The Generality Constraint and the Structure of Thought

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According to the Generality Constraint, mental states with conceptual content must be capable of recombining in certain systematic ways. Drawing on empirical evidence from cognitive science, I argue that so-called analogue magnitude states violate this recombinability condition and thus have nonconceptual content. I further argue that this result has two significant consequences: it demonstrates that nonconceptual content seeps beyond perception and infiltrates cognition; and it shows that whether mental states have nonconceptual content is largely an empirical matter determined by the structure of the neural representations underlying them.

1. Introduction

What Gareth Evans dubbed the *Generality Constraint* lays down a widely accepted requirement that thinkers must meet to have thoughts with conceptual content (Evans 1982, Ch. 4; Peacocke 1992, Ch. 2; Davies 1989; Heck 2000). I will explain this requirement in detail later, but the basic idea is simple enough. Just as words can freely recombine to make new sentences, so too must concepts be capable of freely recombining to make new thoughts. Thus, if you can think that *a* is F and that *b* is G, you must also be capable of thinking that *a* is G and that *b* is F.

As Christopher Peacocke observes, 'The recombinability of concepts to form new thoughts has been largely unquestioned in the published literature' (Peacocke 1992, p. 42). Even nonhuman animals are often taken to exhibit such recombinability, or 'systematicity', as Jerry Fodor and Zenon Pylyshyn call it. They write, 'That infraverbal cognition is pretty generally systematic seems, in short, to be about as secure as any empirical premise in this area can be' (Fodor and Pylyshyn 1988, p. 41). For if cognition were not systematic,

> [i]t would have to be quite usual to find, for example, animals capable of learning to respond selectively to a situation such that *aRb*, but quite

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> unable to learn to respond selectively to a situation such that *bRa* (so that you could teach the beast to choose the picture with the square larger than the triangle, but you couldn't for the life of you teach it to choose the picture with the triangle larger than the square). I am not into rats and pigeons, but I once had a course in Comp Psych, and I'm prepared to assure you that animal minds aren't, in general, like that. (Fodor 1987, p. 153)

As Ned Block wryly remarks, Fodor's argument here is 'uncomfortably anecdotal' (Block 1995, p. 411). In this paper, I will argue that Block's suspicion is well founded. A more sustained scrutiny of the empirical literature on human and animal cognition reveals that an important class of cognitive states — so-called *analogue magnitude* states — are not systematic. Since the Generality Constraint requires states with conceptual content to be systematic, it follows that analogue magnitude states have contents that are not conceptual — that is, *nonconceptual contents.*

This result promises to reorient philosophical debates about conceptual and nonconceptual content in at least two ways. First, in so far as philosophers have contemplated nonconceptual mental content, they have focused almost entirely on perception, the assumption (often tacit) being that cognitive states such as beliefs must surely have conceptual content. Yet, as I will argue, analogue magnitude states are better characterized as cognitive than perceptual, and thus stand as an existence proof of cognitive states with nonconceptual content. Second, the question whether a class of mental states has conceptual or nonconceptual content has generally been approached from the comfort of the philosopher's armchair, the assumption (almost always tacit) being that a priori reflection and introspection are by themselves sufficient to furnish an answer. By contrast, I hope to illustrate that such questions have a large empirical component. To assert that a given mental state has conceptual or nonconceptual content is to stake a claim to the structure of the neural representations that subserve it.

2. Systematicity and the Generality Constraint

In preparation for the argument that analogue magnitude states have nonconceptual content, I begin by explicating the Generality Constraint in greater detail.

It is important to distinguish the closure condition that features in the Generality Constraint from the Generality Constraint itself.

The closure condition maintains that the mental states one is capable of entering into are closed under all meaningful recombinations of the constituents of the sentences that best express them. For example, if one can think that Amy is friendly and that Bob is gracious, then one can also think that Amy is gracious and that Bob is friendly. Or to give a more complex example, if one can think that Amy loves Bob and that Claire is friendly, one can also think that Claire loves Amy. Following Fodor and Pylyshyn (1988), I will say that one's mental states are *systematic* just in case they meet this closure condition.

Notice that this closure condition makes no mention of conceptual content. The Generality Constraint, by contrast, lays down a requirement on possessing states with conceptual content. It holds that one's cognitive states have conceptual content only if they are systematic. The Generality Constraint thus allows that mental states might fail to be systematic. After all, we can clearly imagine a creature that represents that Amy is funny and that Bob is gentle, but that, for whatever reason, completely lacks the capacity to represent that Amy is gentle.[1] The Generality Constraint merely denies that the representational states of such a creature would have conceptual content. In other words, the Generality Constraint is a constraint on *conceptual* content, not a constraint on mental content tout court.[2]

The Generality Constraint is thus a conditional claim that has systematicity as its consequent (*if* a subject's mental states have conceptual content, *then* they are systematic). For our purposes this is significant, since it means that if we can show that certain mental states violate systematicity we can use the Generality Constraint along with *modus tollens* to argue that those states have nonconceptual content. This strategy will feature prominently in my argument in section 4 that analogue magnitude states have nonconceptual content.

To repeat: the Generality Constraint holds that if one's mental states have conceptual content, then one's ability to enter into those mental

[1] Cf. Davies (1992, p. 251), who observes that a creature might have a hawk-diving-on-beetle detector, but no beetle-diving-on-hawk detector.

[2] This helps to explain why Peacocke (1992, pp. 48–51) holds that the Generality Constraint is a necessary truth, whereas Fodor contends that 'it's about as empirical as anything can be whether [animal minds] are systematic' (Fodor 1987, p. 153). To be systematic, minds must obey the relevant closure condition; and it is clearly a contingent matter whether they do. By contrast, the Generality Constraint is a constraint on having states with conceptual content, and so everything turns on how we interpret 'conceptual content'. Philosophers such as Evans and Peacocke pack a lot into this term of art — enough so that the Generality Constraint is understood to be 'partly constitutive of the notion of conceptualized content' (Davies 1989, p. 148). For these philosophers, the Generality Constraint thus emerges as necessary.

states is closed under all meaningful recombinations of the constituents of the sentences that best express them. The appeal to 'meaningful recombinations' is meant to qualify the Generality Constraint in two ways. First, it is intended to exclude syntactically ill-formed recombinations. Although 'Amy is friendly' is meaningful, and 'Bob is gracious' is meaningful, 'Amy Bob' is not meaningful. The Generality Constraint thus does not require someone who can conceptually think that Amy is friendly and that Bob is gracious to also be able to think that Amy Bob. Second, some philosophers hold that even syntactically well-formed sentences fail to be meaningful when they involve concepts that are 'categorially inappropriate' for each other. For example, while it makes sense to ask whether a number is prime, perhaps the question whether a person is prime is ill posed. If so, we should allow that a creature could conceptually think that Caesar is dead and that seven is prime, and yet lack the capacity to think that Caesar is prime.[3]

The Generality Constraint's reference to 'one's ability' to enter into mental states also deserves comment. To say that one is *able* to enter into a mental state is to say that one has the *cognitive capacity* to enter into that state. Thus, a subject might satisfy the Generality Constraint even if some adventitious factor, such as powerful emotions, self-deception, memory limitations, or a neurological hiccup, blocks her from exercising her cognitive capacities—for example, if a blinding rage of hatred toward Amy blocks the subject from even entertaining the thought that Amy is gracious (Peacocke 1992, p. 43). On just about any view of concepts, one will want to distinguish between a case in which a subject cannot think that *b* is F because she fails to possess the concepts *b* and *F*, and a case in which she cannot think that *b* is F because some adventitious factor prevents her from putting those concepts to use. The present point is simply that the Generality Constraint is meant to allow for this distinction. Subjects must have the competence to recombine their concepts, but their performance need not always reflect that competence. I will return to this point in section 4.2.

