from task 4 to task 9.
	Cyan	8, 10	4	4	Stage 4	Criterion	
	Red	8, 10	4	None	–	*Not attended*	

Table 4 Continued.

Age (days old)	Jay	Random sequence tasks	Sequence task	Tasks passed	Piagetian stage	Results	General behaviour development
	Lola	8, 10	4	None	–	*Not attended*	
	Elvis	13, 9	5, 6	9[a], 5, 6	Stage 5— partial	Criterion	
40	Violet	14, 10; 13, 14; 15, 14	8, 9, 10	8, 9, 10	Stage 5 and first task, Stage 6	Criterion	Jays also store non-food items. The hierarchy is changing and Red, the more subordinate one, is now the dominant jay. Between "Lola" and "Elvis", the hierarchy is not yet well defined.
	Cyan	10, 9; 10, 14; 9, 13	5, 6, 7	5, 6, 7	Stage 5 and first task, Stage 6	Criterion	
	Red	8, 10	4	None	–	*Not attended*	
	Lola	8, 10	4	None	–	*Not attended*	
	Elvis	13,10	7, 8	7, 8	Stage 5	Criterion	
42	Violet	[b]	13, 14, 15	13, 14, 15	Stage 6— Fully	Criterion	"Red" and "Lola" continue to not attend to the tasks and they are the most fearful of the jays. "Elvis" partially solves the single invisible displacement of task 13; it searches inside the box but then it stops and does not search under the screen.
	Cyan	14, 10; 13, 14; 15, 14	8, 9, 10	8, 9, 10	Stage 6— partial	Criterion	
	Red	8, 10	4	None	–	*Not attended*	
	Lola	8, 10	4	None	–	*Not attended*	
	Elvis	13, 10	10, 13	10	Stage 6— first task	Criterion	
48	Violet	–	16, S	16, S	Two control tasks	Criterion	Hierarchy is now completely reversed. The dominant one is "Red" and the most subordinate is "Violet". Neophobia is growing faster. However, it is still possible to test "Violet" and "Cyan". Now, the hierarchy reflects the gradient of neophobia reached: the higher the social position, the more developed neophobic behaviour.
	Cyan	13[b], 14, 15	13, 14, 15	13, 14, 15	Stage 6— fully	Criterion	
	Red	8, 10	4	None	–	*Not attended*	
	Lola	8, 10	4	None	–	*Not attended*	
	Elvis	13[b], 14, 15	13, 14, 15	13	Stage 6— partial	Criterion	
50	Violet	–	–	–	–	All the tasks achieved— not tested anymore	The "neophobic stage" is almost completely reached. Jays do not eat mealworms anymore from the experimenters hand and they emit alarm calls when people go close to the aviary. Jays are moved to a wider community aviary. Only "Elvis" is not neophobic and it is still possible to test it for the control tasks after 1 week.
	Cyan	–	16, Shell	16, Shell	–	*Not attended*	
	Red	8, 10	4	None	–	*Not attended*	
	Lola	8, 10	4	None	–	*Not attended*	
	Elvis	14[a], 15, 16	14, 15, 16	14, 15	Stage 6—fully	Criterion for 14, 15 not for 16	
56	Elvis	16, Shell	16, Shell	16, Shell	Two control tasks	Criterion	Also, this subject is moved to the community aviary; end of the experiment.

[a]A jay solved one of the random sequence tasks.

[b]After achieving task 13, tasks 14 and 15 were presented sequentially.

