when categorisation requires the ability to think abstractly. What was lost, according to Goldstein, was a way of thought, and what he called an abstract attitude.

One group of researchers in the Wernicke tradition (Cohen et al. 1980; Kelter et al. 1976) distinguished between types of categorisation tasks in aphasic impairments. Their tasks, similar in design to those used in the Pyramids and Palm Trees Test (Howard & Patterson 1992), asked the patient to decide which two out of three pictures go together. They found that aphasic patients were considerably more impaired if the connection was "perceptual" rather than "situational." For example, aphasic patients failed to connect that a snowman should go with a swan because both are white but succeeded in a task that required putting together a guitar and a bull because both are connected with Spain. Now, it is not a matter of the number of attributes that promotes the distinction, as this number could be small in each case. However, potentially against the case put forward by Pothos, it is possible to argue that decisions about perceptual attributes require rule following whereas this is not the case for situational attributes (Davidoff & Roberson 2004).

Patients with the type of aphasia named after Wernicke actually have difficulty with taxonomic rather than thematic relationships (Bisiacchi et al. 1976; Gardner & Zurif 1976; Semenza et al. 1980) and the reverse has been claimed for more anterior patients (Semenza et al. 1992). Now, if the use of the different procedures is merely situationally dependent, as was argued for the cases in Zurif et al. (1974), then Pothos's line of reasoning would not be seriously damaged by the data from aphasia. However, if, as Goldstein argued, the inability to produce names resulted in a chronic inability to think abstractly, then the need would be for rule-based thought distinct from that based on association (similarity).

The particular difficulty a patient might have for perceptual classification is shown by the performance of an aphasic case, LEW (Davidoff & Roberson 2004; Roberson et al. 1999). The patient, who was unable to name perceptual attributes (e.g., colours, shapes), was completely bewildered by the task of sorting colours as, indeed, were Goldstein's many similar cases. Roberson et al. (1999) argued after Dummett (1975) and Wright (1975) that classification of continuous perceptual attributes is impossible without some non-perceptual mechanism such as a name. Thus, the name acts as a rule whereby the classification takes place. Not all classifications took place in the same fashion for the patient. He could easily divide animals as foreign or British, which he claimed to have done by whether they would be found in a zoo. He could easily decide which colour was the correct one for a particular object by similarity matching to his visual memory.

It could be argued that classification of "foreignness" is multifaceted and that colour classification is not, but that seems to miss the point. Perceptual classification is inherently rule-following and the other could be a matter of association. Moreover, rather against what one might expect upon the "different in complexity but not different in kind" argument proposed by Pothos, the patient's difficulty is for the task where there is only one way of producing a classification. And furthermore, the research on LEW would imply that rule-based reasoning cannot be bootstrapped from the other. LEW was asked to do analogical reasoning tasks of the type used by Gentner (1988; Gentner & Medina 1998). Though his level of performance on analogical reasoning was only that of a 4- or 5-year-old child, it far surpassed his ability to follow rules of perceptual classification.

Studies of categorisation are not the only data in aphasia that speak to a distinction between abstract and concrete concepts. Aphasic patients, in general, show a concrete advantage in word retrieval (Goodglass et al. 1969), but not always (Breedin et al. 1994; Franklin et al. 1995; Goldstein 1948; Warrington 1975). Of course, abstract words are generally less frequent, longer, and so forth, but these, too, have been shown insufficient to explain their difficulty in an anomic patient (Henaff Gonon et al. 1989). The taxonomic difficulty will be seen especially for perceptual terms, such as colour, because these are essentially abstract. Colour, for example, only allows for taxonomic classification. For colour, there are not alignable differences (Markman, 2001) or thematic confusions; hence, their particular difficulty in categorisation tasks.

"Commitment" distinguishes between rules and similarity: A developmental perspective

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Abstract: A qualitative difference between Rules and Similarity in categorization can be described in terms of "commitment": Rules entail it, Similarity does not. Commitment derives from people's knowledge of a domain, and it is what justifies people's inferences, selective attention, and dismissal of irrelevant information. Studies show that when children have knowledge, they manifest these aspects of commitment, thus overcoming Similarity.

