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Animals don't count: Clearing up confusion on subitizing

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Abstract

This paper aims to clear up terminological confusion in the study of numerical cognition, regarding subitizing (Kaufman, Lord, Reese, & Volkmann, 1949). While the term 'subitizing' was originally coined to describe the behaviour of numerate humans, it has since been applied to preverbal infants and animals. I first explore what this more inclusive interpretation entails, including the possibility of seeing subitizing as a cognitive system, and why this leads to confusion. I then argue that framing subitizing as something that is possible in subjects for which there is no conclusive evidence of there being systems that produce numerical content dilutes the concept of number. I end by discussing how the promiscuous interpretation applies to discontinuities in behaviour and in the ontogeny of numerical cognition. In each case, I show that this interpretation leads to confusion about numbers, and forces number nativism where more neutral takes are preferrable.

Keywords: Subitizing; Numerical Cognition; Ethology; developmental psychology; Working memory; Object-Files

Introduction: a brief history of subitizing

While the nature of numbers and of our epistemological access to them has puzzled philosophers for millennia, targeted empirical research of our numerical minds dates from the late 19th century. It is then that Cattell (1886) and Jevons (1871) found that adult humans' ability to label the number of stimuli presented in a visual array – its numerosity[1] – dropped sharply when this number rose above 3. Starting at 4, enumeration errors started creeping in, confidence in answers dropped, and reaction time increased in relation to the number of objects displayed. While research continued for decades to uncover why this ability to quickly and accurately apprehend the numerosity of small collections stopped at four objects, it is only in 1949 that Kaufman and colleagues coined the term 'subitizing' to name it.

The evidence for this behavioral discontinuity in enumeration tasks is robust: since the late 19th century, hundreds of studies have confirmed that numerate humans display at least one behavioural discontinuity in their ability to enumerate (Katzin, Cohen, & Henik 2019; Chen, Paul, & Reeve 2022). Even when experimental manipulations of stimuli slow down enumeration, they generally affect processing both inside and outside the subitizing range, so that the behavioural discontinuity remains visible, as evidenced by the tell-tale elbow-shaped slope change in graphs plotting response times versus number of items in subitizing studies.

While probing the numerical skills of numerate humans comes with its fair share of methodological headaches, probing pre-verbal infant and animal minds is even more difficult, since they cannot verbally report on their behaviour. Thankfully, with the advent of looking-time studies (Winters, Dubuc, & Higham 2015) that exploit paradigms like visual bias, violation-of-expectation and habituation-dishabituation, we can now peer into the minds of these subjects. Such techniques have yielded strong evidence that preverbal infants and nonhuman animals behave differently in response to variation of numerical stimuli in the subitizing range compared to larger numbers.

Consider for example a classic study by Starkey & Cooper (1980), who habituated infants to dot arrays whose numerosity was in the subitizing range (i.e. 2 or 3 dots), and then added or removed a dot after habituation. While infants dishabituated to numerical changes in the subitizing range, they failed to do this for larger numbers, even when the ratio between conditions was preserved (i.e. adding 2 dots to 4 or taking 2 away from 6). The same methods have also been applied to many animal species (Davis & Perusse 1988; Beran, M. J., Perdue, B.M., & Evans, T. 2015; Agrillo 2015) and in many cases the same distinction was found, where subjects responded to small numerical differences in the subitizing range, but not beyond.

Since the behaviour of numerate adults, preverbal infants, and animals all display behavioural discontinuity at the same numerical limit, many now use the term 'subitizing' to describe the behaviour of subjects that do not have the ability to label collections based on their numerosity. The question that interests us for the rest of this paper is: should we apply

[1] I use the term 'numerosity' to describe the number of objects an observer perceives a collection as having. This perceiver-relativity of numerosity emphasizes that numerosities are not numbers, since they are properties of physically-detectable collections of discrete objects, not abstract entities of arbitrary size.

