



## Original Articles

A familiar-size Stroop effect in the absence of basic-level recognition <sup>☆</sup>Bria Long <sup>\*</sup>, Talia Konkle

Department of Psychology, Harvard University, United States

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## ABSTRACT

When we view a picture of an object, we automatically recognize what the object is and know how big it typically is in the world (Konkle & Oliva, 2012). Is information about an object's size activated only after we've identified the object, or can this size information be activated before object recognition even occurs? We previously found that big and small objects differ in mid-level perceptual features (Long, Konkle, Cohen, & Alvarez, 2016). Here we asked whether these perceptual features can automatically trigger real-world size processing, bypassing the need for basic-level object recognition. To test this hypothesis, we used an image synthesis algorithm to generate "textform" images, which are unrecognizable versions of big and small objects that still preserve some textural and form information from the original images. Across two experiments, we find that even though these synthesized stimuli cannot be identified, they automatically trigger familiar size processing and give rise to a Size-Stroop effect. Furthermore, we isolate perceived curvature as one feature the visual system uses to infer real-world size. These results suggest that mid-level perceptual features can automatically feed forward to facilitate object processing, and challenge the idea that we must first identify an object before we can access its higher-level properties.

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## 1. Introduction

Our object recognition system runs so smoothly and automatically in the background that we rarely notice it tolling away. This system seems particularly adept at identifying what we see at the *basic level* – for example, if we see a small, smooth object with a handle, we first identify this as “a mug” rather than as something more general (“an inanimate object”) or something more specific (“the coffee mug I received from my grandmother”, Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). In fact, some work suggests that we can categorize objects at the basic level as quickly as we can detect their presence (Grill-Spector & Kanwisher, 2005). Our automatic and effortless ability to categorize and identify visual objects is often taken as the core goal of the brain's visual recognition system (DiCarlo & Cox, 2007).

However, recently it was also demonstrated that as soon as we see a pictured object, we also automatically activate information about how big or small the object typically is in the world (Chiou & Ralph, 2016; Glikzman, Leibovich, Melman, & Henik, 2016; Konkle & Oliva, 2012; Sellaro, Treccani, Job, & Cubelli,

2015; see also Paivio, 1975; Rubinsten & Henik, 2002). Some evidence for this automatic activation comes from a Size-Stroop paradigm. In this task, participants were asked to compare two objects and decide which one is visually bigger or smaller on the screen, ignoring the real-world size of the objects. The visual sizes of the two depicted objects could either be congruent with their real-world size (e.g. a small cup and a big car), or incongruent (e.g. a big cup and a small car) (see examples in Fig. 1). Critically, the task only required judging which image was bigger or smaller *on the screen*—knowledge about the real-world sizes of the objects was irrelevant to the task. However, participants were faster to make visual size judgments on the congruent trials, indicating that they could not help but automatically process real-world size when presented with pictures of these objects.

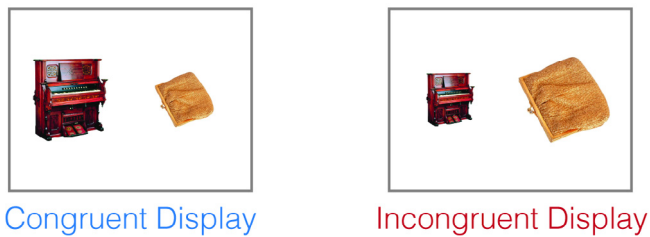
Do we need to recognize a pictured object in order to know its size in the real world? Classic models of conceptual representation argue that semantic knowledge about objects is organized as a series of predicates (e.g., “big enough to support a human”) that are attached to conceptual nodes, such as “chair” (Collins & Quillian, 1969; Jolicoeur, Gluck, & Kosslyn, 1984). These nodes can be activated by the correct sets of input from the visual processing stream, and in turn, serve as the point from which we access knowledge about objects, such as how big or small they are in the real world, or the context in which they are typically used (i.e., a kitchen). On this account, object recognition precedes our ability to access knowledge about an object. However, recognition need not be the gateway through which we access all kinds of

<sup>☆</sup> We have uploaded all data and analysis code to the first author's GitHub account, which is linked to an Open Science Repository for this project (<https://osf.io/dt5a6/>).

<sup>\*</sup> Corresponding author at: 33 Kirkland Street, Cambridge, MA 02140, United States.

E-mail address: [brialorelle@gmail.com](mailto:brialorelle@gmail.com) (B. Long).

