Object individuation in 3-day-old chicks: use of property and spatiotemporal information

Laura Fontanari,1 Rosa Rugani,2 Lucia Regolin2 and Giorgio Vallortigara1

1. Center for Mind/Brain Sciences, University of Trento, Italy
2. Department of General Psychology, University of Padova, Italy

Abstract

Object individuation was investigated in newborn domestic chicks. Chicks’ spontaneous tendency to approach the larger group of familiar objects was exploited in a series of five experiments. In the first experiment newborn chicks were reared for 3 days with objects differing in either colour, shape or size. At test, each chick was presented with two groups of events: two objects differing in one property vs. two presentations of the same object. In both cases, all objects involved in the same group of events were sequentially presented and eventually concealed in a different spatial location, and the number of events taking place at each location was equalized. Chicks spontaneously approached the two different objects rather than the single object seen twice. Chicks did not just prefer the more varied set as they did not choose it when the two elements of each group of events were simultaneously presented (Experiment 2). Chicks succeeded when two different objects simultaneously presented were confronted with three identical ones simultaneously presented (Experiment 3), though they failed with sequential presentation of two different objects vs. one object presented three times if they had been familiarized with up to three identical objects (Experiment 4). Chicks instead succeeded if they had been familiarized with objects that were all different from one another (Experiment 5). These young birds thus proved able to use property and spatiotemporal information for object individuation.

Introduction

Humans organize their visual world by segregating external input into separate objects and forming representations of such objects tracing their identity through time and space. Object individuation is the process that allows us to determine the number of objects in an event and to establish their numerical identity (see for a review: Xu, 2007).

Objects can be individuated as distinct on the basis of several sources of information (Spelke, 1990): spatiotemporal information (e.g. the same object cannot occupy two places at the same time), property information (e.g. objects usually do not change in their features), and kind/sortal information (e.g. objects do not usually change kind membership).

There is evidence that starting from 4 months infants represent objects as entities which travel on spatiotemporal continuous paths (Spelke, Kestenbaum, Simons & Wien, 1995; Xu & Carey, 1996; Aguiar & Ballaigregeon, 1999). When presented with two featurally identical objects in spatiotemporal discontinuity, infants preferentially looked at an overall set of one object (the unexpected outcome) than of two objects (the expected outcome).

Several studies employing preferential looking (Spelke, 1990; Xu & Carey, 1996) or manual reaching (Xu, Carey & Welch, 1999; Van de Walle, Carey & Prevor, 2000; Xu & Baker, 2005) paradigms demonstrated that the critical age at which infants fully develop the ability to use property/kind information is 12 months and a link was hypothesized with the acquisition of language, in particular with noun understanding (Xu, 1999, 2002; Rivera & Zawaydeh, 2006). At around 10 months, infants are only able to use property/kind information for establishing object numeracy when presented with animate (i.e. humanlike) vs. inanimate objects (Bonatti, Frot, Zangl & Mehler, 2002). In the typical paradigm to investigate the use of property information (deemed the ‘is-it-one-or-two’ task; Rips, Blok & Newman, 2006; Rhemtulla & Xu, 2007; Xu, 2007) infants are shown two objects differing in shape, colour or size, appearing one by one from behind one screen and disappearing behind the same screen. Once the screen was removed, differences in looking time showed that infants expected to see two objects in the event.

Nonetheless, infants from 5.5 to 9.5 months succeed in individuating objects when the cognitive demand is reduced by presenting a single uncomplicated trajectory or a single occlusion event (Wilcox & Baillargeon, 1998a; Wilcox & Schweinle, 2002; Wilcox & Chapia, 2002). This is also the case when the event itself is simplified; in such case infants from 4.5. to 11.5 months succeed in...
individuating objects (Wilcox & Baillargeon, 1998b; Wilcox, 1999; Wilcox & Chapa, 2004). Converging evidence is also reported employing a simplified manual search paradigm with infants as young as 5 months of age (McCurry, Wilcox & Woods, 2009).