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the term 'subitizing' to all these subjects? I argue that even though it is common practice to adopt a more inclusive interpretation of subitizing that applies to infants and animals, on closer inspection, use of the term should be limited to its original meaning, which applied to numerate humans. To support this claim, I start by teasing apart inclusive versus frugal takes on what subitizing is in the next section. I then take a closer look at what the inclusive take entails, including the possibility of seeing subitizing as a cognitive system, and of framing subitizing as something that is possible in subjects for whom there is no conclusive evidence of there being cognitive systems that produce numerical content. I end by discussing how the promiscuous interpretation of subitizing applies to discontinuities in behaviour and in the ontogeny of numerical cognition, showing how this forces us towards nativism about numbers, instead of a more neutral stance.

Who subitizes?

When Kaufmann et al. coined the term 'subitizing', they did this in a context where numerate humans that were asked to produce numerical labels for collections did this quickly, accurately, and confidently in a restricted numerical range, compared to how the same task is completed outside this numerical range. In stark contrast to the original meaning of the term, a variety of more inclusive interpretations have extended its use to anumerate subjects that do not produce numerical labels. For example, Starkey & Cooper were already applying the term to 22-week old infants in 1980, and later explicitly wrote that "Subitizing appears to develop before verbal counting." (1995, p.399). As for animals, in an exhaustive review of what they call numerical competence in animals, Davis & Perusse (1988) hypothesized that subitizing could explain much of what they consider as numerical behaviour in animals. Importantly, their version of subitizing substantially differs from Kaufmann et al.'s original, explicitly removing reference to speed and confidence so as to apply subitizing to children as well as to sequentially-presented stimuli. Further, their take distinguishes between "precounting subitizing, which yields tags that do not convey numerical information, and post-counting subitizing, which conveys numerically meaningful labels." (1988, p.563). So, in inclusive interpretations, an underlying commitment is that a subject can display behaviour that is numerical in nature without knowing how to count or produce numerical labels.

On top of loosening the requirement on producing numerical labels, another important difference between the original term and many inclusive takes concerns whether the term applies to behaviour or to the *system* underlying behaviour. According to many of these system-inclusive interpretations, "Subitizing is a universal *capacity* present not only in humans (including babies) but also in animals across disparate genera such as monkeys, rats, parrots, pigeons, crows, bees and dolphins" (Poncet & Chakravarthi 2021, emphasis added). Similarly, Nieder (2016) defines subitizing as follows: "Subitizing: (Also known as object file representation or object tracking *system*). The rapid *tracking* for up to approximately four items by assigning 'files' or 'pointers' to individual items." (p.366, emphasis added) [2]

Is subitizing a system or a behaviour?

In Kaufmann et al.'s original formulation, subitizing was clearly a type of behaviour. Apart from a desire for historical continuity, what reasons prevent us from widening the scope to include the system itself? One reason would be that this conflicts with common scientific practice: in general behaviour is not usually identified with its underlying causes. There's a reason for this: it ends up creating confusion by lumping vastly different phenomena under a common label.

For example, consider the distinction that is typically made between our ability to estimate how many items are in a perceptual display and the system thought to underlies this ability, the Approximate Number System, or ANS (Odic, D. & Starr, A. 2018). There are mountains of evidence suggesting that animals, preverbal infants, and numerate adults display similar perceptual thresholds in quantity discrimination beyond the subitizing range. Despite these similarities, the behaviour displayed is quite different among the subjects: while infants and animals might show longer looking times, they do not write or speak numerals in response to dot arrays. So a problem here is that if we use the same term to label the behaviour and the system, then we end up saying that many disparate types of behaviour are identical, if they rely on the same system. For example, if the ANS were identical to estimating the number of items in a dot array, then so would noticing the difference between two dot arrays, since this ability is thought to be explained by the ANS. But there are clearly important differences between estimating numerosity and noticing a difference in numerosity. One involves explicitly representing absolute magnitude, the other involves comparing magnitudes. Estimation is something we do, while behaviourally responding to differences is something that happens to us. So, unsurprisingly, it looks like identifying the behaviour with the system it recruits confuses distinct phenomena, and should be avoided – at least, when it comes to the ANS.

