COMPARATIVE BEHAVIOR

Matching sounds to shapes: Evidence of the bouba-kiki effect in naïve baby chicks

Maria Loconsole[1]*, Silvia Benavides-Varela[2,3], Lucia Regolin[1]

Humans across multiple languages spontaneously associate the nonwords "kiki" and "bouba" with spiky and round shapes, respectively, a phenomenon named the bouba-kiki effect. To explore the origin of this association, and whether it is unique to humans, we tested the bouba-kiki effect in baby domestic chickens (*Gallus gallus*). As a precocial species, chicks can be tested shortly after hatching, allowing us to control their pretest experiences. Similar to humans, both 3-day-old [Experiment 1 (Exp. 1)] and 1-day-old (Exp. 2) chicks spontaneously choose a spiky shape when hearing the "kiki" sound and a round shape when hearing the "bouba" sound. Results from naïve young animals suggest a predisposed mechanism for matching the dimensions of shape and sound, which may be widespread across species.

In his pioneering work in 1947, Wolfgang Kölher described the spontaneous tendency of adult humans to associate a round shape with the nonword "Maluma" and a spiky shape with the nonword "Takete" (*1*). This was interpreted as a form of sound-symbolism, suggesting that the relationship between sound and meaning is not purely arbitrary. Several studies replicated this effect, which since the 2001 study by Ramachandran and Hubbard has been renamed the bouba-kiki effect (*2*), i.e., the nonwords "bouba" and "kiki" were matched to the round and the spiky shape, respectively.

However, it is yet to be known how the spontaneous tendency to match shapes and sounds originates. These associations could emerge due to early exposure to multisensory information and word sounds (*3*) or to orthography (*3*–*5*): People might consider the sounds [b] and [o] rounder than the sounds [k] and [i] due to the shape of the letters (*4*). Alternatively, it may be an experience-independent and spontaneous ability (*2*, *6*) in which form-to-meaning correspondences constitute a predisposed perceptual mechanism at the basis of language acquisition, facilitating vocabulary construction and communication in infancy (*7*, *8*). The strongest evidence in favor of this view comes from crosslinguistic and language evolution studies, as well as research in preverbal infants. The first attested the bouba-kiki effect in cultures with different linguistic systems and orthographic appearance of letters (*9*–*11*). The latter showed that, before language production, infants (4 months old) already exhibit the bouba-kiki effect (*12*), possibly due to a biologically endowed ability to map and integrate multimodal input (*13*). However, studies on infants could not completely rule out an experience-driven origin of the effect resulting from infants' fast learning rate (*13*–*15*), their high sensitivity to environmental statistical regularities (*16*, *17*) and the large number of symbolic associations of sounds to which they are exposed when interacting with adults (*18*).

Comparative research has provided evidence of other instances of crossmodal correspondences, in which animals spontaneously associate auditory information with another sensory dimension. These include a pitch-luminance association, observed in chimpanzees (*19*) and tortoises (*20*), in which high and low pitches are linked to brighter and darker stimuli, respectively; and a pitch-size association, reported in chimpanzees (*21*), dogs (*22*, *23*), and tortoises (*24*), in which high and low pitches correspond to smaller and larger shapes, respectively. These crossmodal correspondences may be part of a broader set of predisposed associations that reflect natural co-occurrences. Such predispositions would help animals form coherent and meaningful representations of objects and events, facilitating or hindering evolutionary relevant associations (*25*, *26*). For instance, the bouba-kiki effect may stem from the physical properties of objects, in which round objects, when hitting or rolling on a surface, typically produce lower-frequency and more continuous sounds compared with spiky objects of the same size (*27*). However, previous attempts to demonstrate the bouba-kiki effect in adult apes have been unsuccessful. Both chimpanzees and gorillas (*28*), as well as one bonobo (*29*) failed to show a spontaneous bouba-kiki association when tested. This raises the question of whether sound-shape correspondences, such as the bouba-kiki effect, are in fact part of a widespread set of predispositions that aids interaction with the environment, or whether it is a uniquely human system of associations shaped by language-related experiences.