It seems that infants’ previous experience with the physical world plays a crucial role in their ability to use featural information in object individuation. This occurs when the pattern or the colour of an object is experienced as being predictive of its function (Wilcox & Chapa, 2004; Wilcox, Woods & Chapa, 2008), or when infants are allowed multisensory exploration of the objects (Wilcox, Woods, Chapa & McCurry, 2007). Another crucial variable is the comprehension of the words related to objects (Xu & Carey, 1996; Xu, 1999; Rivera & Zawaydeh, 2006).

In spite of evidence supporting the role of language, non-human animal species were demonstrated to use all of the above-described types of information for object individuation. The process of parsing the visual information into distinct objects and forming mental representations of those objects is ecologically relevant to animal survival in the natural environment, to avoid obstacles, find food, detect predators and conspecifics. Munakata, Santos, Spekk, Hauser and O’Reilly (2001) demonstrated that monkeys parse an array of adjacent food items into distinct objects, representing those objects as separately movable whereas it is only at around 12 months of age that this ability is available in infants (Xu et al., 1999).

Other studies have demonstrated that adult non-human primates are able to use spatiotemporal as well as property/kind information for individuating objects. Those studies employed the is-it-one-or-two task either with looking time measures or manual reaching paradigms with both visible and invisible objects (Uller, Xu, Carey & Hauser, 1997; Santos, Sulkowski & Hauser, 2002; Phillips & Santos, 2007; Mendes, Rakoczey & Call, 2008). For example, in the study by Santos and colleagues (2002), monkeys who had at first seen one piece of food being placed inside a box, when allowed to search for it in the box, could find either that same food (consistent condition) or a different food (violation condition). The monkeys detected the change in property, searching longer in the violation condition as compared to the consistent condition. No evidence is available for non-primate animal species. The present research contributes the first attempt to investigate object individuation in a species, the domestic chick (Gallus gallus), belonging to a different class of vertebrate and in very young individuals, allowing us to finally establish whether this ability can be available early in development and independent from experience or from language. Our data complement and extend evidence from pre-verbal infants, as the latter does not completely rule out the role of experience, or of language predisposition, which is inherent in our species. Moreover, the use of an avian model, endowed with a neural architecture quite different from the mammalian one, allows for inferences concerning the remote origin of this ability, which is possibly shared by the two animal classes and inherited from a common ancestor. More broadly, those data contribute to the understanding of the foundations of object representation, which constitute one of the basic functional units hypothesized by the core knowledge theory (see Spekle & Kinzler, 2007; Carey, 2009; for a review on comparative data see Vallortigara, Regolin, Chiandetti & Rugani, 2010).

In order to investigate object individuation in chicks, we exploited filial imprinting onto artificial objects as a behavioural tool, through an experimental design based on a task inspired by the event-mapping task of Xu and Carey (1996). We took advantage of the strong social attachment chicks develop toward objects they are exposed to soon after hatching to the point that, in the very first days of life, motivation for socially relevant stimuli is stronger than motivation to other kinds of stimuli, e.g. food (Hogan, 1984; Regolin, Rugani, Pagni & Vallortigara, 2005). Moreover, employing artificial objects as imprinting stimuli allows better control of motivational factors than food stimuli (i.e. if chicks are food-reinforced, motivation for food changes at each test trial, as the birds become satiated, while motivation to rejoin the imprinting object does not decrease during the test) and the best control for property information offering the possibility to accurately manipulate object features (i.e. colour, size and shape).

**Experiment 1**

The first experiment investigated whether chicks make use of property information provided by Colour, Size or Shape for object individuation.

Chicks were tested in a 2 vs. 2 events comparison (i.e. one object presented twice vs. two different objects each presented once). Previous studies have demonstrated that chicks tend to approach the larger group of imprinting objects (Rugani, Fontanari, Simoni, Regolin & Vallortigara, 2009; Rugani, Regolin & Vallortigara, 2010). Therefore, if chicks use property information for individuating objects, they should approach the group of events featuring two different objects; if chicks do not use such information, they should behave at random, as they are faced with a choice between two sets comprising the same number of events.