Why should we accept the Generality Constraint? A full answer would need to appeal to a worked-out theory of conceptual content along the lines of Evans 1982 or Peacocke 1992, which is more than I can hope to provide here. But briefly, I understand such theories to be

[3] Philosophers who are inclined to view sentences such as 'Caesar is prime' as meaningful but false need not recognize such exceptions to the Generality Constraint (cf. Evans 1982, p. 101, n. 17 and Camp 2004).

committed to two premisses from which the Generality Constraint follows. The first is that possessing a concept is having a very general cognitive ability. For example, to possess the concept *Amy* is to have the ability to think about Amy, and to possess the concept *is friendly* is to have the ability to think of any arbitrary object that it is friendly.[4] The second premiss is that one can be in a mental state with the conceptual content *p* only if one possesses the concepts from which *p* is composed.[5] It follows from this second premiss that if you can think that Amy is friendly and that Bob is gracious you must possess the concepts *Amy*, *is friendly*, *Bob*, and *is gracious*. By the first premiss, you must thereby have the abilities to think about Amy/Bob and to think of any arbitrary object that it is friendly/gracious. Hence, you can think that Amy is gracious and that Bob is friendly.[6]

These two premisses about concept possession bind a thinker's mental contents to her actual psychology: a thinker can only believe that *a* is *F* if she possesses the concepts *a* and *F*, and she can only possess those concepts if she has very specific cognitive abilities. The allure of the Generality Constraint is thus the allure of a marriage between mental content and psychological reality. Although I believe this marriage to be worth saving, I will not press the point here.[7] My present aim is not to defend the Generality Constraint, but to understand it well enough for the argument to come. In section 4 I will argue that if one operates with a sufficiently robust understanding of conceptual content — any understanding sufficient to carry the Generality Constraint in its wake — one cannot maintain that cognition is thoroughly conceptual. First, however, we need a brief tutorial on analogue magnitude states.

3. Analogue magnitudes

In 1965, Mark Rilling and Colin McDiarmid established an experimental paradigm in which a pigeon was required to determine the number

[4] Cf. Evans, 'Thus, someone who thinks that John is happy and that Harry is happy exercises on two occasions the conceptual ability which we call "possessing the concept of happiness"' (Evans 1982, p. 101).

[5] Cf. Peacocke, 'Attitudes are relations to complex contents, composed in a distinctive way from concepts possessed by the thinker' (Peacocke 1992, p. 43).

[6] Similar derivations of the Generality Constraint can be found in Evans 1981 (pp. 337–8) and 1982 (pp. 100–5), Peacocke 1992 (pp. 42–51), and Heck 2000 (pp. 486–7).

[7] Though see Heck 2007 for arguments with which I am sympathetic.

of times it pecked a key. With a row of three keys before it, the pigeon had to peck the centre, illuminated key until the experimenter extinguished it, which he did either after some constant number of pecks — say, 50 — or else after some other number of pecks, *n*, such that $n < 50$. After the centre key extinguished, the two other keys illuminated. If the pigeon had pecked the centre key 50 times, it was rewarded only for pecking the right-most key. If the pigeon had pecked the centre key *n* times, it was rewarded only for pecking the left-most key. Rilling and McDiarmid found that the pigeons succeeded in this task to varying degrees depending on the value of *n*. When *n* was 35, they succeeded about 90% of the time. When *n* was 43, they succeeded about 70% of the time. Once *n* reached 47, however, the pigeons were at chance. They were above chance at discriminating the numerical values of two sequences of pecks until their ratio exceeded 9:10. Although the pigeons were not perfect in their responses, and the error in their responses increased with the value of *n*, the fact that they tended to succeed suggests that they were able to represent the approximate number of pecks that they had executed.

When Rilling and McDiarmid first performed these experiments on pigeons, rats were the only other species whose numerical capacities had been extensively studied (Mechner 1958; Platt and Johnson 1971). But recent years have witnessed a resurgence of interest in the topic, and the ability to discriminate numerical values in this rough and approximate way has now been documented in a wide variety of tasks involving myriad creatures, including fish (Agrillo et al. 2006), monkeys (Hauser et al. 2003), chimpanzees (Beran and Beran 2004), human infants (Xu and Spelke 2000), pre-numerate human children (Barth et al. 2006), and innumerate human adults (Gordon 2005; Pica et al. 2005). Experiments even show that numerate human adults such as *you* have the ability to represent numerical values in this rough and approximate way when explicit counting is impossible. Hilary Barth and colleagues (2003) presented adults with two displays of large numbers of randomly distributed dots, flashing them each for just a second so that there was not enough time to explicitly count them. The adults were above chance at telling which display had more dots so long as the ratio of the dots was no more than 7:8.[8]

[8] For excellent reviews of numerical representation, see Gallistel 1990 (Ch. 10), Dehaene 1997, Feigenson et al. 2004, and Carey 2009 (Ch. 4).

It turns out that the capacity to represent numerical values in this rough and approximate way is a special case of a more general capacity to represent all kinds of magnitudes, including not just number, but duration, rate, distance, area, and volume. Unifying these so-called *analogue magnitude* representations is a systematic limitation, *Weber's Law*, which holds that the ability to discriminate two magnitudes is a function of their ratio.[9] For example, just as the pigeons can discriminate 43 from 50 pecks but not 47 from 50 pecks, they can also discriminate 86 from 100 pecks, but not 94 from 100 pecks. Put more formally, Weber's Law says that ${}^{\Delta I}/_{I} = k$, where I is the value of the magnitude (in this case number), k is a constant, and ΔI is the minimal change in magnitude required for discrimination. For example, when $I = 20$ pecks, the pigeons can just manage to discriminate I from 22 pecks (so $\Delta I = 2$); when $I = 40$ pecks, the pigeons can just manage to discriminate I from 44 pecks (so $\Delta I = 4$); and so on. Thus, the pigeons' Weber constant for discriminating numbers is ${}^{1}/_{10}$, which is why they can discriminate 43 from 50 but not 47 from 50. When the ratio of two magnitudes exceeds that allowed by the subject's Weber constant, the quantities become indiscriminable for the subject.

The Weber constant for a given magnitude (e.g. number) differs across phylogeny and ontogeny. For example, when it comes to discriminating numerical values, pigeons are better than monkeys, and human adults are better than human infants.[10] By contrast, the Weber constant for different magnitudes (e.g. number vs. duration) may be the same relative to a species and stage of development, though the evidence is less clear-cut (Feigenson 2007). In any case, the existence of some positive Weber constant or other is a universal feature of magnitude discriminations by non-human animals and, when explicit measurement is not possible, humans.

The fact that magnitude discriminations typically conform to Weber's Law is worth bearing in mind. It will feature prominently in my argument that analogue magnitude states have nonconceptual content.

[9] I borrow the term 'analogue magnitude' from the psychological literature. For now, the reader is encouraged to treat it as nothing more than a name for a family of states that represent magnitudes and are characterized by Weber's Law. The idea that these states are somehow analogue is discussed and defended in Sect. 6.

[10] See Hauser et al. 2003, Xu and Spelke 2000, and Barth et al. 2003 for the monkey, infant, and adult data, respectively.

4. Systematicity violated

4.1 A first pass

The content of a mental state specifies how that mental state represents things as being. I will adopt a realist stance toward such contents. That is, I will assume that there is a fact of the matter about the content that any given mental state has that is independent of anyone's interpretations, and I will assume that explanations of behaviour that advert to mental contents are genuine causal explanations. This realist stance is not uncontroversial. It has been denied by eliminativists about mental content such as Paul Churchland (1981) and Stephen Stich (1983), as well as instrumentalists such as Donald Davidson (1973) and Daniel Dennett (1987). But I take it to be justified by the many successful explanations in cognitive science that posit mental contents to causally explain behaviour. I will further assume with such thinkers as Peacocke (1997), Fodor (1987), C. R. Gallistel (1990), José Luis Bermúdez (2003), and Peter Carruthers (2004) that this assumption of realism about mental content is justified in application to the mental states of animals as well as humans. The question before us is thus not whether analogue magnitude states *have* contents; it is whether those contents are *conceptual*.

We have already seen one requirement on conceptual content in the form of the Generality Constraint. A second widely accepted requirement on conceptual content — one that will play a background role in the argument to come — is that it be *truth-conditional* (e.g. Evans 1982; Peacocke 1992). The conceptual content of a mental state must specify the conditions under which the state is true and false. Mental states with conceptual content are thus required to be like sentences not only in their properties of recombination, but also in being truth-evaluable.[11]

I propose to argue by *reductio ad absurdum* that analogue magnitude states have nonconceptual content. I will start with the assumption that analogue magnitude states have conceptual content. Given that sentences express conceptual contents, it should thus be possible to find sentences to express the contents of analogue magnitude

[11] Truth and falsity are standards of representational correctness, but they are not the only such standards. For example, representations such as pictures and maps can arguably be evaluated by the standards of resemblance or isomorphism. Thus, while the notion of representation plausibly requires a commitment to content, it does not obviously demand a commitment to *truth-conditional* content. The requirement that conceptual content be truth-conditional is non-trivial.

states.[12] I will argue, however, that the best sentences we can find to express the contents of analogue magnitude states lead to failures of systematicity. Since the Generality Constraint requires states with conceptual content to be systematic, it follows that we must reject our initial assumption and conclude that analogue magnitude states have nonconceptual content.

