Spontaneous discrimination of possible and impossible objects by newly hatched chicks

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14th day of incubation and were kept in an incubator (MG7014). On day 17, eggs were placed into a hatchery (MG1001), or coming from eggs incubated and hatched in controlled laboratory conditions (n = 66). Controlled hatching was required for testing naive chicks. The fertilized eggs were placed at the 14th day of incubation and were kept in an incubator (MG70/100). On day 17, eggs were placed into a hatchery (MG1001), where they were maintained in total darkness, until hatching on day 21.

2. MATERIAL AND METHODS

(a) Subjects
Subjects were 157 female domestic chicks (Gallus gallus) either purchased from a commercial hatchery when they were a few hours old (n = 91), or coming from eggs incubated and hatched in controlled laboratory conditions (n = 66). Controlled hatching was required for testing naive chicks. The fertilized eggs were placed at the 14th day of incubation and were kept in an incubator (MG70/100). On day 17, eggs were placed into a hatchery (MG1001), where they were maintained in total darkness, until hatching on day 21.

(b) Stimuli
Stimuli were static two-dimensional images, printed on a 6 × 6 cm white plastic paper, representing solid edges constituting a 3.5 cm size solid that might or might not be perceived as a three-dimensional cube, depending on the overlapping of intersections between edges that in three-dimensional cubes should lie in different perspective planes.

(i) Rearing stimulus
The stimulus used for familiarization provided no information concerning the critical intersections, these being occluded (figure 1a) by black drawing pins (diameter 1 cm). Owing to the process of amodal completion, human adults see these stimuli as three-dimensional cubes.
Newborn chicks prefer possible objects
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Figure 1. (a) The occluded stimulus employed during rearing to familiarize birds in the occlusion and no-occlusion conditions. (b) The possible cube. (c) The impossible cube. This was taken from a free source (http://en.wikipedia.org/wiki/File:Impossible_cube_illusion_angle.svg) while the other stimuli were produced by the authors, by modifying the impossible cube. (d) Schematic representation of the test apparatus; the bird is required to choose between the possible and the impossible object. Time spent within the area by each stimulus was scored as behavioural measure of choice. The position of the stimuli was randomized between subjects.

(ii) Testing stimuli
All chicks at testing were faced with the choice between a possible and an impossible version of the non-occluded cube. In the possible version (figure 1b), interposition cues of the edges in the critical points were coherent, so that the edges that should be in the first plane were not interrupted by edges underneath. To a human observer, edges appear as correctly overlapping and the stimulus is perceived as a structurally coherent two-dimensional representation of a three-dimensional cube. In the impossible version of the cube (figure 1c), the interposition cues caused the edges lying on the second plane to interrupt those on the first plane. The perceptual result to the human observer was an incoherent two-dimensional representation of a three-dimensional solid cube.

(c) Rearing conditions
All chicks obtained from the commercial hatchery were familiarized with the rearing stimulus (i.e. the occluded version of the cube) over 3 days post-hatching before the test. During this time, they were housed singly in standard metal cages (28 cm width × 40 cm depth × 32 cm height) at controlled temperature (28–31°C) and humidity (68%), with food and water available ad libitum. A subgroup also had experience of physical occlusion of objects and of environmental features (occlusion condition, n = 42) during the 3 days of rearing. This was provided by printing the rearing stimulus onto both sides of two identical vertical screens (8 cm × 14 cm) that were placed within the rearing cage, at the corners. The food jar was positioned behind one screen and the water jar behind the other screen, so that birds learned to associate food and water with the stimulus. Each screen (together with its food/water jar) was moved to a different corner within the cage twice a day, to prevent positional learning. The remaining chicks that had become familiarized with the rearing stimuli did not experience any sort of physical occlusion of one object onto another (no-occlusion condition, n = 49) as such stimuli were printed onto little (6 cm × 6 cm) rigid flags highly visible on top of the food or water jars. The two flagpoles (diameter 0.1 cm) holding each flag were bound directly on the edge of the glass jars, so that the base of stimuli was just over the rim of the jar. Jar positions, at the corners of the cage, were changed randomly within the cage twice a day.

A separate group of chicks came from dark-incubated and dark-hatched eggs (naïve condition, n = 66). They underwent a spontaneous preference test between possible and impossible figures at 24 h post-hatching, during which time they were kept in a thoroughly dark environment, and therefore lacked any visual experience prior to the test.