**Materials and methods**

**Subjects, stimuli and rearing conditions**

Subjects were 41 female ‘Hybro’ (a local variety derived from the White Leghorn breed) domestic chicks (Gallus gallus), obtained weekly from a local commercial hatchery (Agricola Berica, Montegalda, Vicenza, Italy) when they were only a few hours old. On their arrival at the

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laboratory, chicks were immediately housed in standard metal home cages (28 cm wide × 32 cm long × 40 cm high) at a controlled temperature (28–31°C) and humidity (68%), with food and water available ad libitum in transparent glass jars (5 cm in diameter, 5 cm high) placed at each corner of the home cage. The cages were constantly (24 h/day) lit by fluorescent lamps (36 W), located 45 cm above the floor of the cages. Each chick was placed singly in one cage, together with a set of six two-dimensional (approximately 1 mm thick) objects, which constituted its imprinting stimulus. Each object was separately suspended in the centre of the cage by a fine thread, at approximately 4–5 cm from the floor, so that it was located at about chicks’ head height. The stimuli were about 2 cm from each other, and overall they occupied an area of about 8 × 8 cm in the centre of the cage. The imprinting objects were made of uniformly coloured cardboard covered with a transparent plastic film. Each set of six objects was composed of two subsets made of three identical objects each. The two subsets differed in either colour, size or shape depending on the experimental condition. The stimuli for the Colour condition were three green squares and three yellow squares (4 × 4 cm); the stimuli for the Size condition were three yellow squares (4 × 4 cm) and three smaller yellow squares (2.77 × 2.77 cm); the stimuli for the Shape condition were three yellow squares (again, 4 × 4 cm) and three yellow ‘Greek crosses’ (4 × 4 cm axis long, obtained from a 4 × 4 cm square following removal of a square area 1.33 × 1.33 cm from each corner). Within each experimental condition, the same stimuli were used for imprinting, training and test (Figure 1).

Separate groups of chicks were reared and tested with different types of property information available: Colour (N = 12), Size (N = 12) or Shape (N = 17).

Chicks were kept in the standard rearing conditions described above from the morning (11.00) of the first day (i.e. Monday, the day of their arrival, which was considered as day 1) to the third day (Wednesday). In the morning (11.00) of day 3, chicks underwent the training, and approximately 1 hour later, they took part in the first testing session.

**Apparatus**

Training and testing took place in an experimental room, located near the rearing room, in which temperature and humidity were maintained at 25°C and 70%, respectively. The room was kept dark, except for the light coming from a 40 W lamp placed approximately 80 cm above the centre of the apparatus. The testing apparatus (Figure 2) consisted in a circular arena (95 cm in diameter and 30 cm outer wall height) with the floor uniformly lined with a white plastic sheet. Within the arena, adjacent to the outer wall, there was a holding box (10 × 20 × 20 cm), where the chick was confined shortly before the beginning of each trial. The box was made of opaque plastic sheets, with an open top allowing the insertion of the chick before each trial. The side of the holding box, facing the centre of the arena, consisted of a removable clear glass partition (20 × 10 cm), in such a way that the subjects, while confined, could see the centre of the arena. During the training phase, one single cardboard

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screen (16 × 8 cm) was used, positioned in the centre of the arena, in front of and 35 cm away from the holding box. During testing, two opaque cardboard screens, identical in size, colour and pattern (i.e. blue coloured with a yellow ‘X’ on them) to the one used during training, were positioned in the centre of the arena (see Figure 2), symmetrically with respect to the front of the confining box (i.e. 35 cm away from it and 20 cm apart from one another).

