UNIVERSITY OF PADOVA

Department of General Psychology

Bachelor's Degree course in Psychological science

Final dissertation

Innate attraction to asymmetry: domestic chicks' preference is driven by perceptual grouping

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Academic year 2022/2023

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Abstract

In a previous study, day-old chicks (*Gallus gallus*) were habituated for one hour to bi-dimensional sets of elements of different numerosities (all even), colours, and shapes, and then tested for their spontaneous preference between two novel sets of the same colours and shapes, one being an odd composite (9) and one a prime (7 or 11) number. The results revealed a consistent preference for the prime set. This was interpreted as a response to perceptual novelty, as a prime number can never be symmetrically grouped, whereas both even and odd composite numbers can be decomposed in all same-sized subsets (e.g., $6 = 3+3 = 2+2+2$; $9 = 3+3+3$). Here we aimed at better describing the novelty response to perceptual (a)symmetry by habituating chicks to sets of prime numerosities and testing them for their preference between a novel prime (7 or 11), and an odd composite number (9), hypothesizing to now observe a preference for the composite set. Interestingly, chicks inspected longer the novel prime set, even though they had been habituated to prime numerosities. This forces us to reconsider the novelty-based interpretation of previous literature. We speculate that there could be a predisposed preference for perceptual imbalance or asymmetry, reflecting some ecological advantage for this species. This idea is also consistent with previous studies on day- and week-old chicks, showing a spontaneous preference for asymmetric over symmetric artificial and naturalistic stimuli.

1. Introduction

This study has been conducted with the objective of proving and better describing chicks' underlying perceptual mechanisms at the foundation of their mathematical abilities after a series of other studies conducted on the same species of *Gallus gallus* chicks.

Before explaining the research in detail, it is necessary to explain some key concepts to understand better the whole picture and where the studies' aim comes from.

1.1 Perceptual grouping and groupitizing

Numerosity perception, the ability to assess the quantity of items quickly and accurately in a set without counting, is a fundamental cognitive skill that humans (Ciccione & Dehaene, 2020) and various animals possess (Rugani, R., Loconsole, M. & Regolin, L., 2017). This capacity plays a crucial role in some behaviours such as estimating quantities and decision making. One aspect of numerosity perception is the phenomenon of perceptual grouping, which refer to the cognitive processes that enable us to perceive sets of objects as distinct groups or clusters. Our brain doesn't perceive each individual item as isolated; rather, it seeks patterns and structures to simplify the task. These processes were well explained with the Gestalt principles; one example of them is the Gestalt principle of proximity, where elements that are closer to each other tend to be perceived as belonging to the same group (*Figure 1.1*).

Figure 1.1 **This picture shows an example of the principle of proximity in the Gestalt laws. The first group of dots on the left is perceived as a whole group, while the second one on the right is perceived as two separate groups, even though both are made of the same number of circles of the same colour.**

When applied to numerosity perception, these mechanisms allow us to view a set of objects as clusters, which are easier to process than individual items.

Perceptual grouping happens always when the stimulus is already divided in subgroups by the experimenter.

Groupitizing, instead, is a perceptual strategy used to count that the participant is directly using on the stimulus which is not divided in subgroups. It is the phenomenon by which dividing in subgroups a set of elements makes it easier and faster to determine the exact quantity of objects.

The latter process is achieved by using subitizing, which is the ability to immediately perceive the quantity of a small set without counting. When presented with a group of objects, the brain automatically groups them based on shared attributes, enabling a rapid perception of numerosity. This phenomenon is particularly prominent for quantities up to around four or five, where the brain can effortlessly recognize the pattern and magnitude.

A better performance is also due to symmetric or asymmetric groupitizing. In the first case performance is better due to the fact that the subgroups are made of the same number of elements, while in the second case there will always be a subgroup which has a different number of elements.

Numbers which are symmetrically divisible are: 6 (2+2+2 or 3+3), or 9 (3+3+3). Even if the first one is an even number and the second is an odd one, they can be both divided in subgroups with the same numerosity as they are both composite.

This is not the case for the number 7 or 11: they are both prime numbers and the only grouping that can be done with them is the asymmetrical one, for instance 7 = 2+2+3 = 3+3+1.