Consider the behaviour of pigeons described in section 3. How are we to explain their capacity to consistently discriminate various numbers of pecks? The obvious suggestion is to attribute to the pigeons mental states that represent the number of pecks they have executed. For example, the pigeon pecks the left key in response to 40 pecks because it has learned that it will be rewarded for pecking the left key if the number of pecks it has executed is less than 50, believes that it has just pecked the left key 40 times, and believes that 40 pecks are fewer than 50 pecks.

Let us focus just on the last of these attributions — that the pigeon believes (or at any rate, cognitively represents[13]) that 40 pecks are fewer than 50 pecks. Of course, we need to be careful here in deciding precisely how we want to phrase the content of the pigeon's belief. We do not want to over-intellectualize the pigeon by attributing representations to it that are richer than explanations of its behaviour require. This is an important point, and one to which we will return. But for now, let us take this attribution at face value. I can then present a first pass at my argument that analogue magnitude states are not systematic. It begins with the claim that pigeons can represent that

(1) 40 pecks are fewer than 50 pecks

and that

(2) 38 pecks are fewer than 47 pecks

[12] The assumption that sentences express conceptual content is essentially axiomatic among philosophers who talk of conceptual content (e.g. Evans 1982), and so I will take it for granted here. I should note that I will *not* be assuming that the contents of analogue magnitude states can be expressed by the predicates of *current* English. In Sect. 4.3 I thus consider introducing new predicates, such as '50ish', to help express the contents of analogue magnitude states.

[13] Whether we honour the pigeon's representational states with terms like 'belief' rather than, say, 'cognitive representation' or 'proto-belief' will be a function of the substantive issue of how their representational states differ from ours, and the semantic issue of whether we feel those differences are sufficient to warrant a special nomenclature. Much of this paper is concerned with the substantive issue; but the semantic issue cannot be properly discussed here, so I will just register that I use terms such as 'belief' and 'thought' liberally.

But recall that pigeons cannot discriminate numerical values that exceed a 9:10 ratio, the threshold of their Weber constant. They thus seem unable to represent that

(3) 38 pecks are fewer than 40 pecks

or that

(4) 47 pecks are fewer than 50 pecks

The cognitive states with numerical content that pigeons can enter into are thus not systematic. They are not closed under all meaningful recombinations of the constituents of the sentences that best express them.

This argument involves two main claims: the *positive claim* that pigeons are capable of bearing attitudes towards contents best characterized by sentences such as (1) and (2); and the *negative claim* that pigeons are not capable of bearing attitudes towards contents best characterized by sentences such as (3) or (4). I defend these claims in reverse order in sections 4.2 and 4.3, remaining primarily focused on the specific case of pigeons' numerical representations. In section 4.4 I discuss how the argument might generalize beyond the representation of numbers by pigeons.

4.2 Defending the negative claim

My claim that pigeons lack the capacity to represent contents such as (3) and (4) is based on the fact that the pigeons fail to behaviourally discriminate certain numerical values. This inference may strike readers as fallacious. Why should we take the inability of pigeons to *behave* in certain ways as indicative of their inability to *represent* certain contents? After all, there are clearly cases where *you* cannot discriminate two numerical values, though you have the capacity to represent that one is less than the other. Suppose that you are at a political rally on the Mall in Washington D.C. where the organizers claim to have assembled one million protesters. From your vantage point atop the Lincoln Memorial you have an excellent view of the crowd. But of course you cannot tell if there are one million people as the organizers claim or only 900,000 as the authorities estimate. Nevertheless, you clearly have the capacity to think that 900,000 people are fewer than one million. You might even say to yourself, 'Gee, I wonder whether there are one million people here or merely 900,000'. Perhaps the pigeon is in a similar position.

There is, however, a significant disanalogy between what pigeons can do and what you can do. Although you might not be able to discriminate a crowd of one million from a crowd of 900,000, there are other circumstances in which your capacity to think that 900,000 is less than one million would emerge. For example, if someone asked you what number you get if you add 100,000 to 900,000, you could answer correctly. Or if someone gave you a pile of poker chips and told you that they are worth 100,000 each, and then asked you to make two piles — one valued at one million and another valued at 900,000 — you could humour her. There are many things you could do that a person who *ex hypothesi* was exactly like you except could not represent that 900,000 is less than one million would not be able to do. By contrast, let us imagine a creature that is exactly like a pigeon except that it *ex hypothesi* cannot represent that 47 is less than 50. So far as researchers have discovered, there is nothing that pigeons can do that these hypothetical creatures cannot. It would thus seem that we have imagined a pigeon.

This thought experiment is just a colourful way to make the point that attributing the capacity to represent contents such as (3) and (4) adds nothing to our explanations of the pigeon's behaviour. The verdict that the pigeon cannot represent (3) and (4) thus derives not from some verificationist or behaviourist principle that cognitive capacities are *constituted* by behavioural capacities, nor from the implausible principle that *every* failure of discrimination is indicative of a representational failure. Rather, the verdict derives from considerations of explanatory simplicity.

To make these considerations more precise, let Ψ_σ be an assignment of a set of contentful cognitive capacities, Ψ, to a subject, σ, and let us say that assignment Ψ_σ has an *explanatory advantage* over assignment Ψ^*_σ just in case there are actions σ is capable of performing that can be explained using Ψ_σ but not Ψ^*_σ. We can now formulate the following principle.

> *Simplicity Principle*:
> If Ψ is a subset of Ψ^*, and Ψ^*_σ offers no explanatory advantages over Ψ_σ, then, *ceteris paribus*, Ψ_σ is a better assignment than Ψ^*_σ.[14]

[14] The Simplicity Principle is a special case (restricted to instances where $\Psi_\sigma \subset \Psi^*{}_\sigma$) of Peacocke's (1983) *Tightness Constraint*, which roughly holds that Ψ_σ is superior to $\Psi^*{}_\sigma$ if $\Psi^*{}_\sigma$ contains conceptual capacities not in Ψ_σ that do no explanatory work, and every conceptual capacity in Ψ_σ but not $\Psi^*{}_\sigma$ does explanatory work. Thus, philosophers who accept the

For example, let C be the set of cognitive capacities that we might conservatively attribute to a pigeon, let $D = C \cup \{$the capacity to think that the Cold War was the defining struggle of post–World War II Europe$\}$, and let P be a pigeon. The Simplicity Principle would then dictate that, all other things equal, C_P is a better assignment than D_P since (I assume) adding the capacity to think that the Cold War was the defining struggle of post–World War II Europe to a pigeon's stock of cognitive capacities would not enable us to explain any (actual or nomologically possible) actions of the pigeon that we could not already explain with the original stock of cognitive capacities.

More to the point of our present concerns, let us suppose that we are trying to decide between two sets of cognitive capacities that we might attribute to a pigeon: C, which includes the capacity to think (1) and (2), and E, which differs from C only in not including the capacity to think (1) and (2). I would argue that C_P provides an explanatory advantage over E_P since it allows us to explain the pigeon's ability to discriminate 40 from 50 and 38 from 47 pecks. By contrast, let us suppose that C does not include the capacity to think (3) and (4), and that F differs from C only in including that capacity. I claim that F_P offers no explanatory advantage over C_P since there is nothing that a pigeon might do that an appeal to F would help us to explain that we could not explain just as well with C. My justification for this claim is empirical. It is grounded in evidence from the sorts of experiments discussed in section 3. Since such evidence is clearly defeasible, I am certainly not saying that it is a *sure thing* that F_P offers no explanatory advantage over C_P. But I am claiming that that is what the current state of research into these matters indicates. Thus, if we accept the Simplicity Principle, it follows that if all other things are equal we have (empirical, defeasible) reason to resist adding the capacity to represent (3) and (4) to the stock of cognitive capacities that we attribute to a pigeon.

Why should we accept the Simplicity Principle? One reason is that something like it is required to resist outrageous attributions of mental capacities to undeserving thinkers. But a more fundamental reason, I take it, is that the Simplicity Principle is at bottom an application of Ockham's razor to the mental realm. It is a special instance of the general idea that mental capacities should earn their explanatory keep — that is, that mental capacities should be attributed

Tightness Constraint are committed to the Simplicity Principle, though one could accept the Simplicity Principle without accepting the Tightness Constraint.

to the extent, and only to the extent, that they enhance our understanding of the thinker. Thus, when a mental capacity cannot even potentially contribute to an explanation of a subject's actions, we should, all other things equal, refrain from attributing it to the subject.[15]

There are various ways that all other things might not be equal. For example, even if Ψ is a subset of Ψ^*, and Ψ^*_σ offers no explanatory advantages over Ψ_σ, it might be that Ψ^*_σ better respects what we know about the subject's neurobiology or phylogenetic history than Ψ_σ. In such cases, the *ceteris paribus* clause of the Simplicity Principle would be triggered, and so it would be consistent with that principle if Ψ^*_σ were a better assignment than Ψ_σ. So far as I can see, however, attributing the capacity to represent (3) and (4) to the pigeon does not trigger the *ceteris paribus* clause. For example, I am not aware of any reason to think that attributing these capacities fits better with what we know about the pigeon's neurobiology or phylogenetic history, or with any other commitments that we have independent reason to endorse.