Our study tackles sound-shape correspondences from an alternative phylogenetic and ontogenetic perspective, testing the bouba-kiki effect in naïve newborn chicks. The domestic chicken (*Gallus gallus*) represents an optimal model for this aim, as chicks are precocial and can therefore be tested at the earliest stages of life (*30*, *31*) and are known to share analogous predisposed cognitive and perceptual mechanisms with human infants (*31*–*39*). Chicks (3 days old) tested for space-luminance spontaneous crossmodal associations (*40*) performed similarly to adult humans (*41*) (although a lack of evidence was found for pitch-luminance) (*42*). Recently, spontaneous crossmodal associations have been observed in chicks even shortly after hatching, further indicating that the brain may be naturally organized to support such associations (*43*). Specifically, newly hatched chicks first explored a smooth or a bumpy object in complete darkness (tactile-only) and were later able to recognize the familiar object solely by its visual appearance. This implies that the brain might be biologically predisposed to link certain kinds of sensory information, even in the absence of direct experience, through common neural coding mechanisms (*19*, *24*, *25*). These organizational principles can be understood as a species-level prior that structures and orients subsequent learning.

We investigated whether baby domestic chickens are sensitive to the bouba-kiki effect by conducting two experiments that differed regarding age of chicks at testing and the procedures employed. In Experiment 1 (Exp. 1), we employed a validated training-based paradigm already used in crossmodal studies with chicks (*40*, *44*). We trained 42 naïve 3-day-old chicks (17 females) to circumnavigate a panel depicting a shape with both round and spiky edges (Fig. 1A and movie S1). During the test, chicks underwent 24 trials in which they were presented with two panels, one depicting a spiky shape and one depicting a round shape, while either the sound "bouba" or "kiki" (pseudo-randomly alternated between trials) was played (Fig. 1B, movie S1, and audio S1 and S2). We hypothesized that, if chicks rely on human-like sound-shape associations, they will choose the panel with the spiky shape when hearing the "kiki" sound and that with the round shape when hearing the "bouba" sound. In Exp. 2 (40 individuals, 20 females) we tightened control over three critical factors: maturation (the test took place within the first 24 hours after hatching rather than on the third day of life), social experience (individual housing rather than social groups), and trained associations (chicks were tested without any prior training or reward) (see supplementary text for a detailed description of the rearing environment). Each chick underwent a 30-min habituation phase with the ambiguous shape (same as Exp. 1) displayed on a monitor (Fig. 2A and movie S1), followed by 30-min break in an empty, lit cage. The chick was then

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[1]Department of General Psychology, University of Padova, Padova, Italy. [2]Department of Developmental Psychology and Socialisation, University of Padova, Padova, Italy. [3]Padova Neuroscience Center, University of Padova, Padova, Italy. ***Corresponding author. Email: maria.loconsole@unipd.it**

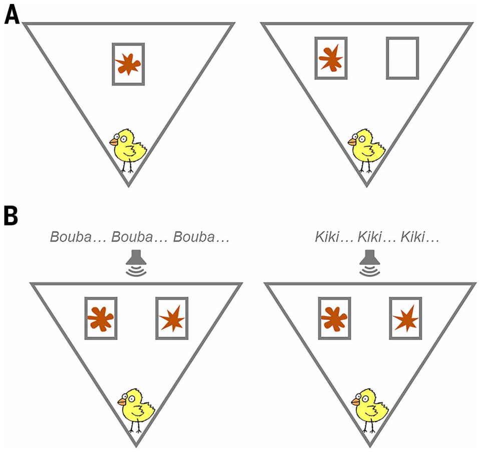

Fig. 1. Exp. 1 experimental paradigm. (**A**) Training. (Left) The chick learned to circumnavigate a central panel depicting an ambiguous shape featuring both spiky and round edges to retrieve a palatable food reward. (Right) Thereafter the chick was presented with two panels (one blank) and learned to circumnavigate the one depicting the ambiguous shape to obtain the food reward. The position (left/right) of the baited panel was counterbalanced between training trials. To pass the training phase, the chick had to detour the correct panel (i.e., the one depicting the ambiguous shape) in six of eight consecutive trials. (**B**) An example of a “bouba” testing trial (left) and of a “kiki” testing trial (right). The chick could see both a round and a spiky shape simultaneously presented each on one of the two panels, while a hidden speaker repeated the nonword “bouba” or “kiki.” Each chick underwent 24 test trials with the background sound and position (left/right) of the shapes pseudo-randomly alternated between trials. At test, no reward was present.