1.2 Numerosity perception in chicks

Various avian species exhibit numerical capabilities and employ perceptual strategies comparable to those of humans, suggesting shared underlying mechanisms (Nieder, 2018; Scarf et al., 2011; Kobylkov et al., 2022). Prior research done by Loconsole et al. (2021), was focused on the utilization of *Gallus gallus* (domestic chicken) species, particularly newly hatched chicks. The advantage of

using this species lies in the fact that domestic chicks are born fully developed and able to interact with their surroundings, enabling the exploration of cognitive abilities, both numerical and non-numerical, in these early stages of life (Rugani, 2018).

Additionally, prior studies have indicated that domestic chicks are able to respond Gestalt principles stimuli, experimenter-induced perceptual grouping, and respond to symmetry (Vallortigara, 2012; Rugani et al., 2017; Forsman & Herrström, 2004; Clara et al., 2007).

Loconsole et al.'s (2021) experiment had the hypothesis that chicks use a subject-activated grouping mechanism to mentally divide sets of elements into subgroups in the same fashion as explained in the previous paragraph. In such experiments the objective was to prove the existence of these mechanisms in newly hatched domestic chicks and if they were able to use the said mechanism to distinguish between symmetrically divisible an asymmetrically divisible (prime) numerosities.

Chicks underwent a habituation process shortly after hatching that lasted one hour. This involved placing chicks within a triangular arena, where one wall (the base of the triangle) featured a screen displaying habituation stimuli. These stimuli were sets of elements, each with distinct characteristics: different colour (green, yellow, red, and blue) and shape (triangle, rectangle, and circle), (See in detail in section 2, Materials and Methods). The numerosities of the habituation stimuli were all even, representing symmetric divisibility (e.g., 6 = 3+3 or 2+2+2).

Following the habituation there was an additional hour of rest. Thereafter each chick was presented with a pair of stimuli for a 6-minute test phase. One stimulus represented an asymmetrically indivisible numerosity, which is also a prime numerosity (7 for some chicks, 11 for others), while the other depicted an odd composite numerosity (9).

Results revealed a preference for the asymmetrically divisible numerosities which were also prime numbers (both 7 and 11). This preference suggests the existence of the hypothesized self-executed grouping mechanism. A chick's preference for one stimulus over another implies the ability to, even at a perceptual level, differentiate between the two numerosities.

The stimuli to which the chicks were habituated (sets of even composite numerosities) may resemble the odd composite stimulus in the test phase more than the prime stimulus. This is because both even and odd composite stimuli are symmetrically divisible in equal subgroups, indicating that the non-symmetric numerosity (7 or 11) would represent an entirely novel stimulus for the chicks.

The authors then tried to explain why chicks prefer this type of numerosity more than the symmetrically divisible odd composite numerosity (9).

Research has demonstrated that newly hatched chicks tend to explore stimuli with slight novelty during the imprinting process (Jackson and Bateson, 1974). Exploring slightly novel stimuli is ecologically advantageous for chicks, motivating them to examine their whole environment from various angles, and so supporting imprinting.

Additional studies have shown that newly hatched domestic chicken chicks display a preference for asymmetric patterns. In a study conducted by Forsman & Herrström, 2004; Clara et al. in 2007, they hypothesize that the preference for asymmetric stimuli might arise from an active avoidance of symmetric stimuli, which could signal the presence of poisonous insects in nature. Another hypothesis proposes that underdeveloped chicks might benefit from pecking at prey with asymmetric patterns, indicating reduced fitness and facilitating predation. Clara et al. (2007) also showed that the preference for symmetry in *Gallus gallus* chicks is experience-dependent, suggesting that the transition from a preference for asymmetry to symmetry might hinge on the fact that active feeding experience teaches chicks that symmetric objects are easier to engage with. The shift from a preference for asymmetric patterns to symmetric stimuli with growth is attributed to improved sensory-motor abilities, making the initial strategy outworn.

Accordingly, in the previously discussed experiments by Loconsole et al., these two important factors of novelty and preference for asymmetric patterns were two concepts that worked together.

The prime number (7 or 11) as both:

- An asymmetrically divisible numerosity, therefore an asymmetric stimulus that elicited a preference.

- A novelty, being interesting for the chicks, since they had been habituated to even symmetrically divisible stimuli.