One possible way of triggering the *ceteris paribus* clause in the Simplicity Principle deserves special consideration. We might have evidence that Ψ^*_σ offers no explanatory advantages over Ψ_σ merely because performance limitations prevent σ from deploying certain capacities. For example, suppose that limitations of attention prevent you from entertaining thoughts with more than *n* embedded clauses. We might nevertheless be justified in attributing the capacity to entertain such thoughts to you on the grounds that it is merely an exogenous factor that blocks you from entertaining such thoughts. This brings us face to face with the issue, discussed in section 2, that the Generality Constraint is meant to apply to a subject's cognitive competence, not to her performance. For systematicity to be violated, it needs to be the case that pigeons lack the conceptual capacity to represent contents such as (3) and (4). It cannot merely be the case that some adventitious factor prevents them from putting those concepts to work. This worry is particularly acute because pigeons are dim-witted creatures. Their inferential, attentional, memory, and learning capacities are dwarfed by our own. Thus, we might reasonably wonder whether their inability to discriminate certain numbers of

[15] I thus take the Simplicity Principle to be based on the same general considerations as Peacocke's Tightness Constraint (see previous note) and Lloyd Morgan's Canon (which holds that, all else equal, animal activity should be explained in terms of 'lower' rather than 'higher' psychological processes).

pecks in various experimental situations reflects performance limitations rather than a total inability to represent contents such as (3) and (4). Perhaps pigeons have fully systematic conceptual capacities, but then have that systematicity masked by some impeding performance factor.

My claim that pigeons exhibit failures of systematicity does not rest on their general stupidity, however. It is grounded in a very specific shortcoming of theirs: their adherence to Weber's Law. On its own, this observation does not rule out the possibility that their discriminatory failures might be chalked up to performance limitations. But it does indicate that any such explanation will have to take a specific form. It will have to locate the source of Weber's Law not in the pigeon's numerical representations themselves, but in some exogenous factor such as memory or attention.

Whether Weber's Law is a product of the numerical representations themselves or some exogenous factor is, of course, a long-term empirical question. However, current research provides at least two reasons to locate the source of Weber's Law in the numerical representations. First, countless experiments that make varying demands on memory, attention, and other performance factors provide no indication that these factors are the source of the noise associated with Weber's Law. Second, when researchers recorded activity from so-called number neurons in monkeys' prefrontal and parietal cortex, the presumed anatomical home of analogue magnitude representations, they found that these neurons fire at an increased rate in response to specific numbers, but with a profile that would explain Weber's Law (Nieder et al. 2002; Sawamura et al. 2002; Nieder and Miller 2003). For example, a 'five-neuron' will fire most in response to the presentation of five stimuli, but also quite often to four or six stimuli, less but still sometimes to three or seven stimuli, etc. Moreover, the amount of variance in the firing rate is proportional to the mean, such that a four-neuron has less variance than a five-neuron, which has less variance than a six-neuron, etc. Thus, as the ratio of two numbers approaches one, they become harder to discriminate by examining the firing rates of their corresponding number neurons, suggesting that the number neurons themselves, and not some exogenous performance factor, are the source of Weber's Law. Admittedly, these experiments were carried out on monkeys, not pigeons. But if, as many researchers suspect, analogue number representations are homologous across diverse species, we should expect these results to transfer to pigeons.

4.3 Defending the positive claim

Given that the point of attributing contentful cognitive states is to provide causal explanations of behaviour, the question whether cognitive states with contents such as (1) and (2) should be attributed to a pigeon largely reduces to the question whether causal explanations of pigeon behaviour are best facilitated by these attributions. I am aware of only one method for answering this question: consider the best alternative attributions we can think of, and compare the explanations they generate to explanations involving contents such as (1) and (2) to see whether they better explain the data. In what follows, I will consider the most plausible alternative attributions I can think of. In each case, I will argue that the alternative either results in inferior explanations of the pigeon's behaviour, or still engenders failures of systematicity.

Alternative #1 Replace the integer concepts in (1) and (2) with non-numerical concepts that correlate with number. For example, instead of representing the total number of pecks they have executed, perhaps pigeons instead represent the duration of their pecking.

Reply Careful controls have discredited such proposals. For example, Rilling (1967) found that duration of pecking was a poorer predictor of behaviour in his tasks than number of pecks. Similarly, after Francis Mechner and Laurence Guevrekian (1962) trained rats to press a lever an arbitrary number of times in return for food, they starved the rats, reasoning that hungry rats would press the lever more quickly, but not necessarily a greater number of times. True to their prediction, although these hungry rats did press the lever at a hurried pace, there was no significant difference in the total number of presses they executed, telling against the hypothesis that the rats were representing the duration rather than the number of their presses.[16]

Of course, duration is just one of many properties that correlate with number in these sorts of experiments, and there is no a priori reason to think that just because duration failed to account for the data that some other correlating property will not succeed. But there is a reason that the existence of representations with numerical content is widely accepted among animal researchers. The dialectic

[16] A further problem with the duration-based explanation is that it is likely that my argument that pigeons violate systematicity could be recast in terms of analogue magnitude representations of duration since they too obey Weber's Law. See Sect. 4.4 for discussion.

exemplified by the duration-based alternative has proved to be the rule rather than the exception.

Alternative #2 Replace the integer concepts with the demonstrative concept *that many*. The use of this demonstrative concept would then allow for free recombination: just as you can think that *that many* jelly beans (pointing to one jar) are fewer than *that many* jelly beans (pointing to a second jar) even if you cannot discriminate the number of jelly beans in each jar, so too, we might suppose, a pigeon can represent that *that many* pecks (attending to 47 pecks) are fewer than *that many* pecks (attending to 50 pecks) even though it cannot discriminate 47 from 50.

Reply The problem with this suggestion is that demonstrative-based thoughts are not able to *explain* the discriminative behaviour of pigeons. One way to see this is to observe that there is no reason to expect demonstrative representations to give rise to Weber's Law. By contrast, as we will see in section 6, there is a perfectly good explanation why number-specific analogue magnitude representations give rise to Weber's Law. Another way to see the same point is to notice that in the jelly bean example you can demonstratively think that one jar has fewer jelly beans than the other even though you are completely incapable of behaviourally discriminating the number of jelly beans in the two jars. To explain the capacity to behaviourally discriminate two cardinal sets, we thus need to appeal to something over and beyond demonstrative concepts. We need to appeal to number-specific representations. And as we have seen, there are reasons to doubt that those representations are systematic.[17]

Alternative #3 Replace the relational concept *are fewer than* with *are different from*. After all, the pigeons in Rilling and McDiarmid's experiment were never required to discriminate numbers of pecks that *exceeded* the target number. So how do we know that they understand the difference between *more* and *fewer*?

Reply The short answer is that it does not matter which of these concepts we attribute to pigeons since the argument that they violate

[17] Evans (1982, p. 229) famously suggests that perceptual experiences are nonconceptual because we can perceptually discriminate more shades than we have concepts for. McDowell (1994) replies that Evans overlooks demonstrative concepts such as *that shade*. In his defence of Evans, Heck (2000) points out that demonstrative thoughts alone cannot explain a person's perceptual capacities. We need to appeal to perceptual experiences to *ground* those capacities. My remarks in the main text follow a similar line of thought to Heck's.

systematicity works equally well with either. The slightly longer answer is that both attributions are probably equally appropriate. There is evidence that animals can represent which of two numerical values is greater or lesser than the other (Dehaene 1997, Ch. 1); and there is evidence that even pigeons have the capacity to represent of two arbitrary things that they are different (Cook 2002).

Alternative #4 Replace the concept *are fewer than* with the concept *are discriminably fewer than*. This suggestion explains why the pigeons reliably peck the left key only when the ratio of the number of pecks they have executed to the target number exceeds the threshold dictated by their Weber constant: only then are the executed pecks *discriminably* fewer than the target number.