Pothos presents an ambitiously parsimonious proposal, according to which Rules and Similarity processes are mere poles within a continuum of similarity. In categorization, for example, the continuum may be described in terms of how many object features the categorizer focuses on, the calibration of feature weights, or the extent of selective attention, suppression of irrelevant dimensions, or perception of salient features. In Pothos's view, these continua capture the most important psychological implications of categorization. Taking a Rules perspective, in the present commentary I sustain that the most crucial psychological implications of categorization derive from *why* categorizers narrow, calibrate, select, suppress, or perceive; and why do they do it in the particular ways in which they do? I offer the notion of "commitment" as an answer to these questions, and more generally as a characteristic that distinguishes between Rules and Similarity processes.

Rules (theories, essentialism) derive from beliefs that constrain boundaries, and degrees of relevance and similarity. But psychologically, rules are more than mere propositions. Rules have a motivational and stabilizing force that derives from people's commitment to rules. Rules are enforced and not given up easily. In categorization, commitment is what warrants expectations about what might and might not be a member of a category and the consequent search for particular kinds of evidence. Commitment is what licenses leaps of faith, allowing categorizers to draw inferences even about novel categories and properties in familiar domains. Commitment is also what gives categorizers the incentive to maintain the rule despite seemingly contradictory evidence. Similarity, in turn, has no commitments. Similarity is free, dynamic, and changeable. When operating under similarity, one does not commit because there is nothing to commit to. Everything might be relevant, nothing can be dismissed a priori.

The literature on children's categorization is filled with examples of this distinction. When children know a rule, they show all signs of commitment. When they do not, they resort to similarity, and promiscuity. Classic examples come from studies by Gelman and Markman (1986) on preschool children's induction. Children were shown triads of animals, in which the target and a test animal were physically similar but belonged to different categories, and the target and the other test animal were physically dissimilar but belonged to the same category. When asked to infer which of the animals shared some internal property, children responded based on physical similarity. Crucially, when told the category names of the animals, children ignored similarity, switching to infer based on category membership. The knowledge of the category prompted the rule, committing children to *suppress* similarity, to use Pothos's term.

Different categories may have different rules. Different rules impose different commitments. Studies with preschool children

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show that the properties they rely on for judging category membership vary with the category. For example, internal properties determine category membership for animals, but not for artifacts (Diesendruck et al. 1998), and for the very same entities, different physical features determine categorization depending on whether they are described as animals as opposed to artifacts (Booth & Waxman 2002; Keil 1995). Calculations of similarity – and of category membership – depend on children's beliefs about what is being categorized. Similarity is in the mind's eye of the categorizer.

Especially with children, we cannot take for granted that they will know when a rule is called for. But provide them with the crucial knowledge, and they will operate by the rule. For example, many studies show that children categorize artifacts based on physical similarity (e.g., Smith et al. 1996). Accordingly, we found that children treated two similarly shaped objects as belonging to the same category (Diesendruck et al. 2003). But when we showed them that one of the objects was actually a container for the other, they abandoned shape similarity (instantiating *classification dissociation*). What was crucial was what the objects were made for. The similarity was the same, what changed was how children conceived of the objects. Without knowledge, rules are slippery; without rules, there is no commitment.

Indeed, given Similarity's lack of commitment, categorizers operating under Similarity need to remain open, and thus susceptible, to contextual variations in the presentation of information. Rules, in turn, do commit to specific kinds of information, directing the categorizer to neglect contextual variations. A recent study conducted in our laboratory demonstrates this distinction (Hammer & Diesendruck 2005). Children and adults saw triads of computer-animated novel artifacts, consisting of a target and two test objects. For half of the participants, the test objects were functionally, but not physically, very distinct one from the other. For the other half, the test objects were physically, but not functionally, very distinct. Participants were asked to decide which of the test objects belonged to the same category as the target. We found *differential performance.* Whereas children's decisions were determined by the relative distinctiveness of the test objects' properties, adults consistently categorized based on functional properties. Differences in the knowledge children and adults have about the domain of artifacts led the former to categorize by Similarity and the latter by Rules. Children were promiscuous, adults committed.

