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It all adds up …. Or does it? Numbers, mathematics, and purpose

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ABSTRACT

No chimpanzee knows what a square root is, let alone a complex number. Yet not only our closest ape cousins but even some invertebrates, possess a capacity for numerosity, that is the ability to assess relative numerical magnitudes and distances. That numerosity should confer adaptive advantages, such as social species that choose shoal size, is obvious. Moreover, it is widely assumed that numerosity and mathematics are seamlessly linked, as would be consistent with Darwinian notions of descent and modification. Animal numerosity, however, involves sensory processes (usually vision, but other modalities such as olfaction can be as effective) that follow psychophysical principles, notable the Weber-Fechner law. In contrast, mathematics may require sensory mediation but is an abstract process. The supposed connection between these processes is described as supramodality but the mechanisms that allow humans, but not animals, to engage in even simple mathematics are opaque. Here, I argue that any resolution will depend on proper explanations for not only mathematics, but language and by implication consciousness. In this light, concepts of purpose are not intellectual mirages but legitimate descriptions of the worlds in which we are embedded. These are both visible (and tangible) and invisible (and although intangible, equally real).

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1. Introduction

One of the finest of spectator sports is watching a biologist duck and weave when the word “purpose” swims into view. Better still, watch the reaction if some disembodied voice murmurs “teleology”. Much huffing and puffing, but let us consider an example of where the difficulty ostensibly lies. Here’s a cheetah, over there a gazelle. Pursuit leads to intersection and thus dinner. Cheetah 1, gazelle 0. Unless we think the cat is a robot—or the gazelle for that matter—presumably the latter *wants* to avoid being eaten, just as much as the cheetah *desires* lunch. Or so we suppose.

2. Beyond the gazelle

So far, so simple. If placental mammals as a whole are any guide then attributes such as playfulness, personality, emotional states and so on might be expected to occur in our cheetah (e.g. Wielebnowski, 1999; albeit in captivity) and gazelle (well, tame fallow deer; Bergvall, Schäpers, Kjellander, & Weiss, 2013). Not to the level we associate with humans, but at least incipiently possessing the necessary substrate that in our context we might identify as fright, if not terror (the gazelle) versus plotting, perhaps even the thrill of the chase (the cheetah). Darwin, of course, was open to this view and although he was self-evidently (if not painfully so) no philosopher, people like Mary Midgley (1995) would argue that at least in one sense we are beastly. But deeper in the history of life? Not everybody agrees (Rose, 2007), but if fish possess emotional states (Portavella, Torres, & Salas, 2004) and personality (Katano, 1987) then perhaps along with the cheetah and gazelle, fish too are capable of intentional actions. Nobody doubts this is a minefield, but either way in most circles it would be a reasonable presupposition that the capacity for intentionality most surely depend on a nervous system, if not a brain.

Not so fast. Possession of a brain, let alone a nervous system, may not be an automatic pre-requisite. So it is that many protistans possess eye-spots (e.g. Spudich, 2006), but their apotheosis is in the

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warnowiid dinoflagellates that have convergently evolved a camera-eye. Other than its function as a dioptric "organ" this eye has no connection at all with its vertebrate equivalent; indeed part of this remarkable structure is derived from the plastid (Gavelis et al. 2015). In most dinoflagellates, of course, these plastids (chloroplast) are employed in photosynthesis, but in the warnowiids obviously this is no longer an option and they have transformed themselves not only into heterotrophs but into hunters. Despite its dioptric properties this protistan eye has generated some unease. Pierre Couillard (1984, 123) notes "If an image is really formed on the retinoid, we fail to see, in the present state of our knowledge, how an integrative computer could exist to analyse it within the cell". Ester Piccini and Pietro Omoden (1975, 72) are even more forthright, declaring "It is unthinkable that [the warnowiid eye] … in spite of the sophistication of its design, can function like an image-forming eye". But the evidence suggests the eye can focus an image (Francis, 1967). So those dinoflagellates have an effective eye but in the absence of a nervous system no mechanism to interpret the image—or so we suppose. Even if the organism possesses both camera-eye and a nervous system, but not a brain—as is the case with the cubozoan jelly-fish (e.g. Nilsson, Gislén, Coates, Skogh, & Garm, 2005)—it is not obvious what exactly the animal *sees*.

These examples encapsulate the questions of perception and intentionality: both warnowiid dinoflagellates and cubozoan jelly-fish hunt, but do they know what they are actually doing? To nearly all evolutionary biologists this question, I suspect, is of little moment, if not totally irrelevant. After all, any organism has to survive and it is not going to do that unless in some way it is "aware" of the world around it and "act" according to circumstance. As for dinoflagellates and cubozoans—and for gazelles and cheetahs—so the same must apply to us?