Procedure

Training
On day 3, in the morning, chicks underwent a preliminary training session. Each chick was placed within the testing arena (not confined in the holding box), in front of one screen, together with a single visible stimulus. The stimulus was identical to one of the six stimuli used during rearing (which type of stimulus was chosen was randomized across subjects). An exception was made in the Size condition, where the larger yellow square was used at training for all subjects (experience with the larger stimulus needed to be equalized in this condition as such a stimulus may constitute a super-normal stimulus for the chicks; Tinbergen, 1948).

The stimulus was held from above by the experimenter (not visible to the chick), via a fine thread, and initially kept suspended between the holding box and the screen. The chick was left free to move around and get acquainted with the environment for approximately 5 minutes. Thereafter, the experimenter slowly moved the stimulus towards the screen, and then behind it, until the stimulus disappeared completely from the chick’s sight. This procedure was repeated a few times until the chick responded by promptly following and rejoining the stimulus behind the screen. Thereafter, the chick was confined within the holding box, behind a transparent frontal partition through which it could see the stimulus being moved and hidden behind the screen. As soon as the stimulus had completely disappeared from sight, the chick was set free in the arena by lifting the transparent partition. Every time the chick rejoined the stimulus, as a reward, it was allowed to spend a few seconds close to it. The whole procedure was restarted and the training ended when the chick had rejoined the stimulus for three consecutive times. On average, to complete the training a chick required approximately 15 minutes.

Testing
At the beginning of each testing trial, the chick was confined within the holding box, behind the transparent partition, from where it could see the two identical screens in the centre of the arena.

The chick was shown two groups of events, each taking place by one of the two screens only (see Figure 3). One group of events consisted of two presentations of the same stimulus (identical to the stimulus employed during training). The other consisted of a single presentation of two different stimuli (each identical to one of the two sub-groups of objects used for imprinting, and therefore the two stimuli at test differed for one property i.e. Colour, Size or Shape). Before the beginning of each trial, all of the stimuli to be involved in the same group of events were positioned behind the same screen; during this manipulation phase an opaque partition (made of a white paper sheet) was temporarily placed in front of the holding box in order to hide the stimuli from the chick’s sight. The opaque partition was then removed and the trial could start. One stimulus from one group of events was made to appear from behind the screen where it had previously been positioned, it was slowly moved towards the front of the confined chick, it remained in front of the chick (beyond the clear partition) for a few seconds, and then it was made to disappear behind the same screen from where it had initially emerged, and was left behind it. It was then picked up once again and the whole procedure was repeated so that the same stimulus was shown twice to the chick. The same procedure was carried out for the other group of events, the only difference being that in this case two different stimuli were sequentially presented, one each, to the chick. In this way, an equal number of events (i.e. two) took place by each screen, differing in the actual number of objects involved (either one or two).

The whole procedure lasted between 40 and 45 seconds. Each stimulus took 3 seconds to be moved from behind the screen to the front of the holding box, where it was kept for another 3 seconds, and then it took 3 seconds to be moved back behind the screen (9 seconds overall). About 2 seconds elapsed from the disappearance of one object and the appearance of the next (either same or different) object. Immediately after the disappearance of both sets (with a delay of 5 seconds), the transparent partition was removed and the chick was left

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free to move around and search for its imprinting stimuli within the arena. To prevent the chicks from spotting the hidden stimuli before having circled almost completely around the screen, the two vertical sides were provided with 3 cm bent back edges. A choice for one screen was scored when the chick’s head had entered the area behind that screen (beyond the side edges); only the choice of the first screen visited was scored and thereafter the trial was considered over. The response time, i.e. the time (in seconds) taken by the chick to go round the chosen screen was also scored. At the end of each trial, chicks were allowed to spend 1–2 seconds together with their ‘social companions’ present behind the screen that had been chosen. If a chick did not approach either screen within 3 minutes, the trial was considered null and void and it was repeated immediately afterwards. After three consecutive null trials, the chick was placed back in its own rearing cage (in the presence of the imprinting objects) for approximately 1 hour before being resubmitted to further trials. After another three consecutive null trials, the same procedure was repeated and if, once again, the chick scored for the third time three consecutive null trials, it was discarded from the experiment (this occurred for about 5% of chicks, not included in the final sample).