In the case of subitizing, the problem of lumping distinct behaviours together under the same label is significantly worsened by the fact that the main candidate underlying system – which, confusingly, is alternately called the Object-File System, Object-Tracking System, or Parallel individuation – is thought to be responsible for a wide variety of behaviours (e.g. Chesney & Haladjian 2011; Feigenson, L., Dehaene, S., & Spelke, E 2004; Trick and Pylyshyn 1994; Agrillo et al 2013). Regardless of which of these labels one favors, each of these candidate systems underly behaviour that differs so significantly from even the most inclusive

[2] Though Nieder here appears to be equivocating between subitizing and the Object-Tracking system, elsewhere he clearly distinguishes between subitizing and a candidate underlying system: "The OTS is thought to be *responsible for* a "subitizing" effect…This effect describes an effortless, fast, and accurate process to judge a small number of items" (2019, p.15, emphasis added)

notion of subitizing that the term loses any resemblance to its original meaning.

For example, let's assume that subitizing is the same as the Object-Tracking System (OTS), as suggested in Nieder's 2016 formulation, quoted above. We can think of the OTS as a limited capacity cognitive system that automatically creates a small number of indexes of visual feature clusters based on their spatiotemporal continuity, allowing us to keep track of what went where in our visual field. If subitizing is this, then any time a predator is following a prey, or even when a person watches sports and follows a hockey puck with their eyes, they would be subitizing, since they would be using their OTS, which we are saying is identical with subitizing. Things may get even worse if we identify subitizing with the Object-File System (OFS), since this systems is arguably even more general (Green & Quilty-Dunn 2021). In short, if our goal is to explain the causes of behaviour in terms of cognitive systems, it is bad scientific practice to lump disparate phenomena under a single label, given the confusion that ensues. So, subitizing is not a cognitive *system*, but a *behaviour*. Unfortunately, as we explore in the next sections, adopting an inclusive interpretation of subitizing leads to similar confusion about our numerical abilities.

Is (nonverbal) subitizing numerical?

Assuming we agree subitizing is a type of behaviour, to which extent does the inclusive take imply that animals and preverbal infants have numerical abilities? And, if it does, is this a desirable extension of the initial use of the term? Under Kaufmann et al.'s original take, subitizing is uncontroversially numerical behaviour, since it is explicitly framed as a way to assign a numerical label to a perceived collection. The question here is: when preverbal infants and animals look longer at stimuli following manipulation of numerical cues, is this behaviour the result of cognitive systems that produce *numerical* representations?

While inclusive interpretations may disagree on the status of counting and other aspects of Kaufmann et al.'s original definition, those who endorse an inclusive take typically agree that subitizing is numerical in nature, even when animals and infants 'subitize'. For example, Hurford attributes numerical abilities in animals based on their ability to subitize: "Crows don't count, they subitize…All animal whole-number ability is based on subitizing" (2007, p.91).

However, there are at least two plausible interpretations of animal and preverbal infant behaviour that do not appeal to any numerical content to explain such behavior. On the one hand, behaviour could be due to representations of continuous magnitudes that co-vary with numerosity, such as contour length or average size. On the other, subjects could be reacting to a mismatch between states of the OFS without explicitly representing the reason for this mismatch.

Regarding the first possibility, studies replicating Wynn's famous (1992) study, which claimed to show arithmetical thinking in infants, found that when continuous magnitudes like total surface area or total contour length in an array were controlled for, infants reacted to changes in these, and did not react to numerosity changes (Clearfield & Mix 1999; Feigenson et al. 2002).[3] However, number-related behaviour has been observed in cross-modal matching studies (e.g. Starkey, P., Spelke, E. & Gelman, R. 1990) that exploit an auditory-visual preference procedure, where stimuli cross modality boundaries, thereby essentially eliminating such modality-specific confounds.