What all these studies show is that when children have enough knowledge about a given category, they commit to the rules appropriate to its domain, thus ignoring similarity considerations. For children, conceptual commitments carry the most meaningful psychological implications. Pothos dismisses knowledge-based accounts apparently because "there has not been a single dominant proposal for understanding general knowledge" (sect. 6.3, last para.). I am not convinced a single similarity-based account can explain the findings presented in this brief review. If anything, the review leads to the opposite conclusion than what Pothos advocates: rather than dismissing knowledge-based accounts, seek them out.

The discontinuity between rules and similarity

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Abstract: In arguing for a rules-similarity continuum, Pothos should demonstrate that a single process or mechanism (a neural network model, for example) can handle the entire continuum. Pothos deliberately avoids this exercise as beyond the scope of the current research. In this context, I will present simulation, neuropsychological, neurophysiological, and experimental psychological results, arguing against the continuity hypothesis.

In section 3.1 (para. 2) Pothos asks us to "Consider two kinds of judgments for an object, one that involves a single property of the object (a Rule), and another that involves more or less all the properties of the object (Similarity)." This characterization of rule – matching a single property – is a huge simplification of what a rule can be, and reveals the fundamental problem in Pothos's analysis: that there are aspects of rule-based behavior that cannot be accounted for by similarity.

One particular case of interest is the use of abstract rules that can be used to generate (or categorize) new sequences in a sequence learning or an artificial grammar learning context. This issue is partially addressed in the discussion of artificial grammar learning in section 4, and it is again mentioned in section 7.3, but in neither case is the problem handled in sufficient detail. Let me proceed by proposing a behavioral task, and human performance in the task, that cannot be explained by the rule-similarity continuum hypotheses.

Consider the abstract rule 123213 in which a triplet of elements is followed by the same triplet that has been systematically reordered. This rule can be used to generate an open set of sequences such as ABCBAC, RSTSRT, and so on. We observed that under implicit learning conditions, human subjects could learn sequences following this rule, but failed to transfer their knowledge to new "isomorphic" sequences following the same rule. In contrast, we observed that subjects that were explicitly aware of the possibility of some underlying rule structure learned the training sequence and could then transfer this knowledge to new isomorphic sequences (Dominey et al. 1998). Interestingly, the processing of rules and instances in this context appears to rely on different neural substrates (Lelekov et al. 2000).

In an accompanying simulation study we demonstrated that a temporal recurrent network (TRN) performed like subjects in implicit conditions: it learned the serial order of the sequence but failed to acquire knowledge that could transfer to the isomorphic sequence. In order to do this, an additional short-term memory had to be added to the model along with a recognition function that compared the current sequence element with the short-term memory contents in order to encode the abstract structure. Likewise, Dienes et al. (1999) demonstrate that the simple recurrent network (SRN) must have additional mapping capabilities in order to realize these transfer tasks of abstract knowledge. In reference to this issue, in the context of Marcus (2001), Pothos states that "Whether neural networks can perform such arbitrary generalizations is a somewhat open issue and beyond the scope of this work" (sect. 7.4, para 4). I think that this is not so. Pothos proposes a characterization of rules and similarity "whereby one extreme of the same similarity process can be associated with rules and the other extreme with overall similarity" (sect. 2, para. 1). In this case, Pothos is obliged to make the effort to show that a system can span this continuity and account for behavior at both extremes.

Similarly, the problem of compositionality has been handled without getting to the hard issue. The claim that "compositional systems are consistent with Rules and not Similarity" (sect. 3.1, last para.) does not seem to illuminate the issue in a deep manner. If there is a continuum along which context free grammars (rules)

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