Reply The problem with this suggestion is that it only saves systematicity if the pigeons can represent that 38 pecks are discriminably fewer than 40 pecks and that 47 pecks are discriminably fewer than 50 pecks. Of course, the pigeons need not *believe* this content, but they should be able to represent it — even if they only represent it as false. Thus, it predicts that when the target is 50 and the pigeons have pecked 47 times, they should reliably peck the right key to register their conviction that the pecks they have executed are *not* discriminably fewer than the target number. But that is not what they do. Rather, they are at chance as between pecking the left and right keys.[18]

Alternative #5 Replace precise integer concepts such as *47* and *50* with approximate numerical concepts such as *47ish* and *50ish*. After all, a pigeon that is trained to peck 50 times in reward for food will peck exactly 50 times perhaps 20% of the time, 49 or 51 times slightly less often, 48 or 52 times slightly less often than that, etc., where their responses form an approximate bell curve centred on 50. So while the mean and mode of their responses may match the selected integer, on any given trial their responses are only likely to be in the correct neighbourhood.[19] Thus, the pigeons do not represent *precise* numerical values — *integers* such as 47 and 50 — but rather 'a blur on the number line' (Spelke and Tsivkin 2001, p. 59). They represent

[18] *Objection*: just because the pigeons do not give any behavioural indication of being able to represent that 47 is not discriminably fewer than 50 does not mean that they are incapable of representing that content. *Reply*: assuming that they can represent that content adds nothing to our explanations of their behaviour, and thus violates the Simplicity Principle.

[19] Note that the bell curve flattens as the target integer increases. More formally, pigeons' responses exhibit the *scalar property*: the standard deviation is proportional to the mean.

approximate values such as 50ish, which are defined such that 'There are 50ish Fs' is true not only if there are 50 Fs, but also if there are slightly more or less than 50 Fs.

As Susan Carey (2009, p. 295) points out, the importance of the successor relation to the integers further supports this idea. In order to represent the integers, one arguably needs to represent the difference between 3 and 4 as the same as the difference between 11 and 12. But pigeons appear incapable of representing 11 as different from 12 since their Weber constant is $^1/_{10}$. And even when they are able to represent that two numerical values are different — as pigeons can distinguish 10 from 20 and 40 from 50 — they are unable to represent this difference as the same in the two cases. Since differences are detected according to Weber's Law, pigeons represent 40 and 50 as much more similar than 10 and 20.

Reply Replacing the integer concepts with approximate numerical concepts still generates violations of systematicity. Pigeons can represent that

(1*) 40ish pecks are fewer than 50ish pecks

and that

(2*) 38ish pecks are fewer than 47ish pecks

But given their Weber constant, they are unable to represent that

(3*) 38ish pecks are fewer than 40ish pecks

or that

(4*) 47ish pecks are fewer than 50ish pecks

Yet at least on a natural reading, (3*) and (4*) are true. Just as an estimated distance of approximately 47 miles is less than an estimated distance of approximately 50 miles, 47ish pecks are fewer than 50ish pecks. There are, however, two ways to challenge this natural reading, which I now consider.

Alternative #6 Treat the approximate numerical concepts as existentially quantifying over a range of integers such that (3*) and (4*) come out as false. For example, we could interpret *50ish* to mean *a precise integer between 45 and 55*. (4*) would then mean something like *for any number of pecks* n *such that* $42 \leq n \leq 52$, *and for any number of pecks* m *such that* $45 \leq \mathrm{m} \leq 55$, n *is less than* m. Given the overlap between the potential values of *n* and *m*, (4*) would then be false.

Reply Like alternative #4, this suggestion gives rise to the prediction that pigeons should be able to represent that 47ish pecks are fewer than 50ish pecks if only to represent it as false. Thus, given a situation in which they are asked whether 47ish pecks are fewer than 50ish pecks, the pigeons should be able to answer 'no'. But in Rilling and McDiarmid's original experiment they failed to do this. During trials in which the light extinguished after 47 pecks, the pigeons did not generally peck the right key to demonstrate their disbelief that 47ish pecks are fewer than 50ish pecks. Instead, they were at chance as between pecking the right and left keys.

Alternative #7 Treat the concepts *47ish* and *50ish* as not just approximate, but vague. We can then view recombinations of those concepts as involving truth-value gaps.[20] This promises to save systematicity since such 'gappy' recombinations will be meaningless, and systematicity only requires that thinkers be capable of grasping all *meaningful* recombinations of their concepts (see Sect. 2). For example, given the vagueness of the concepts *38ish*, *40ish*, *47ish*, and *50ish*, perhaps (3*) and (4*) are neither true nor false, but indeterminate and thus meaningless.[21] The fact that pigeons cannot represent these contents would thus pose no threat to systematicity.

Reply One problem with this suggestion is that it takes for granted that where a proposition is indeterminate it is also meaningless. Yet this assumption is doubtful. Perhaps it is indeterminate whether a person with fifty follicles of hair is bald. Even so, the proposition is perfectly meaningful — we know exactly what it says even if it is neither true nor false. An indeterminate proposition is thus very different from a syntactically ill-formed proposition, or a proposition that combines two terms that are categorially inappropriate for each other (supposing these latter propositions truly are meaningless). The ability to represent (1*) and (2*), but not (3*) and (4*), would thus still count as a violation of systematicity.

[20] I assume here and in what follows that vagueness gives rise to truth-value gaps. Epistemicists about vagueness will disagree. But as will soon become clear, this assumption is concessive since the objection I am considering is not available to epistemicists.

[21] Alternatively, or additionally, one could locate the vagueness in the relational concept *are fewer than*. But for the purposes of this objection, it does not matter where the vagueness is located so long as it turns out that (3*) and (4*) are indeterminate.

Setting aside concerns over the indeterminate-therefore-meaningless inference, a second problem arises for this suggestion. Even if we grant that the pigeons' numerical concepts are vague, it does not necessarily follow that (3*) and (4*) are indeterminate. After all, the thought that very bald people have less hair than somewhat bald people expresses a determinate (and true) proposition despite containing the vague concepts *very bald* and *somewhat bald*. Many if not most of the determinate thoughts we think involve vague concepts. What the objection requires is thus not merely that the pigeons' numerical representations are vague, but that they are vague in *exactly* the ways required to save systematicity. Concepts such as *38ish* and *40ish* have to be defined such that, for example, (1*) and (2*) come out as true, but (3*) and (4*) come out as indeterminate. But aside from a desire to save systematicity, what is supposed to justify this assumption? It cannot merely be that *38ish* and *40ish* have overlapping penumbras, since the same is true of *very bald* and *somewhat bald*. So what is it?

The problem is that the defender of systematicity can respond to *any* putative violation by replying that the subject is operating with a concept whose range is indeterminate over the values that lead to the alleged violation. For example, if I claim to have found a subject that can think that Albert is friendly and that Bob is gracious, but not that Albert is gracious, someone can always object that this is no violation of systematicity since the subject does not really deploy the concept *is gracious*, but rather the concept *is gracious**, which is defined such that *Albert is gracious** is neither true nor false. On the assumption that indeterminate propositions are meaningless, systematicity can thus be trivialized. To avoid being ad hoc, the restrictions placed on the application of a concept should thus be independently motivated — that is, they should be based on grounds *other* than the desire to save systematicity. Yet what further grounds do we have to suppose that (3*) and (4*) are indeterminate as opposed to true but unthinkable by pigeons? Because I see none, I am inclined to view the claim that (3*) and (4*) are indeterminate as ad hoc.

I have now considered a series of alternative content ascriptions to (1) and (2), and argued that they are all either inferior to (1) and (2), or fail to save systematicity (or both). Of course, I do not take myself to have *proven* that (1) and (2) — or, respectively, (1*) and (2*) — are the best of all possible sentences for expressing the contents of the pigeons' thoughts. I doubt whether it is possible to prove such a claim. The best we can do is to consider competing hypotheses and see if they better fit the data. Although I have found flaws with the best competing hypotheses I can think of, it remains possible that there are better hypotheses that I have overlooked that would save the pigeons' thoughts from violating systematicity. But in the absence of any specific hypothesis, we are surely justified in concluding that systematicity is violated, and thus that pigeons' numerical representations have nonconceptual content.

Admittedly, the very idea that we can use sentences to capture the contents of pigeons' mental states has little grounding in actual scientific practice. The scientific literature on analogue magnitudes contains no explicit claims that animals represent contents such as (1) and (2), or (1*) and (2*). Rather, the literature contains mathematical descriptions such as Weber's Law, computational models, and inchoate *gestures* towards the content of analogue number representations with phrases such as 'a blur on the number line' (Spelke and Tsivkin 2001, p. 59) and 'approximate representations of number' (Carey 2009, p. 294). Using *sentences* to express the contents of animals' numerical representations simply has not been a part of the scientific enterprise. But I take this observation to *support* my contention that pigeons' numerical representations have nonconceptual content. For if they do have nonconceptual content, it follows that they cannot be expressed in sentences. No wonder, then, that scientists do not typically use sentences to characterize them.

