Communicative & Integrative Biology 5:1, 1-2; January/February 2012; ©2012 Landes Bioscience

The magical number *four*

A biological, historical and mythological enigma

Hans J. Gross
BEEgroup and Chair of Biochemistry; Biocenter; Julius-Maximilians-University; Würzburg, Germany

Precise recognition of small object numbers without counting is a widespread phenomenon. It is well documented for humans and for a series of non-human vertebrates. Recently this has been confirmed for an invertebrate, the honeybee.[1] This type of inborn numerical competence has been named "subitizing," from the Latin *subito* = *suddenly, immediately*. It differs from the classical, sequential counting which has to be trained, starting with the help of our fingers. For humans it had been established since 1871 by Jevons[2] that only up to *four* objects are precisely recognized and memorized. Under conditions which do not allow sequential counting, mistakes start to occur in case of more than *four* objects. This result has been confirmed whenever the range of visual attention has been carefully tested under a variety of rigorous conditions. It provides the basis for a novel hypothesis about the evolution of counting and numbering systems in ancient civilizations.[3]

Key words: subitizing, honeybee, numerical competence, magical number four

Submitted: 09/19/11

Accepted: 09/19/11

DOI: 10.4161/cib.5.1.18149

Correspondence to: Hans J. Gross;
Email: hj.gross@biozentrum.uni-wuerzburg.de

Using a "delayed match-to-sample" setup in a Y-maze we determined the numerical capacity of honeybees. Even under variable and complex conditions, the insects were able to choose the correct object numbers in more than 80% of the decisions after only 4 rounds of training. Thus, up to 3 objects were memorized for about 5 sec during the flight from the entrance to the decision chamber of our setup, but 4 objects were recognized with less precision and with some difficulties,[1] indicating that the borderline of numerical capacity in this species is between 3 and 4 objects. We were especially careful to avoid any possibility of pattern recognition which would render our results meaningless. Similar numerical capacities have previously been observed for a number of vertebrates.[1] Partly those results were obtained under less stringent conditions because the very rigorous "delayed match-to-sample" setup had not been used or could not be used for all species. Moreover, many such studies, especially with "counting" animals, do not differentiate strictly enough between genuine counting, "subitizing" and pattern recognition. However, under rigorous testing conditions animals "subitize," i.e., recognize and memorize object numbers without the ability of real counting.[4]

In summary, object numbers of more than three or four consequently have the meaning of "many" for honeybees and for other, rigorously examined animals. This seemingly innate ability of humans, of non-human vertebrates and of an insect, the honeybee, to recognize and memorize up to four objects correctly without sequential counting raises the following questions:

(A) What is the benefit for humans and animals to be able to "subitize" object numbers up to four precisely?

We can only speculate about the benefits of this ability. For early hominids, who certainly were not able to count as we do, the ability to estimate within the fraction of a second whether two, four or "many" lions are watching them, the decision to attack and fight, to defend or to try to escape might have been a matter of life and death. For animals the ability to estimate whether two, four or "many" hungry carnivores are approaching may also

have been crucial for survival. In case of the honeybee we have speculated that the memorization of object numbers (trees, houses or other landmarks) may be useful for their orientation and help them to find back home. In addition it may help the foraging bee to recognize branches with less than three to four or with "many" blossoms, or to estimate the number of foraging bees on a blossom, allowing the decision to join or to quit.[1]

(B) Why is there a limit of up to 4 objects in case of humans and animals, even in case of honeybees?

We obviously are dealing with an inborn ability of many species but we do not know the answer—maybe we ask the wrong question.

(C) What is the underlying neurobiological process?

The underlying neurobiological process is still unknown, although neuroimaging techniques like functional magnetic resonance imaging have revealed that defined regions of the brain are activated during calculations.

(D) What is the driving force or evolutionary pressure which sustains this numerical competence from bees to humans?

The driving force for having the inborn numerical competence to differentiate between 2, 3, 4 or "many" objects in a fraction of a second without counting may be or may have been an advantage in the struggle for survival for humans and non-human vertebrates. For honeybees, such a selective advantage appears less essential. Although the ability to "subitize" is a primitive, archaic ability, it appears justified to rule out the possibility of divergent evolution because of the enormous evolutionary distances between humans and honeybees. If we consider the possibility of convergent evolution, we end up again with the question of selective advantage for the survival of a species involving exactly the same magical number *four* in humans and honeybees. What is the benefit for a pigeon mother to know whether she has *four* or "many" eggs in her nest? Pigeons have been shown to have numerical competence—but does this have any meaning for the survival and for the evolutionary success of the species? We have to admit that we do not know the answer. Does a look at the role of the magical number *four* in history and mythology help us to understand its biological significance?