Therefore, the authors can conclude that there is a preference for the prime number, but since there are both factors involved (novelty and asymmetry) they cannot say if the reason lies behind one of them or both together.

1.3 My experiment

In our experiment we are aiming at better describing the spontaneous choice of the chicks by trying to answer some main questions:

1. Is the choice for the prime numerosity driven solely by novelty of the stimulus or is it also due to an innate attraction for asymmetry (for some ecological advantage)?

2. Is the preference for the prime number still the same even if they will be habituated to a prime number (which will not be the novel stimulus anymore)?

What we are going to change from the first design of the experiment by Loconsole et al. is that the chicks will be habituated to prime numbers (3, 5, either 7 or 11, and 13), so that in the test phase the novel stimulus will be the symmetrically divisible composite odd number (9). In this case, if the preference remains unchanged, and keeps being consistent with the data we have from the previous experiments, this means that there is an innate attraction towards asymmetry. If not, this will mean that chicks are driven in their choice solely by novelty.

2. Materials and methods

2.1 Subjects and apparatus

During the time in which we were doing the experiment, we tested 74 domestic chicks (*Gallus gallus domesticus*), 36 females and 38 males. Every week a local hatchery (Incubatoio La Pellegrina, San Pietro in Gu, PD, Italia) would deliver the fertilized eggs to the laboratory (Comparative Cognition Lab, Department of General Psychology, University of Padova) where they were incubated at 37.5°C in a FIEM MG 70/100 (45cm x 58cm x 43cm) with a controlled level of humidity of 55-66%. Soon after hatching each chick underwent a 2-hour experimental procedure.

The experimental apparatus consisted in a triangular arena made of a white plastic floor (60 cm for the base of the triangle and 69 cm the height), two white plastic walls (24 cm for the height) and a computer monitor (Acer B7 Series, 27') that was used as the third wall onto which all the stimuli were presented to the chick. The vertex opposite to the monitor was the subject's starting point, where the chick was placed gently facing the screen. A camera (Canon Legria HFR206) was positioned behind the starting point to film the 6 minutes of the test. These videos were the material used later to do the scoring.

2.2 Habituation

Each chick underwent a 2-hour experimental procedure (*Figure 2.1*). The first phase of the experiment was the habituation, which lasted for 1 hour. The newly hatched chick was taken from the incubator, transported in the nearby testing room in the dark, and gently placed in the apparatus facing the screen. During habituation the chick was free to move around the arena while a series of images were projected on the screen, each one depicting a different group of elements with a different prime numerosity depending on the experimental condition they had to undergo. The testing conditions were two: 7 vs 9 and 9 vs 11. Chicks that were going to be tested with the 7 vs 9 comparison (41 subjects, 17 females and 24 males) were habituated to sets of 3, 5, and 11 elements; chicks that were going to be tested with the 9 vs 11 comparisons (33 subjects, 19 females and 14 males), were

habituated to sets of 3, 5, and 7 elements. In both cases, the elements composing a set were all the same colour and shape. The possible colours presented were red, blue, yellow, or green; the possible shapes presented were triangle, circle, or rectangle. The combination of numerosity, shape, and colour for each presented set was random. The elements of the set were presented in a white square (336px) at the centre of the screen and positioned to avoid overlapping, with each element covering an aera of 36px.

Every stimulus would stay on the screen for 10 seconds and was immediately followed by another image. As a result, the chick would be exposed to a total of 360 stimuli during the habituation phase (*Figure 2.2*).