My argument that (1*) and (2*) are the best sentences we can find to express the contents of pigeons' analogue magnitude representations of number was, recall, part of a reductio. I assumed that these representations have conceptual content, and should thus be expressible in sentences. I then argued that the best sentences we can find to express them lead to violations of systematicity, undermining the initial assumption that they have conceptual content. So my rather unscientific foray into sentential characterizations of pigeons' analogue number representations is to be taken with a grain of salt. My considered position is one of scepticism that the contents of *any* sentences will match the contents of pigeons' numerical representations.

4.4 Generalizing: beyond numbers and pigeons

Thus far, I have couched my argument in terms of the numerical representations of pigeons. But the results are likely to generalize in at least two ways.

First, there is reason to think that the argument could be extended to analogue magnitude representations of non-numerical magnitudes such as distance, duration, and rate. One piece of evidence in support of this claim is that these representations also give rise to Weber's Law, which was the driving force behind the argument that analogue representations of number violate systematicity. On its own, however, this evidence is not sufficient to show that the argument can be extended to non-numerical magnitude representations, since the argument that numerical representations are not systematic also depended on certain auxiliary assumptions, such as the assumption that Weber's Law is a product of the numerical representations themselves, and not some exogenous performance factor. But analogue magnitude representations of numerical and non-numerical magnitudes have more in common than just Weber's Law. They also share many of the same neural structures and engender similar psychophysical profiles (even apart from Weber's Law). As a result, many researchers believe that numerical and non-numerical magnitude representations are all part of a common generalized analogue magnitude system.[22] Thus, while one might question whether all mental states that give rise to Weber's Law violate systematicity, the similarities between numerical and non-numerical analogue magnitude states are so striking that we have reason to expect the latter to violate systematicity if the former do.

Second, there does not seem to be anything essential about the appeal to pigeons. Given the remarkable neurological and psychophysical similarities associated with the numerical capacities of different species, including a universal adherence to Weber's Law, it is likely that a similar argument could be constructed for rats, monkeys, or many other animals. The one tricky case is human adults. Since most adults with a primary school education have the capacity to entertain the thought that *m* is less than *n*, for any integers *m* and *n*, we might be tempted to insist that adults' numerical representations are systematic. But there are also times when human adults look an awful lot like pigeons. Whenever explicit counting is not possible, human numerical discriminations obey Weber's Law. This has led most number researchers to conclude that adults have multiple systems for representing numerical values: an evolutionarily ancient analogue magnitude system that they share with many other species, and a culturally acquired system that is made possible only by the advent of language.

[22] For discussion of the similarities among different analogue magnitude representations and the idea of a common generalized magnitude system, see Gallistel 1990, Meck and Church 1983, Walsh 2003, Buhusi and Meck 2005, Feigenson 2007, and Lu et al. 2009. See also Sect. 3 above and Sect. 6 below.

Thus, human adults may violate systematicity with respect to their nonconceptual analogue magnitude representations even if they satisfy it with respect to their culturally acquired conceptual numerical representations.[23]

5. Perception and cognition

In so far as philosophers have entertained the idea that mental states might have nonconceptual content, they have focused on perceptual states such as visual experiences. Cognitive states such as beliefs have been either ignored or assumed to have conceptual content. It is thus interesting to note that on at least one traditional way of characterizing the perception–cognition distinction, analogue magnitude states emerge as cognitive.

What, exactly, is the difference between perception and cognition? This is a vexed question that surely admits of more than one sensible answer; however, I take it that one familiar answer counts states as perceptual if they are sensory inputs to more central processes, and as cognitive if they involve central processes that are removed from the sensory periphery. We can be a bit more precise about this distinction, and about why analogue magnitudes fall on the cognitive side of the boundary, by considering two specific dimensions along which sensory inputs and central processes differ.

First, as sensory inputs, perceptual states are *stimulus-dependent*. To successfully perceive an object or property, your sense organs need to be in causal contact with that object or property. You cannot see the Empire State Building with your eyes closed or hear the horn of a New York taxicab with your ears plugged, though you can think about either while submerged in a sensory deprivation tank

[23] There are several lines of evidence that lend credence to this two-system view. First, the capacity to represent approximate numerical information in accordance with Weber's Law is present in both pre-numerate children (Feigenson et al. 2005) and humans from non-numerate societies that lack words for precise integers (Gordon 2005; Pica et al. 2005). Second, Dehaene et al. (1999) found that the intraparietal cortex is activated during approximate arithmetic (e.g. Is 4 + 5 closer to 8 or 3?), but that the inferior frontal cortex and angular gyrus, which are implicated in human language processing, are activated during exact arithmetic (e.g. Is 4 + 5 equal to 9 or 7?). Third, damage to the parietal lobe can impair approximate but not exact arithmetic, while damage to the language areas in the prefrontal cortex can impair exact but not approximate arithmetic (Lemer et al. 2003). Finally, bilinguals trained in arbitrary approximate sums became faster at those sums regardless of whether the language of training was the same as the language of testing, while bilinguals trained in arbitrary exact sums showed improved reaction times only when the languages of training and testing were the same (Dehaene et al. 1999).

in Siberia. Note that the appeal here is to causal contact, not literal contact. A dentist can feel his patient's tooth through a latex glove, and you can see the Empire State Building without pressing your eye up against it. The point is that perception at time t_1 requires that your sense organs be stimulated at t_1 by a medium (e.g. light waves, sound waves, a latex glove) that was causally impacted by the stimulus at an earlier time, t_0.[24] Beliefs and other cognitive states, by contrast, do not require an active causal link between their objects and your sense organs. Because they are removed from the sensory periphery, they can be stimulus-independent.

To see that analogue magnitudes are stimulus-independent, notice that a robin might divide the number of worms it finds by the time spent foraging in a given patch to arrive at a rate of return for that patch. By comparing the rates of return of multiple patches — including patches with which it is no longer in sensory contact — it can choose to forage at the patch with the greatest payoff. Similarly, a hummingbird might compare its analogue magnitude representations of the amount of nectar at various distant sources — perhaps by multiplying its representation of the rate at which each source replenishes after depletion by its representation of the duration since it has visited and emptied each of those sources — to select the best source to which to return. Or suppose you are shopping for apartments and comparing their relative sizes, but without taking out a tape measure or relying on blueprints. You might use a stored representation of the size of the apartment you saw yesterday to determine that it is bigger than the apartment you are currently in, though your ability to tell which apartments are bigger than which will be subject to Weber's Law, presumably because you are employing your analogue magnitude representations to estimate their sizes. Because they are stored in long-term memory, states involving analogue magnitudes can thus be activated in the absence of the stimuli they represent.[25]

[24] Perhaps this condition should be weakened to allow for perception to continue for a brief interval after direct causal contact with the stimulus has been lost. For example, perhaps visual perception continues for the half second or so during which a visual image lingers in sensory memory. But it is important to limit any such amendment to *sensory* memory. A representation that is stored in long-term memory is ipso facto not stimulus-dependent.

[25] For evidence that analogue magnitudes are involved in such computations as comparison, addition, subtraction, multiplication, and division, are used to make decisions about where to forage, and are stored in long-term memory, see Brannon et al. 2001, Hauser et al. 2003, Flombaum et al. 2005, McCrink and Wynn 2004, Barth et al. 2006, Gibbon and Church 1990, Gallistel 1990, and Beran and Beran 2004. Of course, there is no presumption that any of

Second, because perceptual states serve as sensory inputs, they are tied to a specific sensory modality. If you perceive a taxicab, you perceive it through some sensory modality or other. You see it, hear it, feel it, smell it, or (God forbid) taste it. But when you think about it, none of your sensory modalities need be active. For example, your belief that a taxicab is ten minutes away is not essentially tied to any particular sensory modality. It is not happily classified as visual, auditory, olfactory, gustatory, tactile, or proprioceptive. Unlike perceptual states, cognitive states such as beliefs can thus be amodal.[26]

As it turns out, there is also evidence that analogue magnitude states are amodal. Russell Church and Warren Meck (1984) found that rats that are trained to press the left lever when they hear 2 tones or see 2 flashes, and the right lever when they hear 4 tones or see 4 flashes, will, when presented with 2 tones and 2 flashes (for a total of 4 events), press the right lever. The rats thus seem to have a representation of 4 that is not tethered to any particular sensory modality.[27] Similarly, Barth et al. (2006) found that the ability to successfully estimate the sum of a collection of visually presented dots and a set of aurally presented tones is present (within the limits imposed by Weber's Law) in human adults who lack time to explicitly count the stimuli. Like rats, human adults thus appear to possess representations of approximate numerical values that are amodal.[28]

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these computations are executed *consciously*. Who knows what it is like to be a robin or hummingbird?

