When you recognize a dog, you also know it's an animal: Evidence from rapid object categorization

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1 Background and Theoretical Approach

How do we understand what we see? Given the ubiquity of our visual experiences, the complexity of the mental machinery that underlies our ability to interpret what we see is often taken for granted. For instance, despite variations in viewing conditions (e.g., luminance, viewing angle, degree of occlusion), humans effortlessly recognize and categorize objects within about 150 milliseconds (ms) [1]. What seems clear is that visually decoding an object—that is, computing its natural-kind properties—must quickly token its stored representation, independent of its viewpoint. Similarly, categorizing an object must, at some stage of processing, also involve the tokening of an abstract, conceptual representation that is common to all token objects belonging to that category. Thus, it seems that for an object to be recognized, it needs to access its stored representation or *concept*—the basic unit of meaning in the brain [2]. However, the nature of the representations that enable object recognition and categorization remains unclear. We investigated the nature of object concepts by identifying (a) *what* kind of information is accessed when an object concept is tokened: are object concepts accessed 'holistically' or through their constituent features? And (2) *when* is that information accessed—that is, what is the time course of conceptual access for objects?

While some of these questions closely parallel the two overarching questions of our study, they have been somewhat dissociated from one another. One reason for this dissociation is that studies have employed experimental paradigms that are not well-suited for investigating the nature of object concepts at the earliest moments of conceptual tokening. For instance, some of the studies investigating the timing and nature of object recognition employ go/no-go or categorization tasks requiring participants to make decisions based on a pre-determined criterion (e.g., whether a presented item is an instance of a *vehicle* or *animal* category) [1]. However, employing such tasks casts doubts on the external and ecological validity of the results, given that participants are primed to lock into pre-determined categories. Other studies have employed stimulus presentations with long duration latencies (e.g., 500-2000 ms) [7]. However, given the rapidity of the recognition system, it is thus of utmost importance that studies investigating the nature of object concepts employ research paradigms that are sensitive to the earliest stages of processing. This allows for a distinction between elucidating what kind of information arises *at the moment objects are recognized* (i.e., at the moment of concept tokening), from information that arises from inferences or associations that are *triggered* by the concept, but which may not be part of the concept itself (e.g., knowing that dogs bark) [6]. Crucially, understanding what kind of information we entertain about an object requires a concerted effort—one that addresses the two questions (*what*, *when*) simultaneously, while employing research paradigms that are ecologically and externally valid as well as sensitive to the timing of perceptual encoding.

Representing two polar opposites on the nature of conceptual representations are theories that either postulate that concepts are decomposable into constituent features or that concepts are 'atomic' (i.e., they are not decomposable into features; e.g., Atomism [3-4]). Prominent within the camp of decompositional theories is the prototype theory. According to this theory, object concepts are represented through sets of weighted features that are averaged over time [5]. Thus, given that concepts are formed through weighting clusters of features, conceptual tokening—via both, visual and linguistic input—is, by hypothesis, dependent on accessing these features. Atomism, on the other hand, postulates that concepts are object-based—in the sense that concepts individuate referents as a whole and not through their semantic properties, given that each individualized property in the world stands for a concept in the mind. According to this view, the representation of object concepts relies on a nomological mind-world relation that takes meaning representation as a link to a referent. Thus, concepts are non-decompositional primitive representations that do not rely on relations to other concepts or features *by necessity*. [6].

The goals of our study are set against this theoretical background: by investigating the early moments of the conceptual processes—the perceptual input of token objects—we can gain knowledge on the nature of the information that gives access to conceptual representation. It is at those early moments where the information about an object first makes contact with stored information in the conceptual system, which is at the core of other cognitive abilities.