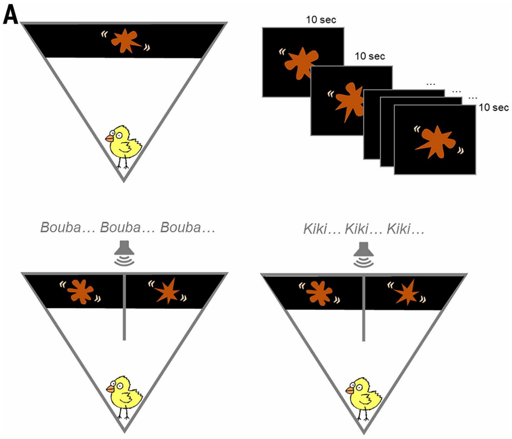

Fig. 2. Exp. 2 experimental paradigm. (**A**) Habituation (Left). The chick was left free to explore a triangular arena while a series of ambiguous shapes (having both spiky and round edges) were sequentially presented at the center of a computer screen. (Right) Each shape remained visible on the screen for 10 s and was immediately substituted by a new one. Each shape performed a small tilting movement to enhance its saliency for the animals. (**B**) At test, two stimuli were projected simultaneously in the right and left halves of the screen: one round shape and one spiky shape (same as those used for Exp. 1). Each stimulus pair remained visible for 10 s before being immediately replaced by the next, and performed the same tilting movement used as an attentional cue during habituation. The test lasted a total of 6 min, during which the chick was free to explore either shape. The sound played (“bouba” or “kiki”) and the position of the shapes (left or right) remained stable during individual tests and were counterbalanced between subjects.

reintroduced into the arena, where the monitor displayed the round and spiky shapes side by side while either the sound “bouba” or “kiki” was played for the first time. Chicks were let free to move around for 6 min while we recorded the first shape approached and the total time spent exploring each shape (Fig. 2B and movie S1). We hypothesized that, if chicks possess an early-emerging predisposition for sound-shape associations, those hearing “kiki” will preferentially approach and spend longer exploring the spiky shape (and the round shape for those hearing “bouba”). Results were similar in the two experiments and in line with our hypotheses, supporting an early-emerging, experience-independent sensitivity to crossmodal associations in chicks, akin to humans.

Studying a precocial animal with tight control on its experience prior to testing (*30*, *34*) allowed us to pinpoint the developmental origin of the bouba-kiki effect and of sound-shape correspondences and to address the role of experience on its emergence. Additionally, evidence from a bird species can provide relevant insights on the evolution of this phenomenon, considering the wide phylogenetic distance between mammals and birds (with the last common ancestors dated between 300 and 320 million years ago) (*45*, *46*).

Results

Exp. 1

Chicks preferred the round shape when hearing “bouba” [P(round) = 0.66, SE = 0.02, $P < 0.001$], and the spiky shape when hearing “kiki” [P(round) = 0.44, SE = 0.02, $P < 0.01$] (Fig. 3). To control for any a priori preference for either the spiky or round stimulus, we ran a control condition on a separate group of 29 subjects. Instead of using the “bouba” and “kiki” sounds, we alternated between silence (i.e., no sound played) and classical music excerpts (see audio S1 and S2). Silent trials aimed at assessing chicks’ spontaneous preferences in the absence of auditory stimulation whereas music trials were employed to assess their responses under auditory conditions that were not expected to influence shape preference. We found no effect of the condition (silence or music). Overall, chicks preferred the round over the spiky stimulus [P(round) = 0.58, SE = 0.02, z.ratio = 3.64, $P < 0.01$]. Notably, this preference remained different from the one observed in the experimental group [Welch’s two-sample t test: (“bouba” versus control trials: $t = 2.48$, $P = 0.02$; “kiki versus control trials: $t = -5.3$, $P < 0.001$) (Fig. 3).