[26] The McGurk effect (McGurk and MacDonald 1976), which demonstrates that visual information about how a speaker moves his lips can influence perception of the syllable uttered, is sometimes cited as a counterexample to the modal specificity of perception. But that strikes me as a bad interpretation of the data. The McGurk effect shows that visual perception can influence auditory perception, not that perception is amodal. After all, what makes the McGurk effect so interesting and surprising is that *what you hear* depends on *what you see*. In other words, there is a difference between the claim that perception involves *intermodal* interactions and the claim that perception is *amodal*. The McGurk effect only supports the former claim.

[27] It is worth emphasizing, with Gallistel (1990, p. 331), how strange a result this is from the perspective of a behaviourist psychology that eschews talk of representations in favour of conditioned associations among stimuli, behaviour, and rewards. The rats have been rewarded for pressing the left lever in response to 2 tones or 2 flashes, so they should have built an association between these stimuli and the left lever. Yet when presented with both stimuli on a single trial, they press the right lever.

[28] The conclusion that analogue magnitudes are amodal is supported by two further pieces of converging evidence. First, although one's Weber constant changes with age, at any given

Given their stimulus-independence and amodality, analogue magnitude states are removed from the sensory periphery of perception. I therefore conclude that nonconceptual content seeps beyond perception and infiltrates cognition.

The existence of nonconceptual cognition may help us to explain a phenomenon that has all too often puzzled philosophers: the nature of animal minds. Even apart from the considerations advanced in section 4 of this paper, it has seemed rather implausible to a number of philosophers that animal cognition is thoroughly conceptual. The cognitive states of animals, urge these philosophers, are not fully integrated in the way that the Generality Constraint presupposes (Camp 2009; Hurley 2003).[29] In Susan Hurley's apt phrase, animals occupy 'islands' of rationality (2003, p. 238). But if that is right, then on the assumption that cognition needs to be conceptual, it is puzzling how animals could cognize at all. This puzzlement may be what drives some philosophers to simply deny that animals have cognitive states such as beliefs.[30] But such a flat-footed scepticism about animal cognition fails to appreciate the complexity of animal minds. After all, animals are not rocks or trees. They are capable of complex mental operations, such as adding numbers across different sensory

age the constant for stimuli presented to one modality (e.g. vision) is always the same as the constant for stimuli presented to another (e.g. audition) (Feigenson et al. 2004). Second, Barth et al. (2003) found that comparing analogue magnitudes across modalities is no more difficult than comparing them within a single modality.

[29] Peter Carruthers (2009) has recently challenged this claim, arguing that the Generality Constraint *does* characterize animal cognition. But Carruthers interprets the Generality Constraint weakly, such that it only requires mental states to be compositional. As I have understood the Generality Constraint, by contrast, it requires mental states to exhibit a specific *type* of compositionality: roughly put, the type exhibited by natural language. I believe that this stronger interpretation is implicit in traditional accounts of the Generality Constraint, such as those of Evans 1982 and Peacocke 1992, as well as in the work of many who have questioned whether the Generality Constraint characterizes animal cognition. In any case, it is in this stronger sense that I have argued that the Generality Constraint does not characterize analogue magnitude states.

[30] Davidson (1975 and 1982) notoriously endorses this position. Other philosophers, such as Dummett (1994, pp. 121–6) and Putnam (1992, pp. 28–31), claim that animals have 'proto-thoughts' but not genuine thoughts. One might be tempted to see this as a terminological variant of the distinction I have been defending between conceptual and nonconceptual cognitive states, but there remain significant differences between their view and mine. For one thing, Dummett and Putnam are intent to emphasize the importance of a public language for genuine thought, whereas nothing I have said entails that a public language is essential for conceptual thought. For another, Dummett writes that animals' proto-thoughts consist of 'spatial images superimposed on spatial perceptions' (1994, p. 123). But analogue magnitudes are not happily classified as spatial images or spatial perceptions.

modalities. By abandoning the assumption that all of cognition is conceptual, we can address this issue more comfortably. We can attribute cognitive states to animals without over-intellectualizing them.

If some cognitive states have nonconceptual content, then being a thinker cannot be equated with being a conceptual thinker. The question thus arises: What is so special about conceptual thought? What advantages does it bestow over and beyond the advantage of simply being able to think? Can we use those advantages to help us understand how some thinkers (e.g. humans) are intellectually superior to others (e.g. nonhuman animals)? These questions point toward novel and potentially fecund avenues of research.

6. Content and format

I have just argued that analogue magnitudes are interesting because they establish the existence of cognitive states with nonconceptual content. I believe that they are also interesting because of what they tell us about the relation between mental content and representational format.

Analogue magnitude states have nonconceptual content because they violate systematicity, and they violate systematicity in large part because they give rise to Weber's Law. But why do analogue magnitude states give rise to Weber's Law? Most number researchers answer this question by appealing to two assumptions about the *format* of the representations underlying such states. First, they suppose that these representations themselves involve an internal magnitude that is a *direct analogue* of the external magnitudes that they represent (hence the 'analogue magnitude' locution). As the external magnitude gets larger or smaller, the internal magnitude follows suit. Thus, as the ratio of two represented magnitudes approaches one, the internal magnitudes that stand for them become increasingly similar. Second, they assume that these internal magnitude representations are intrinsically noisy. For example, a given representation might be activated most frequently in response to sets of 5 stimuli, somewhat less often to sets of 4 or 6 stimuli, etc. Together, these two assumptions provide an explanation of Weber's Law: the closer to unity the ratio of two external magnitudes is, the greater the probability that the noise in the internal magnitudes will lead to failures of discrimination.[31]

[31] Generally speaking, two models of this noise have been proposed. The first assumes a linear mental number line with scalar variability: the noise attending to each internal

An analogy may help to clarify the basic idea. Imagine that you keep track of the number of people in a room by filling a bucket with a hose. Every time someone enters the room, you turn the hose on for about a second; and every time someone leaves, you pour a little bit out of the bucket. The height of water in the bucket will then be a direct analogue of the number of people in the room, and so you can use it as a decent approximation of that value. Of course, the representations provided by this analogue bucket system will not be perfectly precise. Given the imprecision in your method, your bucket representations will be intrinsically noisy. Thus, if you have two buckets representing the number of people in each of two separate rooms, your ability to reliably discern which room has more people will be a function of the ratio of the number of people in each room. As the ratio approaches one, the relative heights of the two buckets will become decreasingly reliable indicators of which room has more people, and below a certain threshold they will not be reliable at all.

Of course, no one thinks that you literally have buckets and hoses in your head. But researchers *do* think that your head contains magnitude representations that are likewise noisy and analogue.[32] For example, perhaps analogue magnitude representations are realized by neural firing rates, such that the size of a magnitude is a function of the rate at which a population of neurons fires. The greater the firing rate, the greater the magnitude is represented to be. So long as the firing patterns among the neurons are noisy — as the findings by Andreas Nieder and colleagues (2002) discussed briefly in section 4.2 suggest — the total firing rate would then be only an approximate indication of the size of the magnitude represented. Comparisons of magnitudes would thus become unreliable when the ratios of those magnitudes approach one, explaining Weber's Law.

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magnitude representation increases proportionally with the size of the magnitude (Gallistel and Gelman 1992). The second assumes a logarithmic mental number line with fixed variability: the noise attending to each internal magnitude representation is a constant, but since the number line is logarithmically compressed (like on a slide rule), the overall effect is the same (Dehaene 2003). For our purposes, it does not matter which of these models proves correct. What matters is that they both explain Weber's Law by assuming that the representations involve noisy internal magnitudes that are direct analogues of the magnitudes they stand for.

[32] Early 'accumulator' models of analogue magnitude representations also invoked the idea, inherent in the bucket-and-hose system, that analogue magnitude representations involve a serial, iterative process (Meck and Church 1983; Gallistel 1990). More recent models, however, have favoured non-iterative, parallel processing of magnitude representations (Church and Broadbent 1990; Dehaene and Changeux 1993). For discussion, see Buhusi and Meck 2005 and Carey 2009, pp. 131–4.

The general point I am making here is independent of the specific proposal that analogue magnitude states are realized by neural firing rates. It relies only on the assumption that the neural representations that realize analogue magnitude states are noisy and analogue, for this assumption by itself is sufficient to explain Weber's Law. By contrast, if we were to assume that the representations realizing analogue magnitude states were like the English words 'five' and 'ten' in being arbitrarily related to their referents, there would be no particular reason to expect discriminations based upon those representations to obey Weber's Law. For even if such representations were intrinsically noisy, a mechanism that was designed to discriminate among them would be no more likely to confuse representations of 5 and 6 than representations of 5 and 10. The supposition that thinkers deploy representations with an analogue format is thus essential to explaining why they obey Weber's Law.