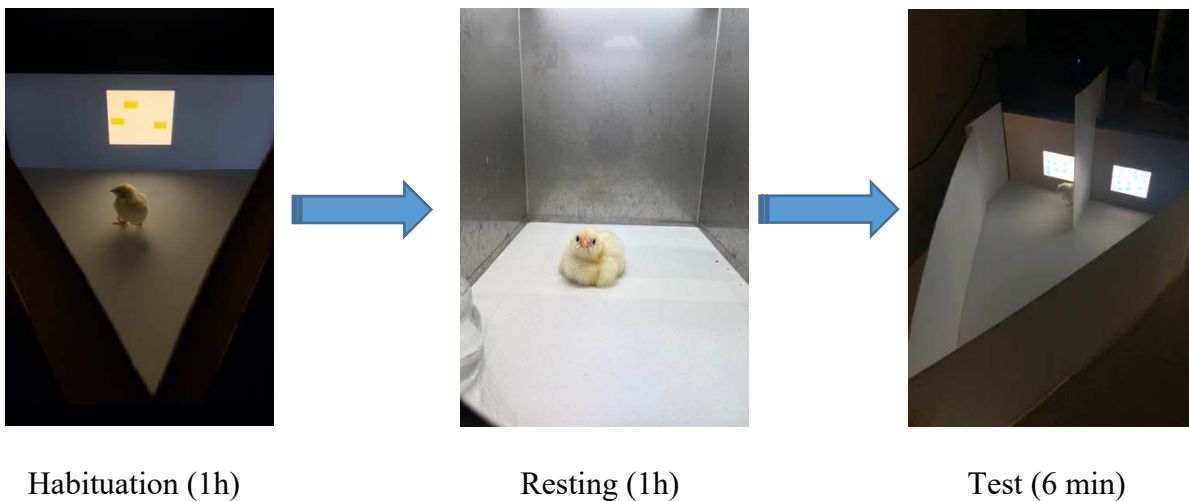| Habituation (1h) | Resting (1h) | Test (6 min) |

Figure 2.1 Experimental procedure. Each chick was subjected to an experimental procedure lasting approximately two hours. The first phase of this process was habituation (1h). Once habituation was completed, the chick was left to rest in a cage for an additional hour (1h). Finally, it was subjected to a test phase lasting 6 minutes (in this case the test is for the 9 vs 11 condition).
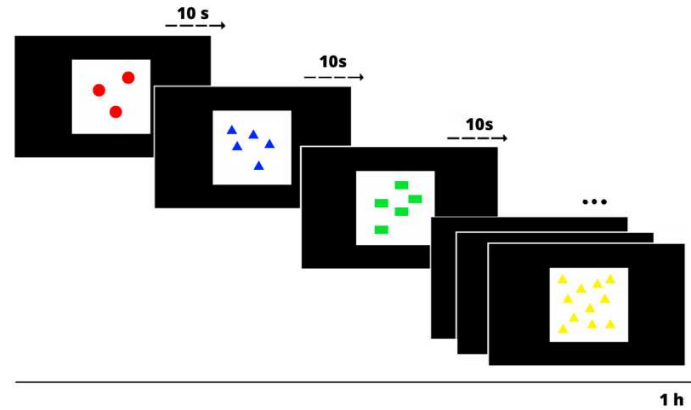
Figure 2.2 Example of a sequence of stimuli presented during the habituation phase (1h). Specifically, this sequence would be shown to a subject belonging to the experimental condition 7 vs 9, as it also contains stimuli composed of 11 elements.

2.3 Test

Once the habituation phase was finished, the chick was placed in a designated cage for an additional hour before undergoing the 6 minutes test. This was needed to restore optimal levels of attention and/or motivation to interact with the experimental stimuli (Rugani, Loconsole, Regolin, 2017).

During the test the chick was placed in the same arena where the habituation took place, with the only difference being that the screen was now divided in two halves using a plastic board (35 cm for the height and 10 cm for the base), so that it was possible to test the chicks by presenting two stimuli at a time, each one on one side of the screen. According to the experimental conditions, both to the left and to the right of the monitor there was a group of elements that had one of the shapes and one of the colours used for habituation. The two stimuli of every pair were made of the same elements, with the same shape and colour but they differ in numerosity, according to the experimental conditions.

Each pair of stimuli was presented every ten seconds (10s), without intervals, for a total of 36 stimuli in the six minutes of the test (*Figure 2.3*).