Exp. 2

Chicks in the “bouba” condition explored the round shape for longer (mean exploration time = 199.56 sec, SE = 25.12 sec) than the spiky one (mean exploration time = 57.53 sec, SE = 21.44 sec), with a significant difference between the two times (contrast round-spiky = 142 sec, SE = 31, $t = 4.58$, $P < 0.001$). Vice-versa, chicks in the “kiki” condition explored the spiky shape for longer (mean exploration time = 144.07 sec, SE = 23.13 sec) than the round one (mean exploration time = 44.1 sec, SE = 17.37 sec), with a significant difference between the two times (contrast round-spiky = –100 sec, SE = 31 sec, $t = -3.22$, $P = 0.003$) (Fig. 3C).

The sound-shape association holds also when considering the first shape approached. Chicks in the “bouba” condition first approached the round shape 80% of the times (odd ratio round/spiky = 16, SE = 12.65, z = 3.51, $P < 0.001$), whereas chicks in the “kiki” condition first approached the round shape 25% of the time (odd ratio round/spiky 0.08, SE = 0.06, z = –3.7, $P = 0.001$).

Discussion

We observed a spontaneous tendency in 3- and 1-day-old chicks to associate a round shape with the “bouba” sound and a spiky shape with the “kiki” sound. Our results, together with previous evidence in domestic chicks (*40*, *43*), points toward a predisposed mechanism for crossmodal associations. This may likely serve the scope of coordinating information from different sensory modalities to build unified representations of entities.

Data from other nonhuman species, including primates (*19*, *21*, *47*), dogs (*22*, *23*), and tortoises (*20*, *24*) suggest that such a mechanism