Each chick underwent one complete testing session of 10 valid trials. The order of presentation (which event was first and which second) of the two groups of events (a same stimulus presented twice vs. two different stimuli presented once each) as well as the position (left screen–right screen) of appearance and disappearance of either set was counterbalanced within each chick’s 10 testing trials.

The number of trials in which each chick chose the screen hiding two stimuli differing for one property (which was regarded as the correct choice) was considered and percentages were computed as: (number of correct choices/10) × 100. Analysis of variance (ANOVA), to compare the percentages of correct choices between the three different experimental conditions based on property information provided by Colour, Size and Shape) and one-sample two-tailed t-test (to assess significant departures from chance level, i.e. 50%) were used. Non-parametric statistics were performed employing the chi-square test for analysing performance in the chick’s initial trials. A repeated measures ANOVA was computed on the response times (seconds) as dependent variable, scored for ‘correct’ vs. ‘incorrect’ trials (repeated measures variable).

**Results**

No statistically significant main effect of the type of property information ($F_{(2,38)} = 0.133; p = .876$) was revealed by the ANOVA run on the percentages of correct choices (Colour $N = 12$, mean = 59.166; sem = 3.362; Size $N = 12$, mean = 60.833; sem = 2.289; Shape $N = 17$, mean = 61.176; sem = 2.829). Data were therefore merged and the overall mean was compared with chance (50%) through a one sample t-test. Chicks preferentially approached the screen hiding two different objects ($t(40) = 6.410; p < .001; mean = 60.487; sem = 1.636$; see Figure 4a).

A chi-square analysis was used on chicks’ initial performance. As chicks’ behaviour in the very first test trial is usually affected by the response to the novelty of the test situation (e.g. two screens are present in the arena), the first three trials were considered. A chick was regarded as successful if it scored at least two correct trials within the first three trials, and this was the case for 27 chicks; the remaining 14 chicks were regarded as unsuccessful (they made at least two mistakes in the first three trials). The difference (27 vs. 14) was significant ($X^2(1) = 4.122; p = .042$).

The ANOVA on the response times showed no differences between the ‘correct’ vs. the ‘incorrect’ trials ($F_{(1,38)} = 0.327; p = .570$), nor a significant interaction (Response time $\times$ Experimental condition $F_{(2,38)} = 0.499; p = .611$).

A statistically significant effect was found when analysing the average response times (considering together correct and incorrect responses) in the three experimental conditions ($F_{(2,38)} = 18.239; p = .0001$; Colour: mean = 43.964; sem = 4.059; Size: mean = 65.239; sem = 5.121; Shape: mean = 30.865; sem = 3.974) (Figure 5). Post-hoc using Fisher’s LSD revealed that each condition differed from the other two (Colour vs. Shape, $p = .027$; Shape vs. Size, $p < .0001$; Size vs. Colour, $p = .0014$). Chicks were
faster when the two objects differed in shape, and slower when objects differed in size. Difference in response times found are in line with results obtained on other species. In fact, similarly to chicks, humans showed that differences in shape are the most salient feature (Leslie, Xu, Tremoulet & Scholl, 1998) compared to the other properties, while, for monkeys colour would be the most salient feature (Santos et al., 2002). Moreover, infants from 4.5 months use shape or size features for individuating that two objects are involved in an event, but it is not until 7.5 months that they use pattern information and only at 11.5 months do they successfully use colour information for object individuation (Wilcox, 1999). The critical age decreases to 4.5 months for pattern and 7.5 months for colour if infants have been previously exposed to events in which the pattern or the colour of an object is experienced as predictive of its function (Wilcox & Chapa, 2004).

Overall, the results of the first experiment show that chicks spontaneously individuate the larger number of objects making use of property information (Colour, Size or Shape).