If crossmodal studies are often considered strong evidence for the presence of numerical content in the subitizing range, it is important to consider that infant reaction here can simply be a matter of establishing one-to-one correspondence between object files in both modalities, and finding a mismatch (Uller, C., Carey, S., Huntley-Fenner, G., & Klatt, L, 1999; Scholl, B.J., & Leslie, A. M. 1999). On this more frugal interpretation, infants are reacting to violations of expected states of the OFS, not to any explicit representations of numbers or quantities of these states. Here, the OFS would produce outputs like OBJECT_a and OBJECT_b when two objects are shown, before producing OBJECT_c when a third appears. When the number of objects exceeds the OFS' limited range, no unitary changes are noticed. In this sense, the OFS could allow computations that produce content such as SAME/DIFFERENT. However, the underlying reason for this difference or sameness, numerical inequality, does not need to be explicitly represented or available to the subject.[4]

Of course, this non-numerical interpretation only holds if there is no decisive reason to think the systems underlying subitizing behaviour in looking time studies produce numerical content. There are two important conceptual distinctions we need to keep in mind to asses this possibility. The first comes from Núñez' (2017) advocacy for a more rigorous distinction between numerical (i.e. exact and symbolic) and quantical (i.e. quantity-related) cognition. The difference, in a nutshell, is between mastery of conventional signs that refer to numbers, and being able to notice differences in quantity in the environment. Here, subitizing is not numerical in nature, but rather "the quick, reliable, and accurate discrimination of small *quantities* (usually within numerosities 1–4)." (2017, 411, emphasis added). While animals and preverbal infants are capable of such quantical cognition, only a handful of unusually enculturated animals have mastered sufficient symbolic reference to number to be candidates for fully numerical behaviour on this framework. The second conceptual distinction we must keep in mind here is between *tracking* numerosity and *representing* it (Samuels & Snyder 2024): if a system co-varies with a feature of the world without producing representations of its associated content, then it merely tracks the content. If the system

[3] This being said, later studies found that infants can respond to both continuous magnitudes like area and contour length but also to numerosity, when the objects have distinguishable features (Feigenson 2005).

[4] This anumerical take is endorsed in one of the most influential models of subitizing (Trick & Pylyshyn 1994).

produces representations that inform the subject about that aspect of the world, then the system represents said content.

Now, keeping in mind that a system can produce quantical content without producing numerical content, and that a system can track numerosity without representing it, does the data concerning infant and animal behaviour in number-related looking-time studies show that the behaviour is caused by cognitive systems that produce numerical content, quantical content, or neither? Two interpretations of the data are congenial to the inclusive take on subitizing: the first claims the OFS produces numerical/quantical content, the second denies that behaviour is attributable to the OFS and instead is due to a quantical system like the ANS.

I argue neither of these interpretations conclusively support the inclusive take. On the contrary: in both cases, the received view goes in the opposite direction.

Consider the first possibility: how likely is it that the OFS produces representations with quantical/numerical content? The following characterization of the OFS (here called parallel individuation) will help here: "The purpose of parallel individuation is to create working-memory models of small sets of individuals, in order to represent spatial, causal, and intentional relations among them. Unlike analog magnitude number representations the parallel individuation system is not a dedicated number representation system. Far from it." (Carey 2009, p.151). According to Carey, because the OFS' job is to produce representations of the sort OBJECT_a, OBJECT_b and to store limited spatiotemporal information about these objects, the numerical content of the OFS is 'entirely implicit' (Carey 2009, 152). It is implicit in that, when one opens a new object file, this is analogous to adding 1. Importantly, it is analogous only to numerate observers, not because the subject experiences the tokening of an object file as numerical. In other words, on this view, if there is quantical/numerical content in the OFS, it is not content that drives subjects' behaviour. At best, it tracks numerosity, without representing it.

In opposition to this view, Margolis (2020) argues that, on top of there being object-files, there is a system, which he calls SuM (for Subitizing Module), that takes the output of the OFS as input and outputs symbols corresponding to the quantity of objects individuated by the OFS. In other words, an extra processing layer is present from birth that produces representations that Margolis considers numerical. The idea here is to interpret looking-time studies as evidence for the existence of an innate domain-specific cognitive system that produces representations of the numbers 1-3. Importantly, these 'numerical' representations are neither ordered, nor do they contain magnitude information (Margolis 2020, p.114-115). In this sense, the representations of SuM lack many of the attributes we tend to associate with numbers, as captured formally in logical axioms like those of Peano or Dedekind.