2 The Experiment: Picture-Word Congruency Task

Participants (N=33) performed a picture-word masked priming congruency task, whereby they had to judge whether a picture-word pair were related to each other, at two presentation rates: 60 ms and 200 ms. Participants wore blue-red anaglyph glasses, with objects and words presented in red or blue in the left (LVF) or right visual field (RVF). Anaglyphs allowed us to investigate the role of early posterior visual projections during object and word recognition, when words were projected to the left hemisphere and pictures, to the right hemisphere, using either ipsilateral or contralateral pathways (Figure 1a). For each picture, one of four word probes was presented for congruency decision: the basic level category label of the picture (dog), a high-prototypical (bark), low-prototypical (fur), or superordinate feature (animal). These words were selected based on a separate norming study with 100 participants and 260 pictures, totalling 75,000 features. The experiment consisted of a 2 x 2 x 2 x 4 factorial design with 32 distinct conditions: *presentation times* (2): 50/60 ms, 190/200 ms; *picture-word hemispheric projection* (2): left-right, right-left*; pathway* (2): ipsilateral, contralateral; and *target type* (4): basic level label, high prototypical feature, low prototypical feature, or superordinate feature. There was a total of 128 experimental word-picture pairs for each of the 32 conditions. Materials were counterbalanced among 32 lists, such that each list contained 4 items from each of the 32 conditions. Participants completed two lists in a given testing session, in random order. The list combinations were counterbalanced, such that no participant viewed the same picture-word combination twice. We hypothesized that, if object concepts are accessed via features, high-prototypical features would yield faster response times (RTs) and greater accuracy, at both presentation rates, given that high-prototypical features supposedly give privileged access to concepts. However, if object concepts are primarily accessed via lexical labels representing the whole object, the category label (e.g., dog) would yield faster RTs and greater accuracy at both presentation rates. Further, we predicted that prototypicality effects would only arise in the longer presentation condition (i.e., 200 ms), given that a concept is activated before its features. Response times and accuracy to congruency decisions were analyzed through linear mixed effects models.

3 Results and Discussion

Preliminary results (Fig. 1b) suggest that, at both presentation times, object names and superordinate features yield shorter response times and greater accuracy than high-and low-prototypical features. Additionally, results showed that participants were more accurate in responding to picture-word pairs when stimuli were presented for 200 ms rather than 60 ms. But crucially, object names yielded significantly greater accuracy than all other probe types, at both presentation times. Taken together, these results suggest that concept tokening may rely on non-decompositional processes, and that conceptual features are processed only after concepts have been accessed. Moreover, we suggest that object concepts are represented in the brain by abstract atomic symbols, not through their constituent or salient features. While objects might first be accessed via their primitive visual properties (lines, vertices, color, texture, shape), these properties may not be semantically active: they contribute to the object file compilation but not to the representation of the concept to which the object file is linked. Exploratory analyses investigating participants' accuracy on congruency decisions as a function of feature cue validity and distinctiveness will be discussed.

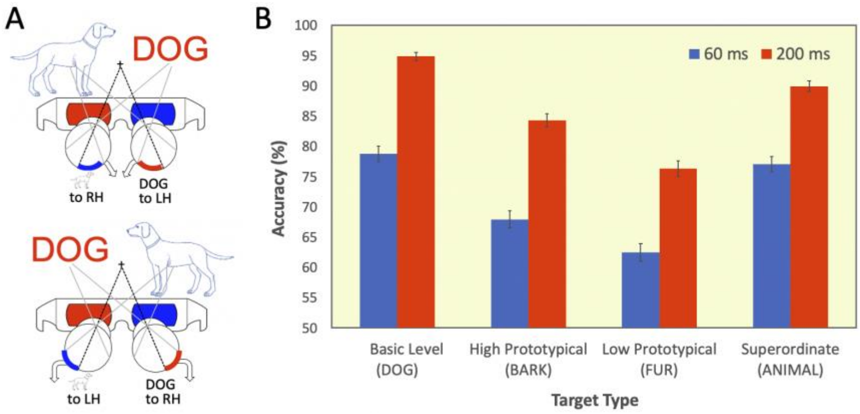

Fig. 1. (A) An illustration of the procedure showing the retinal projections of words and pictures via contralateral (top) or ipsilateral pathways. In the experiment, visual field, retinal projections for words and pictures, and pathways were all counterbalanced. **(B)** Accuracy results for the different target label types.

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