As mentioned earlier, the testing conditions were two: 7 vs 9 and 9 vs 11. In both the position (left or right) of the prime set was counterbalanced between subjects. Every chick was tested in just one of the conditions.
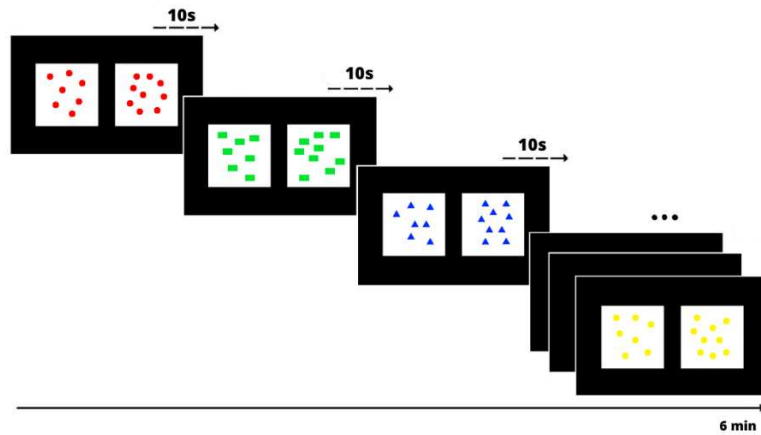
Figure 2.3 Example of a stimulus sequence presented during the testing phase. Specifically, these stimuli belong to the experimental condition 7 vs 9.

During test the chick were free to move in the arena. By using a customized program for scoring ethological behaviours, we registered the time that the chicks spent close to each stimulus. A choice was considered done when the chick reached a minimum distance of 5cm from the screen. This conclusion can be made because, due to the partition in the middle of the screen, when the chick is at a minimum distance of 5cm from the screen, it means that they are not able to see the stimulus presented on the other side of the screen.

3. Results

3.1 Data analysis: the software

The 74 subjects were tested using the two conditions: in the 7 vs 9 (41 chicks) and in the 9 vs 11 (33 chicks).

The analysis of the performance of the chicks were done using the software R (R 4.2.1), using a generalized linear model, where all the subjects were included in the model as the random effect.

3.2 Data analysis: variables and effects

The variables considered for the first part of the analysis are:

- Dependent variable: time spent of each chick in each choice area (left or right)

- Independent variables:

  - Condition of the test: 7 vs 9 and 9 vs 11.

  - Type of stimulus: prime or non-prime (composite).

  - Sex of the chick: male or female.

  - All the possible interactions between these variables.

Subsequently, all the effects of these variables have been evaluated and the value of statistical significance of the p-value was set to 0.05.

3.3 Data analysis: results

The analysis of the data has shown that there is just one effect of the type of stimulus (prime or non-prime; $X^2 = 6.421$, p = 0.011). There was no effect found for the condition of the test (7 vs 9 and 9 vs 11; $X^2 = 0.741$, p = 0.389) indicating that the chicks behave in the same way in both conditions. No effect was found neither for the variable sex (female or male, $X^2 = 0.005$, p = 0.942), or for any of the considered interactions (all p values > 0.05).

The post-hoc analysis that was conducted to compare the means (R package: emmeans) for the effect of the type of stimulus has shown that chicks spend more time exploring prime numerosities

(M = 133.7 s, SE = 12.2 s) in contrast with the time spent exploring non-prime numerosities

(M = 93.5 s, SE = 12.2 s) as explained by the graph (*Figure 3.1*). Non-prime – prime = -40.1 s, SE =

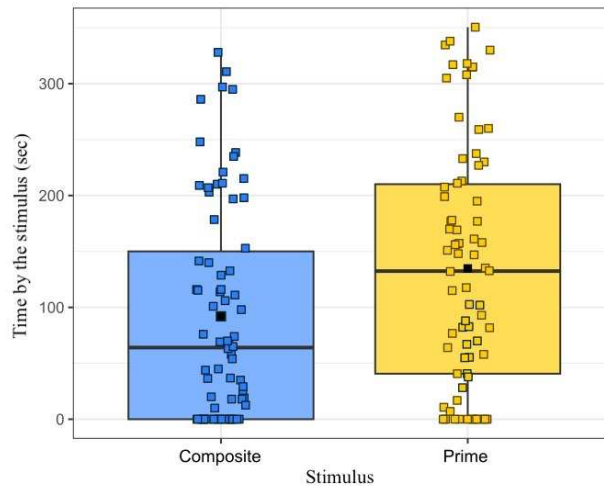17.2 s, t = -2.333, p = 0.023.

Figure 3.1. Interaction between stimulus and permanence time (s). On the y axis, the time

spent close to either stimulus in seconds. On the x axis, the type of stimulus, composite (in blue

on the left) or prime (in yellow on the right). The bars indicate the medians, the black square

indicates the mean. The coloured squares indicate individual subjects' performance.