Darwin's triumph was not only to root us to the Tree of Life, but show how we are "Just another twig". Yet here, I want to suggest that the questions of perception and action (in the broadest sense) lead us back to one of the eternal questions: how do we know anything at all? So too given that the processes of evolution which were responsible for our emergence are blind and without purpose, as has been repeatedly pointed out the naturalistic assumption must be we fool ourselves that a purpose has any deeper meaning than as a word to describe our actions as an agent. Darwin was, of course, well aware of this dilemma. It is no criticism of his intellect that his doubts verged on the semi-articulate. In his well-known letter, written in 1881 to William Graham, Darwin wrote "Nevertheless you [Graham] have expressed my inward conviction, though far more vividly and clearly than I could have done, that the Universe is not the result of chance. But then with me the horrid doubt always arises whether the convictions of man's mind, which has been developed from the mind of lower animals, are of any value or at all trustworthy. Would any one trust in the convictions of a monkey's mind, if there are any convictions in such a mind?" (Darwin Correspondence Database, http://www.darwinproject.ac.uk/entry-13230; accessed October 26th, 2015). Darwin's query that the mind of the monkey might be conviction-free will be extended below to enquire whether its capacity to understand, as against recognize, numbers is any more secure.

But if monkeys, or any other animal, are excluded can we be confident that we are not in the same predicament? One response is that we think we understand but are deluding ourselves, imposing meaning where none exists. As we will see, this is by no means as ridiculous as it might seem. To be sure if we pursue this line of enquiry we seem ultimately to be doomed to solipsism. One might also protest that the word "doom" cannot be used unless we have some sense of finality. May be so, but the fact remains that as products of evolution (involving natural selection or whatever; the principle remains) there are inexorable pressures to make "sense" of the surrounding world. Unfortunately, at least so far as I can see, this provides no guarantee (as Darwin also intuited) that we possess the equipment (again a product of evolution) that allows us to make sense of everything or even a rather small fraction of everything. Indeed, we possess no ultimate warrant for anything, and are doomed—that word again—to "live" in a "world" of undetermined depth and of radical uncertainty. Now that, oddly enough, should not only be an encouragement to scientists, but as I will mention below also to theologians.

Lest it be thought that all I have done is lead the reader into a miasma, or into a hall of mirrors, let me protest this is not my intention. Rather it is to explore one particular area to suggest that apparently clear-cut divisions, specifically between sensory inputs and abstract concepts, are not nearly as clear as might be thought, or we would like.

3. Numerosity

I suggest that a very interesting test-case revolves around the perception of numbers. Welcome to what is known as numerosity. As outlined in a little more detail below many animals can assess numbers. So can we, but for us numbers are not only central to arithmetic but can be treated in an entirely abstract fashion (whilst this is the general default assumption as with much of this area few matters are completely clear-cut; in this context see Cohen Kadosh and Walsh (2009)). This in turn may provide an unexpectedly interesting connection to the question of consciousness, and perhaps ultimately purpose. Given that the words consciousness and purpose are slippery enough concepts, to the extent that some might even deny their existence, it would seem that to choose numerosity as a test-case requires some justification. Hopefully this will become more apparent below, but in outline numerosity seems to offer a special advantage. This is because in animals the perception of numbers can be shown to be a sensory process, following psychophysical laws that apply equally, for example, to the perception of different weights.

So too we humans "see" numbers, seeing meaning not only in terms of vision but at first sight surprisingly other modalities, such as smell. But we also *understand* numbers. It is open question whether this applies to animals, but one reason to think they cannot comprehend numbers is because they seem incapable of either elementary manipulations, let alone excursions into the realms of higher mathematics. So we perceive numbers but they become (or already are) abstract entities, and in terms of recognition presumably dependant on consciousness. But so too they can be manipulated in surprising ways. Most people know the famous story of Hardy going down to meet the sick Ramanujan and declaring the number of the taxi that brought him to Putney not being of a particular interest. On the contrary, Ramanujan reproved Hardy: the taxi number 1729 was "the smallest number expressible as a sum of two cubes in two different ways" (Hardy, 1940, 12). This anecdote takes very far from animal numerosity, but first some background.

The first observation is that when rhesus monkeys (and convergently in corvids; Ditz & Nieder, 2015) are tested for numerosity (Nieder & Miller, 2003; also Dehaene, 2003), be it in terms of numerical distance and numerical magnitude, their response follows the so-called Weber-Fechner law. This is a psychophysical assessment of perception which in following a logarithmic distribution necessarily implies a proportionality of response. For example, if the minimum additional weight that needs to be added to eighty ounces (or if you prefer 2268 g) for me to perceive a tangible difference is one ounce (for those of you wedded to Gallic certainty that is of course is 28.35 g), then if the weight in question is now