So, in choosing between Carey's take on the OFS and Margolis'SuM, who is right?

While this is an ongoing debate, there are many reasons to hesitate before siding with Margolis and others that associate numerical content to the OFS. First, if object-files were accompanied by a numerical processor, this would lead to a situation much like that which we mentioned when exploring the possibility that subitizing was identical with the OFS, in that many things not normally considered numerical would now have to contain numerical content. Any time we individuate an object, it would count as numerical. Any time a subject would experience sameness or distinctness, this would be a numerical experience. This is because if we say the OFS produces numerical content, this means that SAME/DIFFERENT would be numerical (or even quantical) content, and that OBJECT_a also somehow has numerical content, say. So Margolis' proposal strips the concept of number of some of its essential properties and dilutes it to situations that are difficult to conceive as being numerical. This is not the case for Carey.

There are also evolutionary reasons to doubt Margolis' proposal: in stark contrast to the domain-general takes of Carey and others who explain behaviour in terms of the activity of domain-general systems like the OFS, the existence of which is plausible independently of discussions of numerical cognition, Margolis' proposal adds an entirely distinct cognitive system to our cognitive arsenal that is purely dedicated to representing 1-3 (or, rather, their unordered cousins). However, it is difficult to see what sort of evolutionary pressures would select a system whose object files involve numerical content. The information would be useless in most cases and costly in terms of cognitive resources.

For these reasons, it seems unlikely that we can attribute numerical/quantical content to the OFS, so we need to look elsewhere if we are to find where the inclusive take's numerical content comes from. As mentioned earlier, another way to support the inclusive take is to consider the possibility that looking time responses are due to quantical/numerical system, and that a system other than the OFS is responsible for behaviour in the subitizing range. On this option, a single system underlies both quantical and numerical behaviour, both inside and outside the subitizing range. Apart from the ANS, there aren't that many systems that could fit this bill.

Such a single-system approach to the origin of our numerical abilities was once prominent in the study of numerical cognition. Proponents of the single-system option either proposed that subitizing is a form of rapid counting (e.g. Gallistel & Gelman 1991, 1992, 2000; Cordes, S., Gelman, R., Gallistel, C. R., & Whalen, J. 2001), or that it is a form of rapid estimation (e.g. Dehaene & Changeux 1993; Dehaene 1997/2011; van Oeffelen & Vos 1982; Vetter, P., Butterworth, B., & Bahrami, B. 2008). Importantly, in a testament to how fast the study of numerical cognition is growing, many authors who once advocated the single-system option have switched sides. A notable example is Stanislas Dehaene: in the second edition of his 1997 monograph *The number sense*, he explicitly recants the one-system position adopted in the first edition, following a study in which reaction times for quantity estimation tasks were compared in relation to the ratio of the quantities displayed (Revkin, S. K., Piazza, M., Izard, V., Cohen, L., & Dehaene,

S. 2008). If a single system were involved, the difference in time between identifying 4 objects and 1 object should be proportional to the difference in the time it takes to identify 40 objects compared to 10 objects, given the same ratio in both cases. This does not appear to be the case. Rather, the speed with which we identify numbers of objects within the subitizing range is consistently faster than any other range, even when matching for ratios between quantities of objects.

Thus, evidence points towards (at least) two systems at the core of our numerical abilities, and that the one that produces the quantical/numerical content is the ANS, not the OFS. Why does this matter? As I mentioned earlier, while some variants of the inclusive take on subitizing strip away certain parts of Kaufmann et al.'s original formulation, the inclusive interpretation generally takes subitizing as being numerical – or at least in Núñez' case, quantical – in nature. However, given this section showed that non-quantical interpretations had more going for them, it looks like the inclusive interpretation clashes with the original in an important way, in that it extends the concept of number to cases that are at the very least, not obviously numerical. Human behaviour that led to the concept of subitizing is based on number, while it is uncertain, at best, that animal and preverbal infant behaviour is. In other words, the inclusive take frames subitizing as numerical behaviour that is produced by systems that might have no numerical content. This blurs the difference between numerical and non-numerical content – in the context of studying how we think about numbers. Such confusion has important downsides for the epistemology of arithmetic and number (Pantsar 2024). As I highlight in the next sections, blurring over this important difference by using the inclusive take not only makes the concept of subitizing rest on a confusion about what counts as numerical, but it has negative implications for how we frame important discontinuities in the ontogeny of numerical cognition.

