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DECLARATION OF INTERESTS

The authors declare no competing interests.

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Visual anagrams reveal high-level effects with ‘identical’ stimuli

Tal Boger and Chaz Firestone

A fundamental question in psychology and neuroscience concerns how the mind represents not only lower-level stimulus features such as luminance, contrast, or spatial frequency, but also richer, higher-level properties such as animacy, emotion, or real-world size. Numerous findings suggest that such high-level properties are encoded automatically[1,2], engage visual attention[3,4], and organize neural responses[5,6]. However, a critical challenge arises when interpreting such findings: High-level categories systematically covary with lower-level features, such that effects attributed to high-level properties may instead be driven by their lower-level covariates. Can this challenge be overcome? Here, we introduce a novel approach by leveraging ‘visual anagrams’ — a diffusion-based technique for generating images whose interpretations change radically with orientation, such as a cow when upright and a mouse when inverted[7]. Using real-world size as a case study, we generated anagrams depicting a canonically large object in one orientation and a canonically small object in another, and placed them in classic experimental paradigms. Five experiments revealed that many (but not all) effects of real-world size persisted under such conditions. Together, our findings address a longstanding challenge in perception research and establish a broadly applicable tool for psychology and neuroscience.

Consider the rabbit and elephant in Figure 1A. Although they occupy roughly the same amount of space on the page, they differ in their real-world size. An extensive body of research suggests that this high-level difference is actively represented by the mind: Real-world size intrudes on orthogonal perceptual judgments[1,2], drives visual search[4], and constrains cortical representation[5]. But real-world size is not the only feature distinguishing the rabbit and elephant: They also differ in shape, curvature, spatial frequency, viewing angle, and other mid- and low-level properties. Thus, while differences in representation of these objects may arise from differences in real-world size, they may instead arise from correlated lower-level differences (an especially salient possibility given similar findings with distorted, unrecognizable stimuli[2,4,8]). Despite progress on this problem[6,9], isolating high-level properties from lower-level features remains an enduring challenge.

Now consider the rabbit and elephant in Figure 1B. These are actually *the very same image*, rotated 90°. They are ‘visual anagrams’, created using a diffusion-based technique that generates static images whose interpretations change radically when rotated[7]. The two images are pixel-wise identical subject to rotation, thus differing in a high-level property (here, real-world size) without differing in features such as curvature, spatial frequency, luminance, contrast, and so on.

Here, we exploit this technique to investigate high-level effects with otherwise ‘identical’ stimuli, minimizing the lower-level covariation associated with conventional approaches. We generated images depicting a large object in one orientation and a small object in another (for example, rabbit-elephant, butterfly-bear), placed them in classic paradigms exploring real-world size (https://perceptionresearch.org/anagrams), and asked whether the original findings persist under these conditions.

We first investigated automatic encoding of real-world size using the familiar-size Stroop task[1]. In this task, two images are displayed at different sizes, and subjects must say which is larger on the screen. Despite real-world size being explicitly task-irrelevant, performance is better when displayed size is congruent with real-world size (for example, rabbit-small, elephant-big). Experiment 1 adapted this design to our anagram stimuli. Consistent with previous work, we found a familiar-size Stroop effect

(Figure 1C): Subjects were faster and more accurate on congruent trials than incongruent trials (–21.9 ms, $t(50) = 4.75$, $p < 0.001$; +0.8%, $t(50) = 3.80$, $p < 0.001$), even when the images were simply rotated versions of one another.

We next explored a connection between real-world size and aesthetic preferences. Previous work suggests that observers prefer canonically small objects to be displayed small, and canonically large objects to be displayed large[8,10]. Consistent with this work, Experiment 2 revealed that subjects preferred canonically large objects to be displayed larger than canonically small objects, even with visual anagrams (+29.3 px, or +9.6%, $t(197) = 8.60$, $p < 0.001$; Figure 1D).

Whereas Experiments 1 and 2 included a familiarization phase in which subjects first matched category labels to the anagram stimuli, Experiments 3 and 4 replicated those experiments without this phase. The same patterns emerged (Stroop: –31.7 ms, $t(45) = 5.58$, $p < 0.001$; Preferred size: +24.3 px, or +8.2%, $t(197) = 8.23$, $p < 0.001$), replicating our results and demonstrating that visual anagrams are readily identifiable without prompting.