Experiment 2

Experiment 1 supports the idea that chicks can individuate objects using property information provided by Colour, Shape or Size as in all cases chicks chose the screen hiding two different objects. A possible objection would be that chicks chose two different objects because they may simply prefer a more varied group of events (two different stimuli could be preferred to two identical stimuli). To test this possibility, a new group of chicks were presented with two identical vs. two different objects, both objects in the same pair being simultaneously visible. In fact there is clear (though indirect) evidence from previous literature that chicks are able to individuate identical objects as separate if these are seen simultaneously (Rugani et al., 2009, 2010).

If chicks’ responses favoured the higher number of objects, no screen would be preferred, as both screens concealed two objects. If, on the other hand, chicks were attracted by a more varied set of objects, then they would have preferred to search the screen hiding two different objects.

Since in the previous experiment there was no difference due to objects’ features, the Colour condition was arbitrarily used in Experiment 2.

Subjects, stimuli and procedure

A new group of 12 female chicks were tested. Imprinting and testing stimuli, apparatus and general training procedures were identical for all chicks and identical to those used in the Colour condition of Experiment 1.

At test two events were sequentially presented, and each event consisted of the simultaneous presentation of two objects: either two identical squares (e.g. yellow + yellow) or two squares of a different colour (i.e. yellow + green). In each event the two objects were made to simultaneously appear from one screen, coming in front of the chick confined in the holding box and then made to slowly disappear behind the same screen. The whole procedure took approximately 20 seconds. After a delay of 5 seconds, the chick was set free within the arena.

The use in the two events of the colour (yellow or green) of the objects was randomized between subjects, whereas the order of events (e.g. yellow + yellow vs. yellow + green) as well as which screen concealed which event were counterbalanced within each chick’s 10 testing trials.

The circumnavigation of the screen hiding two different objects was arbitrarily chosen as correct choice, and percentages were computed, as described for the previous experiment.

Results

The mean percentage of correct responses did not differ from chance level ($t(11) = -0.232, p = .820; \text{mean} = 49.166; \text{sem} = 3.579$) (Figure 4b).

When two events are compared, each comprising a group of two objects presented simultaneously, the chicks did not show any preference, even though one group was made of two identical stimuli and the other was made of two stimuli differing in colour. The lack of choice in this experiment supports the conclusion that chicks’ performance in the previous experiment was based on the use of property information for object individuation, rather than on a general preference for the most varied set of stimuli.

Experiment 3

In the third experiment, chicks’ ability to use spatio-temporal information was assessed. Chicks were pre-
sent with a two vs. three objects comparison in which each set of objects was presented simultaneously. Two different objects were compared with three identical objects for providing further support to the findings of Experiments 1 and 2, to rule out the possibility that chicks’ choice depended on attraction for the more varied group of stimuli.

If chicks do use spatiotemporal information, they would approach the screen hiding the larger number of objects.

Subjects, stimuli and procedure

A new group of 12 female chicks were tested. Rearing conditions were identical to those previously described.

Imprinting and test stimuli, apparatus and general training procedures were identical for all chicks and identical to those used in Experiment 2. The procedure was also similar to that employed in Experiment 2, but three identical squares (e.g. yellow + yellow + yellow) were simultaneously presented and confronted with another event featuring the simultaneous presentation of two stimuli of different colour (i.e. yellow + green). The whole procedure took approximately 20 seconds, and after a delay of 5 seconds, the chick was released in the arena.

Stimuli used and their presentation were balanced at test. Correct choices (i.e. going round the screen hiding three identical objects) were computed as percentages.

Results

Chicks preferred the screen hiding three identical objects ($t(11) = 4.304; p = .001; \text{mean} = 63.333; \text{sem} = 3.097$; see Figure 4c).

As regards chicks’ initial performance, seven chicks scored at least two correct trials within the first three trials, while five chicks scored at least two mistaken trials in the first three trials, the difference (7 vs. 5) being non-significant ($X^2 (1) = 0.333; p = .563$).