Changing behavioural discontinuity

Another important difference between the original take and the inclusive one is that subitizing is *relational* in nature: the reason that it stood out as a behaviour worth investigating early on is because of the discontinuity in performance in enumeration tasks. Numerate humans can perform *the same task* within and beyond the subitizing range, both by counting and by estimating. Of course, infants and animals also can respond to differences in numerosity between stimuli beyond the subitizing range. But their responses are just that: mere responses. In numerate humans, the task is not "respond to stimuli". It's "say how many dots you see", for example.

To hammer in this point home, if we were to plot response times for infants or animals vs numerosity of stimulus – say, we measure the time it takes from target stimulus onset until we observe longer looking time – there is little reason to think it would look anything like the telltale elbow-shaped graph of subitizing. Sure, there would be a discontinuity at around the subitizing range, but we would not see a gradual, proportional increase in response times afterwards. And we could not plot error rates, since subjects are not producing responses that can be interpreted as mistakes.

This is why influential models of subitizing include accessing numerical labels as part of their model (e.g. Trick & Pylyshyn 1994; Mandler & Shebo 1982): the slight increase in reaction times in the subitizing range vs the bigger increase outside this range also needs explaining. In a graph plotting animal or infant behaviour, there would be no such slight increase to explain, and no bigger increase outside the subitizing range. Virtually no animals or infants produce labels for numerosity, no matter how inaccurate. In this sense, inclusive interpretations of subitizing not only force us to dilute the concept of number, as seen in the last section. They also change the type of behaviour we are trying to explain.

Labelling is important. From a subjective point of view, how we interpret and categorize an experience will licence inferences and behaviour that are specific to this categorization. From an external point of view, when we label such disparate behaviour under a single term, we lump radically different experiences together. For us to talk about subitizing in both numerate and anumerate subjects, the behaviour must be discontinuous *in the context of completing the same task*. Only under the loosest possible interpretation of the word 'task' does responding to the environment count as a task.

(Over-) Simplifying ontogenetic discontinuities

Similarly, another problem with the inclusive take on subitizing is that its numerically-enriched interpretation of behaviour substantively modifies how we frame the development of numerical abilities in children. When we say infants and animals are subitizing and that subitizing is numerical/quantical, we are saying they have a cognitive system that produces numerical/quantical content in the subitizing range, from birth. In so doing, we risk glossing over important questions regarding the transition between being able to detect changes in our environment to being able to apply numerical label to these changes, and any steps passed along the way. It takes children years to learn how to enumerate, through a slow, gradual process (Barner 2017). Whatever cognitive systems and processes underlie subitizing, if the inclusive take is right in saying animals and infants subitize and that their behaviour is numerical, then the story we tell about what enculturation and learning gives children will be radically different, since the specifically numerical aspects of their behaviour are already present from birth, latent, waiting.

To be clear: there are compelling reasons behind nativism about number, which concerns whether or not humans are born with cognitive systems that produce representations with numerical content (Clarke 2025). However, while the debate on number nativism is certainly related to whether or not subitizing should be seen under a more promiscuous light, these are separate questions. Number nativism is certainty consistent with adopting a more inclusive take on subitizing. But there seems to be no reason for a number nativist to *require* this interpretation. After all, one can claim that we are born with some numerical abilities and still allow that the numerical abilities displayed in studies like those of Kaufmann et al. are of a different nature and deserve a different label. In this sense, we can be nativists about numbers and still see subitizing as an ability that is only possible for individuals with developed numerical abilities of the sort that require familiarity with a counting routine.