Notice that the sense of 'analogue' in play here differs from that which many philosophers employ. Fred Dretske (1981) maintains that a representation carries the information that *a* is F in analogue form just in case it carries additional information about *a* beyond that entailed by its being F. By this criterion, an analogue magnitude representation of 8 tones would not be analogue since it tells us nothing about the tones that does not follow from there being 8 of them. David Lewis (1971) requires analogue representations to be (nearly) primitive in the language of physics. But why rule out the possibility that they might be primitive in the language of neuroscience instead, as our example of neural firing rates proposes? Nelson Goodman (1976) maintains that a representational system is analogue only if it is *dense*—that is, only if there exists a third representation in between any two. Yet analogue magnitude representations need not be dense to explain Weber's Law. For example, if analogue magnitude representations were realized by the total *number* of neurons that fire within a fixed population (such that more neurons firing represents a greater magnitude), analogue magnitude representations would not be dense. But given some noise, discriminability would still be a function of ratio. For a representation to be analogue in the sense being used here, we thus need not make any assumptions about carrying additional information, being primitive in the language of physics, or being dense. We need only assume that the representation itself involves a magnitude (e.g. height of water, rate of neurons firing, number of neurons firing, etc.) that directly mirrors the magnitude represented. Assuming some noise, discriminability will then be a function of ratio, explaining Weber's Law.

In arguing that analogue magnitude representations are analogue, we have really been focusing on just one part of such representations — the part that represents the magnitude's *size*. But in order to account for the full range of animal and human behaviour, they must also have parts that represent the magnitude's *mode* (whether the magnitude is number, duration, distance, etc.) and *object* (whether the magnitude is of light flashes, tones, dots, pecks, etc.). For only then can we explain why subjects are able to discriminate and generalize among stimuli that vary along each of these dimensions (e.g. treat eight flashes of light as distinct from eight tones if the object is made salient, or treat them as similar if the mode and size are made salient), and perform computations that require treating these representations as having common components (as in the case of the rats described earlier that can add tones and flashes to generate a representation of the total number of both).[33] An analogue magnitude representation can thus be conceptualized as an ordered triplet, {*size*, *mode*, *object*}. Notice, however, that I have only argued that the first member of this triplet is noisy and analogue. This is important for two reasons. First, it shows that having nonconceptual content does not require being *purely* analogue. Simply having a noisy, analogue component is sufficient to generate violations of systematicity. Second, it shows that being *compositional* or *discursive* is not sufficient for being *conceptual*. Analogue magnitude representations are compositional and discursive in that they are composed from a variety of distinct, specialized constituents that together determine the content of the representation as a whole. But as we have seen, they are not conceptual.[34]

The fact that Weber's Law is best explained by appealing to representations with an analogue format has implications for the idea, still dominant in many quarters of cognitive science, that the mind is a kind of digital computer. There are really two ideas here: that the mind is a physical symbol system — a system that manipulates symbolic representations to perform computations; and that those

[33] Viewing analogue magnitude representations in this way also helps to explain a variety of findings that suggest that representations of number, time, space, etc., recruit overlapping neural mechanisms (Meck and Church 1983; Walsh 2003; Lu et al. 2009). They all share the same size component.

[34] Cf. Fodor 2007, where being conceptual is analysed in terms of being discursive.

representations are structurally analogous to the symbols in digital computers — for example, that they decompose into ones and zeroes or map onto the sorts of constituents familiar from programming languages. Analogue magnitude representations show that these two ideas can come apart. Analogue magnitude representations can be manipulated to perform computations such as comparison, addition, subtraction, multiplication, and division, but they are not purely digital or language-like in their structure. Of course, this does not show that the digital computer is a poor model for *all* aspects of the mind. Some of our cognitive representations might genuinely decompose into symbols that are purely digital or language-like. But analogue magnitudes reinforce the idea, already familiar from work on mental imagery and connectionist networks, that the mind is not *solely* a digital computer.

The explanation of Weber's Law in terms of analogue representations should be of interest to philosophers too. For if analogue magnitude states have nonconceptual content because they violate systematicity, and if they violate systematicity in large part because they obey Weber's Law, and if they obey Weber's Law because they have constituents with a noisy analogue format, then *the fact that analogue magnitude states have nonconceptual content largely traces back to the fact that they are realized by neural states with a noisy analogue format*. The representational format of a mental state thus helps to determine the type of content it has.

This strong connection between representational format and mental content derives from the Generality Constraint, which makes the attribution of *conceptual* content conditional on systematicity.[35] As Fodor (1987; Fodor and Pylyshyn 1988) has long argued, systematicity places a substantive constraint on cognitive architecture. Our discussion of analogue magnitude representations reinforces Fodor's insight by showing that not just any neural organization is capable of explaining systematicity. Thoughts with conceptual content cannot have a noisy analogue format (even in part). But nor is a purely digital format sufficient. Supposing that one's mental representations were structured like a sentential calculus would make them digital, but it would not account for systematicity. For if one's representations

[35] Of course, one could always give up on the Generality Constraint, but as we saw in Sect. 2 that would involve a fundamental shift in the philosophical conception of conceptual content, and precipitate a divorce between mental content and psychological reality. The type of content a mental state had would no longer reflect the global patterns of inference it can participate in.

decomposed into sentences (P, Q, R, …) and logical constants (&, ∨, ¬, …), but no further, there would be nothing stopping one from representing (say) that Amy is funny and that Bill is good, but completely lacking the capacity to represent that Amy is good or that Bill is funny.[36] Not that it would be *impossible* for one's thoughts to be systematic if one's mental representations mirrored a sentential calculus — or even if one had no mental representations at all. But we would then lack any *explanation* of the systematicity of thought, which seems like a good enough reason to provisionally reject these theoretical options, conceivable though they are. Just as explaining Weber's Law gives us reason to posit analogue representations, explaining systematicity gives us reason to posit digital representations that have more structure than a sentential calculus. Although it is perhaps too strong to require such representations to be structured *exactly* like a predicate calculus, some sort of sub-sentential, language-like structure is required if we want to explain systematicity. In so far as your thoughts have conceptual content, we thus have (empirical, defeasible) reason to suppose that your brain implements some version of a language of thought.[37]

The philosophical notions of conceptual and nonconceptual content thus have an empirical component. They are intimately related to the format of underlying neural representations. Yet philosophers have largely ignored this empirical component in their discussions of conceptual and nonconceptual content, and focused almost exclusively on considerations gleaned from the armchair. For example, it is common to defend the thesis that perceptual experiences have nonconceptual content by appealing to introspective claims about the phenomenal richness of one's experience (Heck 2000), and to defend the opposite conclusion with a priori claims about the nature of justification (McDowell 1994). While I am not saying that these armchair approaches have nothing to contribute to our understanding of perception, the fact that a mental state's content is significantly constrained by the format of the representations underlying it does ring alarm bells about the adequacy of such approaches.

[36] Sometimes systematicity is interpreted as requiring no more than compositionality. On this weak interpretation, even if a subject's thoughts had the structure of a sentential calculus, they would still be systematic. This is *not* how I defined systematicity in Sect. 2. If systematicity is to be used to argue for a language of thought with sub-sentential, predicative structure, it has to require more than compositionality.

[37] Davies 1992 and Heck 2007 contain similar lines of reasoning that link conceptual content to a language of thought.

At the very least, philosophers interested in mental content, including perceptual content, would surely benefit from integrating knowledge of the cognitive sciences into their armchair reflections.[38]

7. Conclusion

In this paper, I have argued that analogue magnitude states stand as an existence proof of cognitive states with nonconceptual content, and that a large part of the reason these states have nonconceptual content is that the representations underlying them have an analogue format. It has not been my contention, however, that all of cognition is analogue or nonconceptual. For one thing, not every corner of the mind is characterized by Weber's Law. For another, some of our cognitive states — particularly those cognitive states that underlie our use of language — truly are systematic. The upshot is that cognition is not homogenous. There are at least two fundamentally distinct kinds of cognitive states, marked by two distinct structures and hallmark properties: conceptual states, which have a language-like structure and are governed by the Generality Constraint; and analogue magnitude states, which have an analogue structure and are characterized by Weber's Law.[39]

[38] Along these lines, notice that many perceptual phenomena (such as loudness, felt pressure, and brightness) are subject to Weber's Law. It would thus be worth exploring whether an argument similar to that of Sect. 4 could be developed to show that states of *perception* have nonconceptual content.

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