Furthermore, we analysed the chicks' first choice, defined as the first stimulus approached by the

subject at the start of the test. In this case we defined the variable as a binomial one:

- 0 = choice of the non-prime number
- 1 = choice of the prime number

As for the analysis of the exploration times, we only found an effect of the type of stimulus (prime or

non-prime; $X^2 = 5.697$, p = 0.017). There was no effect found in the testing conditions (7 vs 9 or 9

vs 11; $X^2 = 0.024$, p = 0.877) proving that chicks behave in the same way in both tests. No effect

was found neither rf the variable sex (female or male; $X^2 = 0.021$, p = 0.89), or for any of the

considered interactions (all p values > 0.05).

The post-hoc analysis showed that chicks have a higher probability of preferring the prime set of

elements as the first choice (P(non-prime)/P(prime = 0.452, SE = 0.156, z = -2.039, p = 0.021).
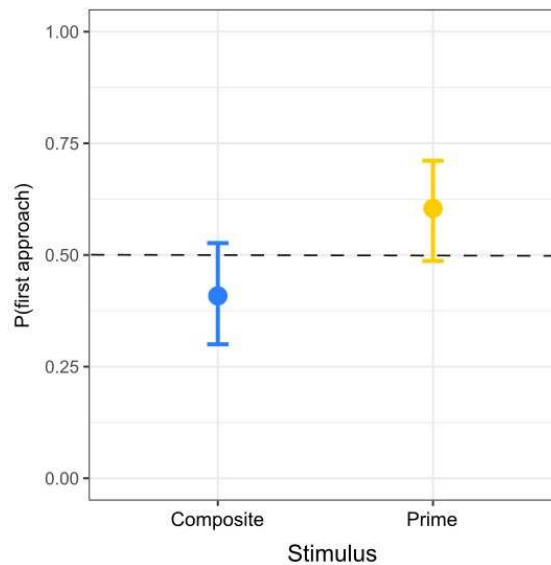
Figure 3.2. Interaction between stimulus and first choice. On the y axis the probability (from 0 to 1) to choose a stimulus. On the x axis the two employed stimuli, on the left (in blue) the composite stimulus (9) and on the right (in yellow) the prime stimulus (7 or 11). The bars indicate the standard error. The dashed grey line indicates chance level (0.5). By looking at the graph it is clear that the yellow is above chance level, which indicates that the interaction is significant for prime numbers; this means that chicks tend to choose the prime stimulus as their first choice.

3.4 Discarded subjects and criteria

On the total of subjects, the performance of 27 of them was discarded (approximately 27%).

The subjects discarded were the ones that did not make a choice and preferred to stay in the area of the arena that was not considered as the choice area. During the 6 minutes of test, some of them stayed still in in the starting point, while some others explored the arena staying always in the centre without ever reaching the distance from the screen of 5 cm.

This behaviour was probably a result of uneasiness and fear, and therefore there was a reduction of movement.

The performance of 9 subjects was also discarded because during the habituation process the screen did not work properly and shut down during the hour.

4. Discussion

4.1 Prime number spontaneous preference does not depend on novelty

The purpose of this study was to explore the nature of the preference for prime numbers exhibited by domestic chicks in Loconsole *et al.*'s study (2021). Specifically, the investigation aimed to determine whether this preference was inherent in the chick and could manifest even when placed in opposition to the novelty effect.

The analysis of the data collected so far revealed that chicks' performance is not influenced by the type of comparison (7 vs. 9 or 9 vs. 11), nor by their sex, nor by any possible interaction between them. There is instead an effect of the set, for which chicks explored longer the prime number (7 or 11) over the non-prime number (9).

This was evidenced by the significantly greater amount of time spent exploring sets of prime elements, rather than composite ones. This outcome aligns with the previous research (Loconsole et al., 2021) that suggests a predisposition for processing prime numbers differently due to their unique perceptual or mathematical properties and potential significance in nature. The findings support the idea that the preference for prime numbers might be an innate predisposition among chicks, which prompts them to engage more with stimuli possessing prime attributes.

We also investigated the chicks' initial choices, defined as the first stimulus approached at the beginning of the test. The analysis confirmed a statistically significant effect of the type of stimulus on the chicks' initial choices. About the testing condition effect, the sex effect and all the considered interactions effects, there were no statistically significant values found. The only variable that had an effect was the type of stimulus (prime or non-prime), in line with the results from total time of approach. Chicks exhibited a higher probability of preferring prime numerosities as their initial choice. This outcome underscores the robustness of the preference for prime numbers even at the earliest stages of decision-making.