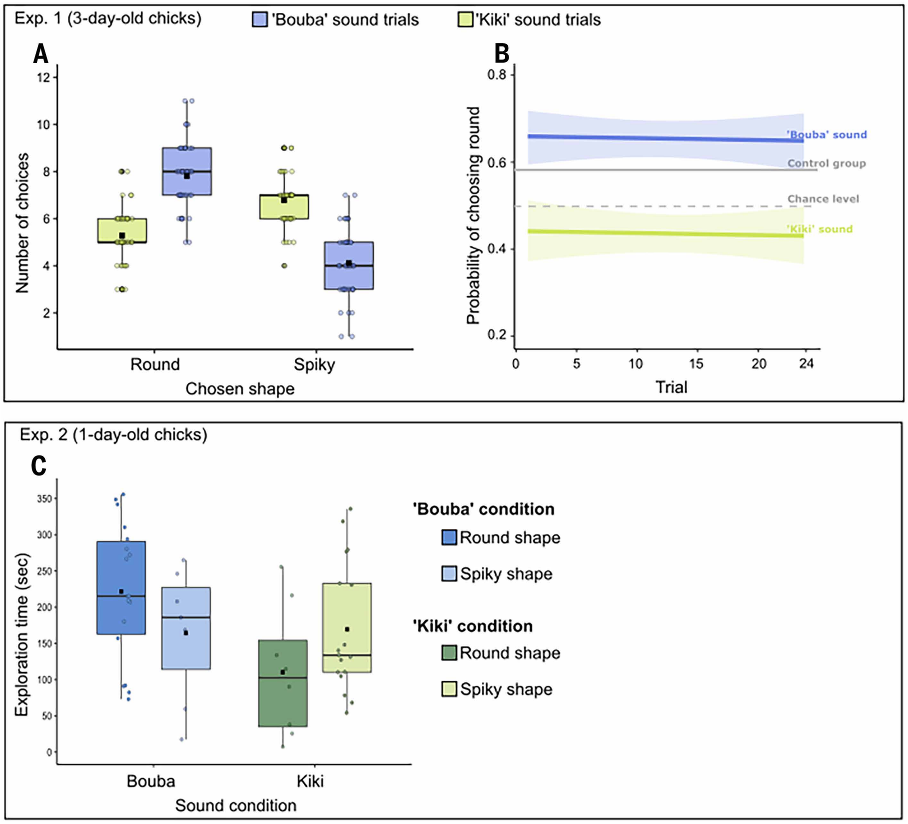

Fig. 3. Results. (**A**) Results from Exp. 1. On the *y*-axis, the number of choices (out of 12 trials) in which the chicks circumnavigated the round (left) or spiky (right) panel while being presented with the "kiki" (green) or "bouba" (blue) sound. The boxplot shows the 25th percentile and the 75th percentile; the horizontal bar in the boxplot represents the median and the black square represents the mean. Each dot represents the performance of a single subject. Overall, chicks consistently chose the panel with the spiky shape significantly more often when hearing "kiki" and that with the round shape when hearing "bouba." (**B**) Results from Exp. 1 plotted by trials. The *x*-axis represents the testing trials (from 1 to 24). The *y*-axis depicts the probability of approaching the round shape when hearing the "bouba" (light blue) or "kiki" (green) sound. The shaded areas indicate 95% confidence intervals. The dashed gray line represents chance level ($P = 0.5$). The solid light-gray line represents chicks' average preference for the round shape in the conditions with no sounds/classical music ($P = 0.58$). Overall, chicks consistently chose the panel with the spiky shape when hearing "kiki" significantly more often and that with the round shape when hearing "bouba." Their choice is significantly different from both chance level and from the preference baseline established with the control group. (**C**) Results from Exp. 2. The *y*-axis represents the time (in seconds) chicks spent exploring each stimulus when hearing the "bouba" (left) or the "kiki" (right) sound. Preference for the round shape is shown in dark blue ("bouba" condition) and dark green ("kiki" condition); preference for the spiky shape is shown in light blue ("bouba" condition) and light green ("kiki" condition). The boxplots display the 25th percentile and the 75th percentile; the horizontal bar indicates the median and the black square indicates the mean. Each dot corresponds to an individual subject. Overall, chicks tested in the "bouba" condition explored the round shape longer whereas chicks tested in the "kiki" condition explored the spiky shape longer.

may be shared across different taxa and possibly reflects an old evolutionary organizing principle of the brain (*19*, *24*). Notably, in humans there is evidence of noncognitive processing of bouba and kiki sounds, which may evoke different levels of emotional arousal (*48*). Further studies reinforce this view, showing that the effect is mainly related to perceptual, rather than speech-related factors, such as the possibility of perceiving the sounds as linguistic (*49*) or mechanical-articulatory constraints and pronounceability (*50*).

Altogether, these findings suggest that the bouba-kiki effect represents another case of unlearned crossmodal correspondences. Rooted in a shared system of crossmodal associations, species-specific sensory, perceptual, and cognitive capacities may yield different developmental outcomes and adaptations to their ecological contexts. In humans for instance, sound-shape associations may contribute to early lexical development by helping infants structure and attend to referents in a complex environment, building a vocabulary (*7*, *8*, *14*), and potentially reducing cognitive load (*8*, *14*). From this perspective, one potential utility of crossmodal correspondences could lie in their contribution to communication. Indeed, several nonhuman species display communicative systems that map specific acoustic signals to external referents, such as alarm calls for different predators in vervet monkeys (*51*, *52*) and Japanese tits (*53*, *54*), or food-specific grunts in chimpanzees (*54*). Similarly, domestic chickens exhibit a surprisingly rich vocal repertoire, with around 30 distinct vocalizations identified in both adults and juveniles (*55*, *56*) and including referential and socially modulated calls that vary in acoustic structure depending on the context and threat type. Although these communicative behaviors are not necessarily sound-symbolic they may still build upon early developing predispositions for associating structured auditory signals with external stimuli. Even though newly hatched chicks produce only rudimentary vocalizations, primarily distress calls and pleasure notes (*55*–*57*), they may already possess the neural foundations for processing such multisensory correspondences, similar to how human infants are sensitive to linguistic structure well before they begin to speak (*12*).