The results suggested that chicks are able to use spatiotemporal information for establishing the numerical identity of objects presented in a visual scene, even though they do not perform above chance in the very first trials.

Experiment 4

From the previous experiment it appears that chicks are able to correctly identify up to three objects if spatiotemporal cues are available. A fourth experiment was carried out to assess whether, in the absence of such cues, increasing the number of events taking place would affect the use of property information. Chicks were required to choose between a larger set of identical objects contrasted with a smaller set of different objects; objects of both sets were presented in spatiotemporal discontinuity.

The procedure was identical to that employed in the first experiment, except for the fact that one group of events was composed of a higher number (i.e. three) of events (i.e. one stimulus sequentially presented three times) and was compared to a group of two events comprising two different stimuli, each sequentially presented once only.

Would the chick regard three presentations of the same object as ‘more’ than two presentations each involving a different object?

Subjects, stimuli and procedure

A new group of 12 female chicks were tested. Rearing conditions, apparatus, as well as imprinting and testing stimuli were identical to those already described.

The testing procedure was also identical to that of Experiment 1, with the difference that one group of events was made of one stimulus sequentially presented three times whereas the other group of events was made of two different stimuli sequentially presented once each. The whole procedure took approximately 45 seconds and the overall time of presentation of each group of events was comparable (to this purpose, for the group of three events the time of presentation of each object was reduced to 6 seconds). After a delay of 5 seconds, the chick was let free within the arena.

At test, the order of presentation of the groups of events as well as the screen of appearance and disappearance of the two sets were counterbalanced within each chick’s 10 test trials, whereas the colour of the stimuli was randomized between subjects.

The percentage of correct choices was computed considering the number of trials in which each chick chose the screen hiding the two different stimuli, and data were analyzed as for the previous experiments.

Results

The percentage of correct responses did not differ from chance level ($t(11) = 0.000; p = 1; \text{mean} = 50.000; \text{sem} = 3.692$; see Figure 4d). Results showed that chicks did not prefer a larger number of presentations of the same stimulus (three events) to a smaller number of presentations of two different objects (two events).

Experiment 5

In the previous experiment, chicks did not show a preference between a group of two events made of two different stimuli and a group of three events made of one stimulus presented three times. Chicks’ lack of choice may indicate some limits in the process of object individuation. Alternatively, chicks may have identified three repeated presentations of the same stimulus as three different, though identical, objects. Due to rearing conditions, chicks were familiar with the fact that up to three distinct but identical objects can be actually encountered.
Experiment 5 was devised to deal with this issue. In this experiment, chicks experienced during rearing objects that were all different from one another: a set of five imprinting stimuli differing in their individual features was employed. Chicks were then tested in a three vs. two events comparison, one stimulus presented three times vs. two different stimuli presented once each.

**Subjects, stimuli and procedure**

A new group of 13 female chicks were tested. Rearing conditions were identical to those previously described. Imprinting and test stimuli consisted of a group of five two-dimensional yellow squares (4 × 4 cm). Each stimulus differed from the others by the relative orientation of two black segments (each 2 cm long × 0.90 mm wide), printed on both sides of each square (Figure 6). Previous studies have demonstrated that chicks are sensitive to these kinds of features, which would allow for individual object recognition (Vallortigara & Andrew, 1991, 1994).

The apparatus and the general training and testing procedures were identical to those of Experiment 4. All the stimuli employed in the test phase were different from each other and were also different from the single stimulus that was used during training (which stimulus was used at training was randomized across subjects).

The order of the events, as well as the screen (left–right) of appearance and disappearance of the two sets were counterbalanced within each chick’s 10 test trials. Moreover, each stimulus was randomly assigned to either group of events trial by trial, in order to avoid effects due to learning.

The percentage of correct choices was computed considering as correct the trials in which the chick chose the screen hiding two different stimuli.