Based on the results available to us and the considerations made in the previous sections, it is possible to propose a series of potential interpretations.

We can conclude that, since the results have remained unchanged and are consistent with the original experiment by Loconsole et al. (2021), there is an innate preference for asymmetrical patterns (prime numbers).

However, it is important to keep in mind that when considering the emergence of a preference from the analysed data, reference is made to the ensemble, to the totality of the performances of the examined chicks. There could be individual differences in chicks during the test phase: potentially, each chick could have made a preferential choice for one or the other type of stimulus. Despite this, the performance of the entire group still appears statistically significant regarding our research questions. Consequently, it would be relevant to analyse the behaviour of individual chicks in more detail. If both predispositions (novelty and preference for asymmetry) were equally valid, a single chick would be capable of switching between them, making choices that wouldn't show a specific preferential direction. However, it is equally possible that particular subgroups of subjects consistently prefer one strategy over the other, as showed by our results.

4.2 Possible ecological advantages

The results of our experiment can be explained through the extensive research that has been done on chicks and on their preference for asymmetry.

As already mentioned in section 1.2, research into the behavioural tendencies of newly hatched chicks offers intriguing insights into their cognitive and perceptual development. During the imprinting process, it has been demonstrated that these chicks show a propensity to explore stimuli with subtle novelty, a behaviour that carries significant ecological advantages. This exploratory behaviour not only engages the chicks with their environment but also supports the imprinting process, wherein they form strong associations with objects and organisms they encounter early in life (Jackson and Bateson, 1974).

In the realm of avian research, particularly with domestic chicken chicks, a series of studies has shed light on their preferences for different patterns and shapes. Notably, these newly hatched chicks

exhibit a preference for asymmetric patterns. This preference has sparked intriguing hypotheses that provide deeper understanding of their cognitive processes.

Forsman and Herrström (2004) and Clara et al. (2007) postulate that the preference for asymmetric stimuli could stem from an innate aversion to symmetric patterns. In nature, symmetric coloration could signal the presence of poisonous insects, prompting chicks to actively avoid them as a survival strategy. This hypothesis underscores the intricate ways in which chicks might have evolved to identify potential threats based on visual cues.

An alternative hypothesis suggests that newly hatched chicks might derive benefits from engaging with prey displaying asymmetric patterns. This type of pattern could be indicative of reduced fitness, making the prey easier to catch. This idea proposes a pragmatic perspective, suggesting that even at an early developmental stage, chicks are making calculated choices to optimize their foraging efficiency (Forsman & Herrström, 2004; Clara et al., 2007).

Interestingly, Clara et al. (2007) introduced the concept that the preference for symmetry in *Gallus gallus* chicks is not inherent, but rather experience-dependent. This implies that as chicks engage in active feeding experiences, they learn that symmetric objects are easier to interact with. This learning process involves sensory-motor development, wherein chicks progressively acquire the skills to manipulate and engage with objects more effectively.

The shift from a preference for asymmetric patterns to symmetric ones as chicks grow is attributed to their enhanced sensory-motor abilities. As these abilities develop, the initial strategy of preferring asymmetry becomes less advantageous. The preference for symmetry likely emerges as chicks realize the ease of interacting with symmetric patterns, contributing to their efficiency in foraging and engaging with their surroundings.

In conclusion, the developmental journey of newly hatched chicks' preferences reveals a dynamic interplay between ecological advantages, survival strategies, sensory-motor development, and learning experiences.

Conclusion

The aim of the present study on domestic chicken chicks was to investigate the preference for prime numbers that emerged from the previous study by Loconsole et al. (2021). The results, show a significant effect on the type of stimulus, highlighting a preference for the prime numerosities over the composite ones. These results emerged despite the conflicting nature of the two predispositions under examination: the preference for novelty and the preference for asymmetric patterns. These predispositions could have interfered with each other in a way that could have prevented the emergence of a preferential choice for either type of stimulus at the group performance level (across all chicks). Furthermore, there was a preference shown for prime numbers during the testing phase, suggesting a choice guided by an innate attraction toward asymmetry. On the contrary, a preference for non-prime numbers would suggest a choice primarily guided by the novelty effect. Nonetheless, even in this case, it would not be entirely correct to dismiss the chick's attraction to novel stimuli (exploring the strength of these respective effects is expected to clarify these uncertainties).