While there may be reason to think some aspects of numbers are innate, there are also many reasons to think that an important transformation of numerical cognition's building blocks – whatever these turn out to be – takes place before we can label collections in terms of their numerosity. If this is the case, it is important (not to mention, better scientific practice) to name different abilities using different terms. Given the difference between tokening object files and naming collections based on their numerosity, we should not assume that subitizing is continuous with naming numerosities. If this is the case, then the stricter, original interpretation of subitizing should be favored in the literature.

By assigning numerical abilities to infants and animals, the inclusive take implicitly endorses nativism about numbers. But number nativism is only one of many ways to explain where our number concepts come from. Given that how we overcome the discontinuity between the content produced by systems like the ANS and the OFS and our formal numerical abilities is one of the most important questions in the study of numerical cognition, any linguistic practice that presumes one explanation over another – especially one as controversial as number nativism – should be avoided. As Simon and colleagues put it, "The change from not having a concept of number to having a concept of number is perhaps the single greatest mathematical advancement that a human learner can make." (Simon, M. A., Della Volpe, D., & Velamur, A. 2023, p.465) Unless we assume number nativism is correct, in order to respect the importance of this change, we should abstain from labelling number-sensitive responses as numerical. This means we should avoid the inclusive interpretation of subitizing. Importantly, using a stricter take on subitizing does not in any way prevent one from being a nativist about number. It just allows us to maintain a neutral, agnostic position on the matter. [5]

Conclusion

The short history of the study of numerical cognition is littered with cautionary tales of over-attribution of numerical abilities in subjects where more frugal, anumeric interpretations of behaviour turned out to be more accurate. For animals, the tale of Clever Hans, a horse once thought to know how to count but whose behaviour was actually caused by his ability to detect subtle cues coming from his master's arithmetical knowledge, serves as a stern warning not to read numerical behaviour everywhere. Similarly, Wynn's celebrated work was successfully recast in anumeric terms.

Unfortunately, some lessons are hard to learn. More recently, it has been claimed that bees can count, distinguish between odd and even numbers, and even have an understanding of the concept of zero (Howard, S. R., Avarguès-Weber, A., Garcia, J. E., Greentree, A. D. & Dyer, A. G. 2018). In every case, a non-numerical interpretation of the data is not only possible (Shaki & Fischer 2020), but preferable.

While polysemy is natural – and sometimes even desirable in scientific practice (Sterner 2022) – it can also lead to miscommunication and misinterpretation and can complicate data sharing and categorizing (Sterner, B. W., Witteveen, J., & Franz, N. M., 2020), especially when semantic variation is too high. I have argued here that the polysemy surrounding the term 'subitizing' is problematic in this sense, and that a stricter use of the term, in line with its original meaning, should be adopted. Inclusive use of the term 'subitizing' to label responses to variations in quantities in the subitizing range on the part of infants and animals whose numerical abilities are far from being established creates confusion and glosses over important stages in the development of formal arithmetical abilities. This is a problem for everyone investigating the origins of our numerical abilities, irrespective of whether or not they endorse nativism about number. This confusion has led some (e.g. Baroody, A. J., Paliwal, V., & Li, H. 2026) to distinguish between different types of subitizing, as had been done by Davis & Perusse in 1988, seen above. While this does help deal with the confusion created by the inclusive interpretation, it does so only partially, since we still presume the term applies to subjects that might not have numerical knowledge. Another option that has the advantage of not generating a plurality of subitizings is to restrict application of the term to demonstrably numerate subjects, as I've argued here.

While it may seem like what we include under terms like 'numerate', 'number', or 'subitizing' is stipulative in nature, some contexts favor some interpretations over others (Parkinson-Coombs 2025). My claim here has been that the context of studying the origins of numerical abilities favors a more strict interpretation of subitizing, since this reflects important discontinuities in our learning trajectories that we otherwise lose under the more promiscuous interpretation, meanwhile respecting some of the key formal properties of numbers that we wish to explain.

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[5] See Clarke 2025 for a related discussion about agnosticism towards number nativism.

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