## Size-Stroop Effect



**Fig. 1.** Example Size-Stroop displays from Konkle and Oliva (2012). Two objects were displayed and the task was to judge which item was bigger on the screen. In congruent trials, the object that was bigger on the screen was also a bigger object in the real world. In incongruent trials, the object that was bigger on the screen was a smaller object in the world. Participants were faster to make visual size judgments when the visual size of the object was congruent with the real-world size of the object, even though the object's real-world size was irrelevant to the task.

object knowledge. On an alternative account, perceptual feature evidence accrued in parallel to the process of object recognition could be used to make inferences about different functional properties of objects, including their size in the real world. Some evidence for this alternative was recently provided by Cheung and Gauthier (2014), who demonstrated that specific perceptual features, like smoothness and symmetry, can automatically activate conceptual information about whether something is animate or inanimate. Thus, an alternative possibility is that perceptual features can automatically activate real-world size information.

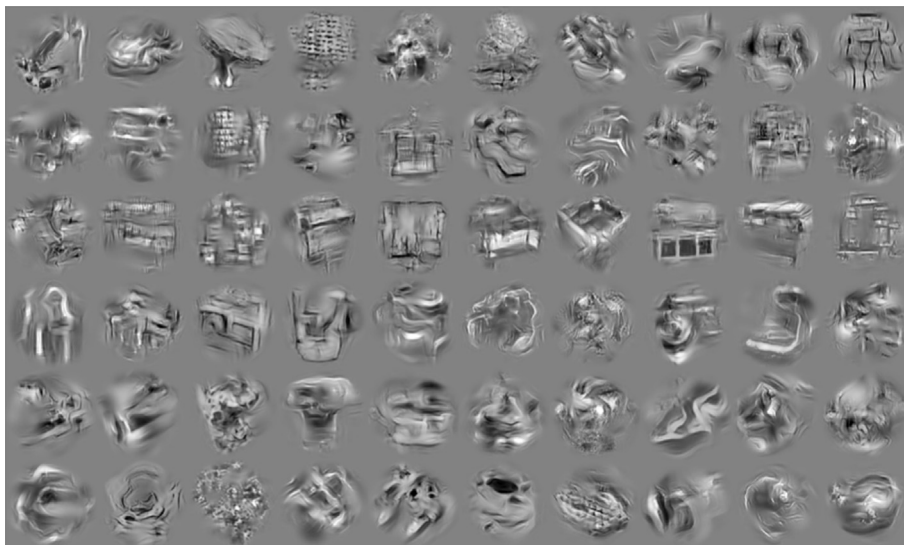
In prior work we established that there exist systematic perceptual differences that distinguish big objects from small objects. To do so, we used a visual search task, with the logic that visual search is slower when targets and distractors are perceptually similar (Duncan & Humphreys, 1989; Long, Konkle, Cohen, & Alvarez, 2016). We found that participants searched more efficiently for a small object target (e.g. cup) among big object distractors (e.g. couch, piano, chair), and vice versa. Critically, this visual search advantage persisted even when participants were searching for unrecognizable versions of big and small objects that preserved some texture and form information—“texform” stimuli (Freeman & Simoncelli, 2011; Long et al., 2016). These results indicate that big objects and small objects have systematic perceptual differences that are preserved in “texform” stimuli.

Given this existence proof of feature differences, we can now directly test the deeper question about the role these might play in our cognitive architecture: do these perceptual features directly activate size concepts and automatically trigger real-world size processing, without requiring basic-level object recognition? To do so, we used the Size-Stroop paradigm from Konkle and Oliva (2012), but with unrecognizable texform stimuli. If basic-level recognition is a necessary precursor to real-world size inferences, then these texforms should not trigger any real-world size related processing, and thus should not impact the speed of visual size judgments in the Size-Stroop task. However, if these texform stimuli do trigger real-world size processing, we should see evidence for a Size-Stroop effect.

To anticipate our results, we find that unrecognizable texform stimuli generate a Size-Stroop effect (Experiment 1), and the strength of this effect depends on the degree to which texforms preserve information related to real-world size (Experiment 2). To provide some intuitions about the features preserved in the texforms that underlie these effects, we explored several properties. We found that the perceived curvature of the texforms, but not perceived viewing distance or depicted depth, predicted the magnitude of the Size-Stroop effect for individual displays. Taken together, these results demonstrate that real-world size information is automatically activated by perceptual features, including curvature properties, when observers perform a visual size task. Broadly, these results are consistent with the possibility of a modified cognitive architecture in which early visual processing can directly trigger the processing of higher-level object properties, including real-world size.

## 2. Experiment 1

Texform images of big and small objects were generated using a computational model of early visual processing (all stimuli in Fig. 2; Freeman & Simoncelli, 2011; Long et al., 2016). In the first experiment, two texforms were presented simultaneously at different visual sizes, and we asked participants to make a visual size judgment about which of two texforms was bigger or smaller on the screen. Unbeknownst to the participants, on some displays, the relative visual sizes of the texforms were congruent with the real-world sizes of their original objects (e.g. a big piano texform and a small key texform). On other displays, this relationship between



**Fig. 2.** All 60 texforms used in Experiments 1 and 2. The top three rows correspond to texforms generated from pictures of big objects, and the bottom three rows correspond to texforms generated from pictures of small objects.

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