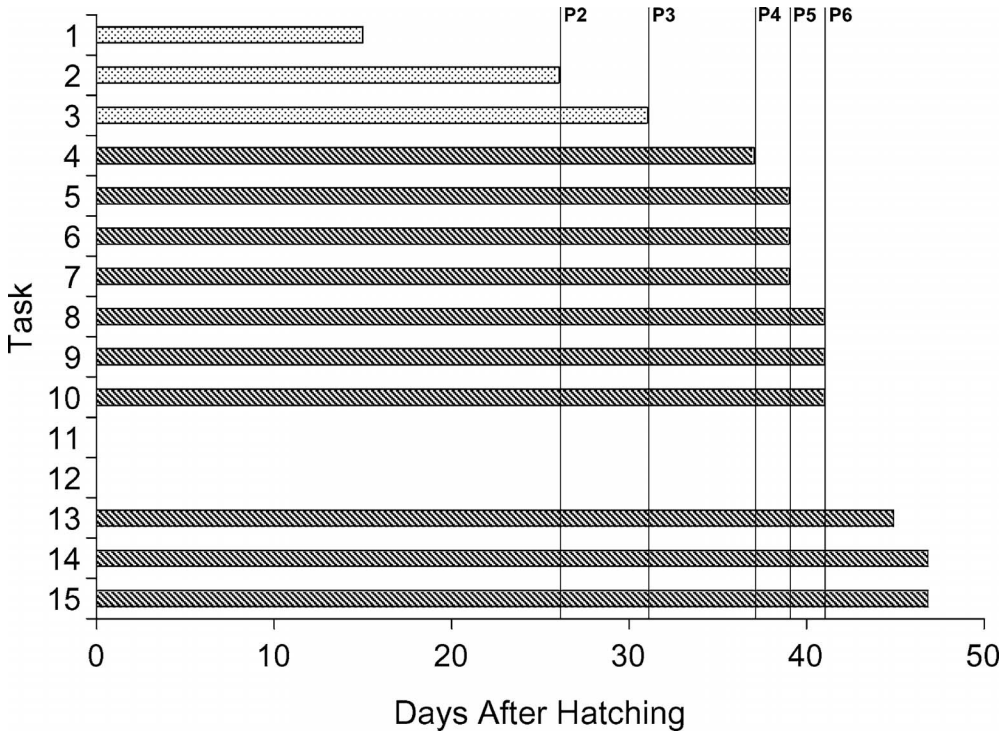

Fig. 4 Experiment 2, younger jays: mean age at which the younger jays mastered the tasks of scale 1 by Uzgiris and Hunt (1975). After task 3, two of the young jays, Red and Lola, did not attend to anymore experiments and for this reason the following *bars* are based on three jays, Violet, Cyan, Elvis. Tasks 11 and 12 were not administered to younger jays, see also the Task section of experiment 2. *Lines* labelled with P2–P6 show the corresponding piagetian stages

jays in experiment 2, which were tested before they reached the "neophobic stage" [$t = 3.07$, $df = 5$, $p = 0.02$]. This suggests that "neophobia" increased the time needed to pass to the next session because the older jays in experiment 1 did not attend to a higher number of sessions than the younger jays in experiment 2. Although in experiment 2, tasks were administered in a random order, animals mastered them in the same sequence as reported in the Uzgiris and Hunt scale 1 (1975). Only one subject met the criterion in a randomly presented task, solving task 9 after task 4 (see also Table 4). Furthermore, the maturation of general behaviour seems to relate very well to the different steps of the development of object permanence (see Table 4) and there is also a correspondence with the results of Pollok et al. (2000) with magpies and of Bugnyar (personal communication 2004) with ravens.

General discussion

The results gathered from our two experiments indicate that jays can fully achieve piagetian stage 6 of object permanence. Although a stage 5 competence would suffice to account for food caching abilities, it is probably not enough to account for the abilities in social interactions that have been described in these birds. Protection of cachings from potential pilferers is probably associated with the understanding of a conspecific's intentions and the manipulation of its beliefs (Clayton and Dickinson 1998; Heinrich and Pepper 1998; Bugnyar and Kotrschal 2002; Clayton et al. 2005; Bugnyar and Heinrich 2006). It is possible that only a full stage 6 competence allows jays to manage these aspects too.

Jays, like magpies (Pollok et al. 2000), cats (Dumas and Doré 1989) and dogs (Gagnon and Doré 1994) do not appear to show A-not-B errors. This appears not to be true for other avian species. Grey parrots, for example, search for the disappeared object where they previously found it even though the object is hidden in another location (Pepperberg et al. 1997). The occurrence of the A-not-B error is probably related to a differing resistance to interference. It seems that passerine food-storing birds have a high resistance to interference (Clayton and Krebs 1994; Hampton and Shettleworth 1996) and this adaptive specialisation could explain the differences among avian species. The validity of the piagetian framework for comparative cognitive studies has been discussed by Doré and Dumas (1987) and by Pepperberg (2002). One source of controversy is given by the detailed descriptions of the ages at which different species achieve the piagetian stages. According to several authors, however, the value of the piagetian framework is not in its specific (i.e. in the particular task that is mastered or when a stage is achieved), but in the idea that such stages of cognitive development exist, that they progress through fixed sequences and that they can be applied across different species (Pepperberg 2002). The results of our experiments with jays seem to support the latter view. The achieving of a piagetian stage in jays seems to

follow a fairly fixed sequence, even when tasks are shown in a random order to the animals, as in experiment 2.

Our results also show that the achieving age of a certain stage is affected by other variables, such as "neophobia" which is not directly related to specific cognitive abilities. Neophobia affected the response of the birds in terms of their times of achievement; both the younger and the older jays achieved a full stage 6 competence but it took longer for the older neophobic birds to master the complete scale 1. An influence of emotional/motivational variables in object permanence task has been reported also in the domestic chick (Regolin et al. 1994b). Another interesting result is the relation that seems to exist between the development of cognitive abilities allowing jays to achieve the different piagetian stages and the development of "mimicry" behaviour. During the developmental period, the earliest jays were able to achieve stages 5 and 6, the earliest jays start to repeat word-like sounds ("babbling behaviour") and to show a full "mimicry" behaviour without any training.

The great development of cognitive studies on corvids during the past years (Hunt 1996; Pollok et al. 2000; Bugnyar and Kotrschal 2002; Chappell and Kacelnik 2002, 2004; Bond et al. 2003;Clayton et al. 2003; Emery 2004; Emery and Clayton 2004a, 2004b; Hunt et al. 2006; Weir and Kacelnik 2006) suggests that certain cognitive abilities that, 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* (Rogers 1997; Vallortigara 2004, 2006; Jarvis et al. 2005). The avian brain is in fact considerably more similar to the mammalian brain than previously thought. According to the new understanding of avian brain organization and its evolutionary relationship (Reiner et al. 2004), it has been estimated that, as in mammals, the adult avian pallium makes up about 75% of the telencephalic volume (Jarvis et al. 2005). The evidence that a large and well-developed avian pallium processes information like the mammalian sensory and motor cortices (Jarvis et al. 2005) supports, from a neuroanatomical and functional point of view, the behavioural studies about the complex cognition and mental abilities of birds. Comparative studies on corvids' and primates' cognition could set the basis for a better understanding of brain functions and mental evolution.

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