In Exp. 1, chicks in the silent and classical music conditions showed an initial preference for the round shape, consistent with previous evidence in this species (*58*–*60*) and human infants (*61*, *62*). This preference was then strengthened when hearing "bouba" or overridden when hearing "kiki." Similarly, a stronger response to "bouba" is also reported in humans (*11*). We also observed that the bouba-kiki effect remained stable throughout testing, which contrasts with previous studies on other spontaneous crossmodal associations (*24*, *40*). By including refresh trials (rewarded) prior to each test block (unrewarded), and a time break between each block, we may have reinstated chicks' attention and motivation toward the testing stimuli (*63*), thus preserving the initial association. Alternatively, sound-shape associations may be deeply rooted and thus less subject to habituation or extinction. In Exp. 2, we replicated the sound-shape association effect under more stringent conditions. By testing chicks on the day of hatching, we minimized the possibility of prior experience, directly tackling the question of whether the effect arises from postnatal learning or maturation, or rather reflects an early-emerging predisposition. Notably, the convergence of results employing two different experimental paradigms supports the robustness of the finding and further points to the precocial or predisposed origin of sound-shape associations. In both experiments, our analysis focuses on population-level effects rather than individual preferences as we consider sound-shape correspondences to be a general predisposition, representing a readiness to form associations (individual performance for both experiments is available in data S1 and the supplementary text). As such, it not expected to appear in all participants to the same extent due to both intrinsic (and functional) phenotypical variations or environmental conditions (*64*–*66*). Research in chicks as well as other animal models (*24*, *40*, *42*, *44*) and humans (*67*–*69*) supports this idea, showing that although predispositions are broadly present, they exhibit high interindividual variability rather than strict universality.

Previous studies on nonhuman primates (chimpanzees, gorillas, and one bonobo) failed to observe the bouba-kiki association (*28*, *29*). It seems unlikely that a predisposition for sound-shape association could have evolved separately in birds and humans while being absent in our closest relatives, the other great apes. We argue that this inconsistency likely stems from methodological differences as well as from key features such as age, level of prior expertise, and training of the subjects. For instance, at the time of testing, the bonobo Kanzi was already capable of associating sounds and shapes to the point that he could match up to 500 visual-auditory pairs (*29*, *70*, *71*). Thus, it is possible that the properties of his limited "lexical repertoire" could have influenced or biased his responses. Another relevant factor could have been the use of random reward schedules that may have reduced animals' motivation in trying to respond correctly. Thus although it remains possible that apes may not be sensitive to sound-shape associations, it is crucial to re-evaluate their responses in light of the task they are facing and their ecological needs (*72*).

In conclusion, in our study we showed that baby domestic chickens (*Gallus gallus*) respond to sound-shape associations, similar to humans, preferentially matching the sounds "bouba" and "kiki" to a round and a spiky shape, respectively. In particular, our data place the origin of sound-shape crossmodal matching at the earliest stages of life, possibly hinting at a predisposed experience-independent mechanism. Direct evidence in an animal model suggests that, rather than being a culturally learned phenomenon unique to humans, the bouba-kiki effect and sound-shape correspondences may belong to a set of predisposed associations shared across species.

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SUPPLEMENTARY MATERIALS

science.org/doi/10.1126/science.adq7188
Methods; Supplementary Text S1; References (*47*, *48*); Data S1 and S2; Movie S1; Audio S1 to S4

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Matching sounds to shapes: Evidence of the bouba-kiki effect in naïve baby chicks

Maria Loconsole, Silvia Benavides-Varela, and Lucia Regolin

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Editor's summary
In linguistics studies across cultures, humans have been shown to associate certain nonsense words with shapes; the iconic example is "bouba," which associates with a round shape, and "kiki," which sounds spiky. This phenomenon has been hypothesized to be associated with language and language development, among other human-associated traits. Loconsole *et al*. showed that this same phenomenon occurs in newborn chickens, which show a preference for the shape (round or spiky) associated with the sound (round or spiky) played (see the Perspective by Perlman and Winter). This finding suggests that this kind of pattern association in the brain may not have to do with language and may be much older than previously believed. —Sacha Vignieri

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