Finally, we investigated links between real-world size and attention. Previous work reports that targets are easier to locate when their real-world size differs from distractors[4]. Using that paradigm, however, Experiment 5 found little-to-no effect with anagram stimuli (11.1 ms advantage, $t(48) = 0.51$, $p = 0.61$, BF10 = 0.176; Figure 1E), suggesting that the original findings may indeed be driven by correlated lower-level properties. Importantly, Experiment 5's design replicated earlier search findings using non-anagram stimuli[4]; those stimuli successfully reproduced previously reported effects (102.6 ms advantage, $t(48) = 4.89$, $p < 0.001$), which were significantly stronger than the (non-significant) effects with anagrams (91.5 ms difference, $t(48) = 3.68$, $p < 0.001$).

Our work confronts the longstanding challenge of disentangling high-level properties from lower-level covariates.

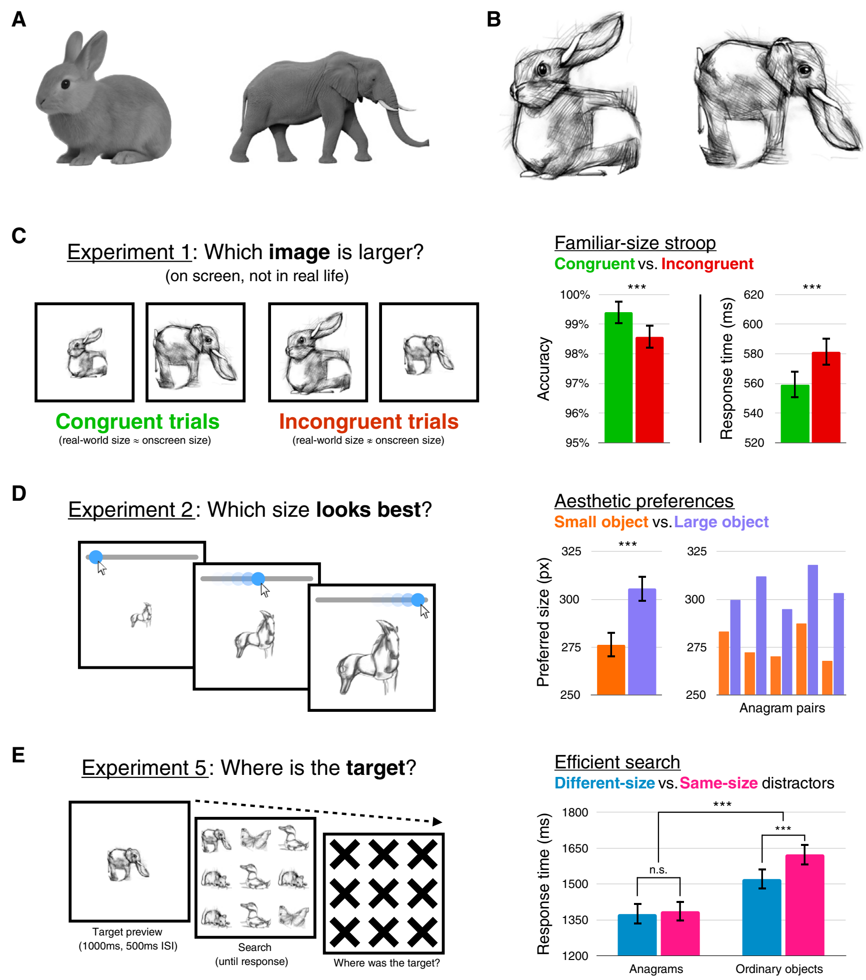

Figure 1. High-level effects with visual anagrams.
(A) This rabbit and elephant differ in a high-level property — real-world size — but also in several mid-level and low-level properties, such as curvature, spatial frequency and contrast. (B) This rabbit and elephant are 'visual anagrams'[7]; they also differ in real-world size, but contain identical pixels (being the same image rotated 90°). (C) The familiar-size Stroop effect arose with visual anagrams (Experiment 1). (D) Real-world size drove aesthetic preferences with visual anagrams (Experiment 2). (E) Visual search was not facilitated by real-world size when using visual anagrams, although previously reported effects arose with non-anagram stimuli.

Our results suggest that real-world size *per se* is represented by the mind: It is encoded automatically and drives aesthetic judgments, in ways that go beyond its lower-level correlates. Not all effects persisted in this way, however, highlighting how this approach can both support and reframe high-level psychophysical effects.