(d) Test apparatus and procedure
The experimental room, located near the rearing room, was kept at controlled temperature (25°C) and humidity (70%); the only light came from a lamp (40 W), placed 25 cm above the apparatus. The apparatus consisted of a cage identical to the rearing ones, with the floor and internal walls lined with uniform white plastic sheets. On one of the short walls were hung the two testing stimuli, spaced 10 cm apart, at 5 cm from the floor and 5 cm from the side walls (figure 1d). The left/right position of the stimuli was balanced across individuals.

At the beginning of the test, each chick was positioned at the starting point, i.e. at the exact midline of the short wall (about 3 cm away from it) opposite to where the stimuli were, so that it faced them. Each chick was then observed for 6 consecutive minutes, during which time it could freely move within the apparatus and approach either stimulus.

The internal area of the apparatus was virtually divided into three areas: two identical and symmetrical choice areas situated by each stimulus (14 cm × 25 cm depth) and a no-choice area located away from the stimuli, by the opposite wall (28 cm × 15 cm depth), which contained the starting point. Choice of the possible (or impossible) figure was scored, using a computerized event recorder: every time the bird entered (with its head and at least half its body) a certain choice area, the time (s) counter for that area was set until the chick had walked out of it. The overall number of seconds spent by the chick within the choice area located by the two stimuli during the whole test was considered.

Since we expected a preference for the perceptually coherent stimulus, an index of choice of the possible cube was computed.
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their first exposure to point-light animation sequences eliciting imprinting. For example, naive chicks at
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tal conditions strongly suggests that experience of
occluding events is not necessary for the emergence
of such discrimination. Even more convincing, visually
occluded object experienced during familiarization.
In all conditions, chicks significantly preferred to
approach the ‘possible’ cube.
An analysis of variance considering the three exper-
imental conditions as between factors did not reveal
any effect owing to different rearing ($F_{2,154} = 0.95$;
$p = 0.39$).

4. DISCUSSION

Newly hatched chicks are able to discriminate between
two-dimensional images depicting possible and
impossible three-dimensional objects. Chicks selec-
tively approached the possible cube, which they
probably regarded as more similar to the partly
occluded object experienced during familiarization.
The lack of difference between the first two experimen-
tal conditions strongly suggests that experience of
occluding events is not necessary for the emergence
of such discrimination. Even more convincing, visually
naive chicks, tested soon after hatching as they
kept in darkness, showed a spontaneous preference
for the possible cube and those less than 50 per cent indicated a
preference for the impossible cube.

3. RESULTS

Results are shown in figure 2. A one-sample two-tailed
$t$-test was performed to compare chicks’ responses with
chance level (50%), separately for the three experimen-
tal conditions: occlusion: mean = 63.48; s.e.m. = 4.45;
t_{41} = 2.86, \ p = 0.006; \ no \ occlusion: \ mean = 57.99;
s.e.m. = 3.08; \ t_{48} = 2.58, \ p = 0.013; \ naive: \ mean =
58.01; s.e.m. = 2.06; t_{65} = 3.89, \ p = 0.0001.

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naive chicks, tested soon after hatching as they
emerged from an incubator in which they had been
kept in darkness, showed a spontaneous preference
for the possible version of the cube.

It is known that, as a result of exposure to a particu-
lar object in early life, nidifugus birds develop a social
and exclusive attachment to a particular object, a pro-
cess dubbed ‘filiation imprinting’ [13]. It is also known
that some stimuli are more effective than others in
eliciting imprinting. For example, naive chicks at
their first exposure to point-light animation sequences
exhibit a spontaneous preference to approach biol-
ological motion patterns rather than other kinds of
motion [14]. Here the fact that visually inexperienced
chicks spontaneously preferred to approach the possible
cube suggests that at birth, chicks not only possess
mechanisms to establish pictorial depth perception
(§1) but that they use them to integrate image fragments
into spatially coherent three-dimensional object repre-
sentations. Stimuli that cannot be successfully
processed as globally coherent three-dimensional
objects may be regarded as less attractive by chicks.

It may be argued that evidence from precocial
species cannot easily be transferred to altricial
(slowly developing) species, and in particular to the
most altricial of the species, the human one. None-
theless, from a computational point of view, these
results show that, in principle, natural selection can
produce organisms perfectly able to deal with the pro-
blem of global coherence in three-dimensional objects
as recovered from two-dimensional images in the
absence of any specific experience of real three-
dimensional objects. This has obvious implications
with regards to the current debate (e.g. [3]) about
the role of innateness and learning on the origins of
knowledge.

The experiments comply with the current Italian (Ministero
della Sanità, Dipartimento Alimenti, Nutrizione e Sanità
Pubblica Veterinaria – Ufficio X’) and European Community
laws for the ethical treatment of animals.

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