(E) The role of the "magical" number 4 in history.

The earliest use of number 4 is the puzzling presentation of honeybees and honeybee hieroglyphs with 4 legs as early as 4,600 y ago throughout the history of ancient Egypt. There is no explanation why the correct number of 6 legs was not implemented by the Egyptian artists although an efficient numbering and counting system had been available.[3]

Another puzzling episode goes back to Aristotle (384-322 B.C.) who knew that animals with 4 legs never have wings. He wondered that the dayfly, whose short life-cycle he precisely described (4) is an exception in that this insect has wings despite of having 4 legs. Other examples for the importance of number four are the 4 seasons, the 4 sides and the 4 corners of a square, the rare four-leafed clover, a symbol of good luck in some cultures, in Hinduism the 4 faces of Brahma the creator, the 4 directions, the 4 elements water, fire, earth and air and, finally, the 4 human temperaments: sanguine, choleric, melancholic and phlegmatic.

The 4 Cardinal Virtues *sapientia* (wisdom), *iustitia* (justice), *fortitudo* (courage) and *temperantia* (moderation) are frequently associated with Christian religion. Historically, however, these virtues go back to Plato (428/427-348/347 B.C.).

In a religious context the following examples for the importance of the "magical" number 4 come to mind:

(1) The possibility for a Muslim to have up to 4 legal wives if he can support them. This rule has often been misinterpreted and misunderstood, but it had the function to support widows, with and without children, whose husbands had lost their lives on the battlefields. But why precisely 4?

(2) The 4 gospels and their corresponding evangelists. It was the Roman emperor Konstantin I. who decided that an obligatory, state-controlled religion with a single god—instead of the vast variety of gods, goddesses, half-gods, god-like previous emperors and cryptic oriental rites—would be an enormous advantage for ruling his huge but heterogeneous empire. He assembled more than 300 bishops at the Council of Nicaea in the year 325, and under his guidance—the religious delegates held different opinions about the existence of one single God or of a Trinity—only 4 out of more than hundred gospels existing at that time were selected as authentic. But why 4 and not 3 or 5 gospels? Could this be a reference to the 4 corners of the quadratic celestial Jerusalem[5] or because 4 is the first non-prime in the endless sequence of numbers?

(F) The occurrence of the "magical" number 4 in mythology.

Among the oldest cases presented here are the 4 celestial emblems of the Chinese emperor: The Black Tortoise (=North), the White Tiger (=West), the Red Bird (Phoenix = South) and the Blue Dragon (=East), ancient symbols which are several thousand years old.

In summary, questions about the evolution and the putative evolutionary advantage to "subitize" up to 4 objects without counting for the survival of a species remain without answer. We do not know why is this "magical number four" is common among humans, non-human vertebrates and honeybees. Moreover, a synopsis of the occurrence of this magical number in culture, religion and mythology highlights its universal significance but does not enlighten our understanding of the widespread, archaic, inborn ability for "subitinization." The "*magical number four*" remains a biological, historical and mythological enigma.

Acknowledgments

I thank my colleagues Profs. H. Beier, H. Hoehn and J. Tautz for critical reading of this manuscript and Dr. Mario Pahl for helpful suggestions.

References

1. Gross HJ, Pahl M, Si A, Zhu H, Tautz J, Zhang S. Number-based visual generalization in the honeybee. PLoS ONE 2009; 4:4263; http://dx.doi.org/10.1371/journal.pone.0004263; PMID:19173008.
2. Jevons WS. The power of numerical discrimination. Nature 1871; 3:281-300; http://dx.doi.org/10.1038/003281a0.
3. Gross HJ. Give me 5… The invention of number *five* in ancient civilizations—A consequence of our limited inborn numerical competence. Commun Integr Biol 2011; 4:62-3; PMID:21509181.
4. Gross HJ. To bee or not to bee, this is the question: the inborn numerical competence of humans and honeybees. Commun Integr Biol 2011; 4:590-3.
5. The Revelation of St. John 21, §16.