These findings build on previous work showing that many real-world size effects occur even with unrecognizable 'texforms' that preserve mid-level features such as curvature[2,4,8]. That work raises the question of whether real-world size effects are fully captured by such features or instead go beyond them. Experiments 1–4 suggest that there are indeed effects that go beyond mid-level stimulus features, whereas Experiment 5 suggests that at least some effects are driven mostly or only by such features (in ways that are nevertheless consistent with the original claims).

Importantly, our approach is perfectly general. Though we manipulated real-world size, one could generate anagrams of happy faces and sad faces, tools and non-tools, or animate and inanimate objects, overcoming low-level confounds associated with such stimuli[3,6]. The present work thus serves as a 'case study', yielding concrete discoveries about real-world size and validating a broadly applicable tool for psychology and neuroscience.

DECLARATION OF INTERESTS

The authors declare no competing interests.

SUPPLEMENTAL INFORMATION

Supplemental information including additional methodological details and analyses and author contributions can be found with this article online at https://doi.org/10.1016/j.cub.2025.08.036.

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Coalitionary intra-group aggression by wild female bonobos

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In humans and non-human primates, male aggression and physical violence are common strategies in the struggle over power and are efficient in exerting control over individuals and groups. In contrast, our close relative, the bonobo (*Pan paniscus*) is often described as an exceptionally peaceful primate due to the lack of lethal aggression or infanticide and the tendency for individuals to reconcile after conflicts. Nonetheless, rates of male aggression are high[1], but, atypically for primates, bonobo females are observed to confront males without support from others. Despite female exogamy, forming coalitions of unrelated females in response to male aggression appears to be a common strategy, mostly involving charging or chasing and, in some cases, escalating to physical attacks[2–4]. Here, we report on a violent coalitionary attack by resident females against an adult male in a well-studied group of wild bonobos habituated to observation, detailing participants' violent actions and the victim's responses. The assault involved a fraction of the group, while almost everybody was present, and bystanders, including some close maternal kin, did not support the victim. Our observations detail a rare behavior that is not easy to reconcile with the assumed peaceful nature of bonobo society, but which contributes to evolutionary models of aggression[5].

The following observations lasting two hours were made by S.P., S.L.K., and L.B. on February 18th, 2025, at the research site of the LuiKotale Bonobo Project. At 15:30, a sudden outburst of communal vocalizations indicated an aggressive encounter. The first observer arrived at the spot about two minutes late, the other two about five minutes late. They saw an adult male bonobo, soon identified as Hugo, lying on the ground face down and being continuously assaulted by several adult females: Polly, Tao, Ngola, Djulie and Bella. Polly is a long-term resident, whereas the other four females immigrated into the community between 2012 and 2018 (Table 1). Almost the whole community was quietly observing the scene from a distance of 5–10 meters. The females jumped alternatingly on Hugo's body, stomping on his back and biting his head, legs, neck, fingers and toes. One female bit off a part of Hugo's ear, two others engaged in genito-genital rubbing with each other on top of him. One of the perpetrators bit into his foot and chewed on the removed tissue, then bit his testes. Throughout the attack, Hugo was lying on his belly, covering his head with his hands, emitting monotonous stress hoots. When Hugo's body became more visible, observers noted that his face was disfigured with bleeding marks on lips and eyebrows. He had lost much hair on his head, shoulders and back, and a large chunk of skin was missing from his neck. His hand knuckles were bitten to the bone, several toe phalanges were bitten off, and there were wounds on his testes and penis. After around 25 minutes of constant assaults, the main perpetrators paused and, for the next 90 minutes, were licking blood off the male's body and their own fingers. Throughout that time, other bonobos, including females and their juvenile offspring who had not been involved in the aggression, licked the victim's wounds or fingers of the attackers. Apollo, Hugo's maternal half-brother, approached Hugo and licked his injured scrotum. At 17:30, a part of the group started moving away. Hugo first walked a few steps bipedally and, being pursued by some of the group members, managed to lean on his injured knuckles and run away, pursuers and observers falling behind. Since the event, members of the community have been followed for more than 150 days without seeing Hugo. Given the severity of his injuries, it is likely that the attack was fatal.

Despite no apparent coordination in the violent acts (i.e., females acted simultaneously but independently of each other), the assault against