The study conducted by Geraci et al. (2022) involving 4- and 8-month-old infants has provided interesting evidence supporting the hypothesis that children of this age are also capable of mentally grouping objects to discriminate between symmetrically and asymmetrically divisible numerosities.

The results from Geraci et al.'s study raise similar questions as those posed by Loconsole et al. (2021): What is the nature of the preference for prime numbers? Is it an innate preference? Thus, we have conducted a study that, in terms of purpose and structure, closely mirrors the latter, to address these same questions in chicks.

The results of this study provide valuable insights into the numerical preferences of chicken chicks, shedding light on their predisposition toward prime numbers and their behaviour in relation to numerical comparisons. These findings contribute to our understanding of numerical cognition and preference in non-human animals.

Understanding the preferences and cognitive abilities of animals such as chicks in the numerical domain can provide insights into the broader concept of numerical cognition in the animal kingdom.

It prompts further questions about the universality of numerical biases and the potential ecological advantages of these biases, as already noted in section 4.2 *Possible ecological advantages* Additionally, investigating the potential developmental trajectory of these preferences, as well as their adaptive value in the context of natural environments, could further enrich our understanding of numerical cognition in avian species and beyond.

References

Ciccione, L., & Dehaene, S. (2020). Grouping Mechanisms in Numerosity Perception. *Open Mind*, *4*, 102–118. https://doi.org/10.1162/opmi_a_00037

Clara, E., Regolin, L., & Vallortigara, G. (2007). Preference for symmetry is experience dependent in newborn chicks (*Gallus gallus*). *Journal of Experimental Psychology: Animal Behavior Processes, 33*(1), 12–20.

Forsman, A., & Herrström, J. (2004). Asymmetry in size, shape, and color impairs the protective value of conspicuous color patterns. *Behavioral Ecology*, *15*(1), 141–147. https://doi.org/10.1093/beheco/arg092

Geraci, A., Loconsole, M., Regolin, L. Four-month-old infants rely on symmetry /asymmetry in perceptual grouping to discriminate sets of elements. International Congress on Infant Studies (ICIS). Ottawa, 7th – 10th July 2022.

Jackson, P. S., & Bateson, P. P. G. (1974). Imprinting and exploration of slight novelty in chicks. *Nature*, *251*(5476), 609–610. https://doi.org/10.1038/251609a0

Kobylkov, D., Mayer, U., Zanon, M., & Vallortigara, G. (2022). Number neurons in the nidopallium of young domestic chicks. Proceedings of the National Academy of Sciences, 119(32), e2201039119. https://doi.org/10.1073/pnas.2201039119

Loconsole, M., De Agrò, M., & Regolin, L. (2021). Young chicks rely on symmetry/asymmetry in perceptual grouping to discriminate sets of elements. *Proceedings of the Royal Society B: Biological Sciences*, *288*(1957), 20211570. https://doi.org/10.1098/rspb.2021.1570

Nieder, A. (2018). Evolution of cognitive and neural solutions enabling numerosity judgements: Lessons from primates and corvids. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*(1740), 20160514. https://doi.org/10.1098/rstb.2016.0514

Rugani, R., Loconsole, M., & Regolin, L. (2017). A strategy to improve arithmetical performance in four-day-old domestic chicks (*Gallus gallus*). *Scientific Reports*, *7*(1), 13900. https://doi.org/10.1038/s41598-017-13677-6

Rugani, Rosa. (2018). Towards numerical cognition's origin: Insights from day-old domestic chicks. *Philosophical Transactions of the Royal Society B: Biological Sciences*. 373. 20160509. 10.1098/rstb.2016.0509.

Scarf, D., Hayne, H., & Colombo, M. (2011). Pigeons on Par with Primates in Numerical Competence. *Science*, *334*(6063), 1664–1664. https://doi.org/10.1126/science.1213357

Vallortigara, G. (2012). The cognitive chicken: visual and spatial cognition in a non-mammalian brain. In The Oxford handbook of comparative cognition, pp. 48- 66. Oxford, UK: Oxford University Press.