**Results**

Chicks preferred the screen hiding two different objects (t(12) = 5.333; p < .001; mean = 62.307; sem = 2.307; see Figure 4c).

As regards chicks’ initial performance, 10 chicks scored at least two correct trials within the first three trials, and three chicks scored at least two mistaken trials within the first three trials, the difference (10 vs. 3) being marginally non-significant (Χ² (1) = 3.769; p = .052).

Results support the hypothesis that chicks can use the property information provided by a peculiar feature of the stimuli for individuating the larger number of elements irrespective of (and against) the number of events. Unlike the previous experiment, in which chicks failed, here chicks had become familiar with five unique individuals prior to the test, making it unlikely that a repeated presentation of the same individual would be computed as two or even three distinct and identical individuals.

**General discussion and conclusion**

A spontaneous ability to use property and spatiotemporal information for object individuation was demonstrated in very young chicks. In the first experiment chicks approached the screen that definitely hid two objects (differing for Colour, Size or Shape) as compared to the screen from which the same object had been presented twice, and such a screen could therefore either hide one object or two identical ones. This result though can be explained in terms of use of property information for object individuation or of chicks’ preference for the more varied group. This last alternative explanation was ruled out in Experiment 2. Chicks employed spatiotemporal information for object individuation, and correctly identified up to three objects that were simultaneously presented (Experiment 3). In Experiment 4 we assessed whether increasing the number of events would affect the use of property information. If chicks computed three presentations of the same object as more than two presentations each involving a different object, they would have approached the screen hiding only one object, whereas if they individuated the actual number of objects using property information they would have approached the screen that hid two different objects. Results demonstrated that chicks did not show a preference for either group of objects. This lack of choice could be due to some limits in the process of object individuation or to chicks’ exposure during imprinting to objects identical in groups of three, hence becoming familiar to the fact that three identical objects can be encountered. In Experiment 5 chicks were exposed to imprinting stimuli all differing from one another in their individual features, making it unlikely that chicks computed a repeated presentation of the same individual as many identical distinct individuals. When birds were tested in a three vs. two events comparison (i.e. one individual stimulus presented three times vs. two different stimuli presented once each), chicks chose the screen hiding two distinct objects. Chicks therefore showed that they were able to use property information provided by a particular

![Figure 6](https://example.com/figure6.png)
feature for individuating the larger number of objects irrespective of (and against) the number of events.

Employing an event-mapping task, infants at around 10 months of age succeeded in the is-it-one-or-two task only when they were presented with one humanlike object (i.e. a doll’s head) vs. one inanimate (e.g. a motorcar) or one animate but non-humanlike (i.e. dog-like) object (Bonatti et al., 2002).

This evidence suggested the existence in our species of a system for recognizing (at least): humans, animals and objects/inanimate things earlier than a system for recognizing property differences within the same category (e.g. a duck-toy vs. a car-toy as in Xu & Carey’s 1996 study). In our research the procedure for investigating object individuation employed social stimuli such as imprinting objects that are very likely treated as animate objects by young chicks (see Mascalzoni, Regolin & Vallortigara, 2010). Nonetheless, demonstrating object individuation ability in the social domain does not exclude that the same or a similar mechanism can be available to the animal for individuating stimuli in other, non-social, domains (e.g. food). These results contribute to our comprehension about object representation with evidence coming from a class of animals never tested before and, for the first time, from very young individuals. Domestic chicks, which belong to a precocial species, seem to be able to use spatiotemporal as well as property information for object individuation at 3 days old. Moreover, our data extend evidence obtained with pre-verbal infants and non-human primates allowing us to conclude that this ability can be independent of language and of experience.

The next challenge, currently under consideration in our laboratory, will be investigating whether chicks can also use kind/sortal information for establishing the number of objects presented in an event.

In this sense, evidence obtained from the newly hatched chicks, or from other non-human species, can contribute to the issue of core knowledge systems and to the validation of animal models for future neurobiological investigations.

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