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General object recognition is specific: Evidence from novel and familiar objects

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ABSTRACT

In tests of object recognition, individual differences typically correlate modestly but nontrivially across familiar categories (e.g. cars, faces, shoes, birds, mushrooms). In theory, these correlations could reflect either global, non-specific mechanisms, such as general intelligence (IQ), or more specific mechanisms. Here, we introduce two separate methods for effectively capturing category-general performance variation, one that uses novel objects and one that uses familiar objects. In each case, we show that category-general performance variance is unrelated to IQ, thereby implicating more specific mechanisms. The first approach examines three newly developed novel object memory tests (NOMTs). We predicted that NOMTs would exhibit more shared, category-general variance than familiar object memory tests (FOMTs) because novel objects, unlike familiar objects, lack category-specific environmental influences (e.g. exposure to car magazines or botany classes). This prediction held, and remarkably, virtually none of the substantial shared variance among NOMTs was explained by IQ. Also, while NOMTs correlated nontrivially with two FOMTs (faces, cars), these correlations were smaller than among NOMTs and no larger than between the face and car tests themselves, suggesting that the category-general variance captured by NOMTs is specific not only relative to IQ, but also, to some degree, relative to both face and car recognition. The second approach averaged performance across multiple FOMTs, which we predicted would increase category-general variance by averaging out category-specific factors. This prediction held, and as with NOMTs, virtually none of the shared variance among FOMTs was explained by IQ. Overall, these results support the existence of object recognition mechanisms that, though category-general, are specific relative to IQ and substantially separable from face and car recognition. They also add sensitive, well-normed NOMTs to the tools available to study object recognition.

1. Introduction

Increasingly, an individual differences approach is being used to characterize the mechanisms that underlie cognition. Such an approach can help to clarify the number, real-world relevance, and developmental origins of mechanisms relied upon to complete a given cognitive task (Wilmer, 2008). Here, we use an individual differences approach to better understand the number of separable mechanisms used to recognize objects.

In the study of object recognition, a distinction can be made between domain-specific mechanisms, which are used for a smaller number of object categories (in the extreme, just one), vs. domain-general mechanisms, which are used for a larger number of object categories (in the extreme, all). To date, much of the research on individual differences in object recognition has focused on domain-specificity, and moreover, on the domain-specificity of a single, widely-researched object category: faces (e.g., Duchaine & Nakayama, 2006; Hildebrandt, Wilhelm, Herzmann, & Sommer, 2013; Shakeshaft & Plomin, 2015; Wilhelm et al., 2010; Wilmer et al., 2010, 2012). Here, we take the opposite approach, focusing on domain-generality and aiming to elucidate principles that may apply broadly across a wide variety of object categories.

There are many good reasons to examine domain-general mechanisms, one of which is the potential real-world predictive power of individual differences-based measures. A basic question arises in this context: Can one capture mechanisms that are broad enough to potentially predict behavior across a variety of life situations, yet specific enough to not simply reflect the sorts of highly general mechanisms that are already well-captured by general

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intelligence (IQ) tests? Could one, for example, create a test that predicts learning of fingerprints, faces, and X-rays in a group of people who score similarly on IQ tests? Our interest in capturing domain-general components of object recognition is thus driven in part by a desire to identify consequential non-IQ abilities, something that has rarely been achieved in studies of cognitive variation (Schmidt & Hunter, 2004; Wai, Lubinski, & Benbow, 2009).

Our second motivation for focusing on domain-generality is to enhance our understanding of the number of dissociable mechanisms used to recognize objects. Past work in neuropsychology (Farah, 1990, 1992), neuroimaging (Kanwisher, 2000, 2010), individual differences (Dennett et al., 2012; Duchaine & Nakayama, 2006; Wilhelm et al., 2010; Wilmer et al., 2012), and behavioral genetics (Shakeshaft & Plomin, 2015; Wilmer et al., 2010) has frequently focused on a simple dichotomy between faces and objects. This work tends to assume, implicitly or explicitly, that non-face object processing is accomplished via a common set of highly overlapping mechanisms that vary little from one non-face category to another. Not infrequently, this assumption motivates the use of a single non-face object category to test for a dissociation of face processing from domain-general object processing. For example, Shakeshaft and Plomin (2015) concluded, based on results from a face test and a single object test (a car test), that the genes underlying face recognition dissociated from those underlying "general object recognition."

The assumption of common mechanisms for different object categories can, however, be questioned on multiple grounds. First, dissociations have been found between the neural areas supporting the processing of animals vs. tools (e.g., Chao, Weisberg, & Martin, 2002), large vs. small objects (e.g., Konkle & Oliva, 2012) and objects that are curvilinear vs. rectilinear (e.g., Nasr, Echavarria, & Tootell, 2014; Yue, Pourladian, Tootell, & Ungerleider, 2014). Second, behavioral dissociations are found between object categories, and, interestingly, the degree of behavioral dissociation predicts the degree of neural dissociation (Cohen, Konkle, Rhee, Nakayama, & Alvarez, 2014; Cohen, Nakayama, Konkle, Stantić, & Alvarez, 2015). Third, and most relevant to the current focus on individual differences, are recent studies of correlations in performance across object recognition tests (e.g. butterflies, cars, planes, shoes, dinosaurs; McGugin, Richler, Herzmann, Speegle, & Gauthier, 2012; Van Gulick, McGugin, & Gauthier, 2015). The mean pairwise correlation found among these tests ($r = 0.33–0.34$) was no larger than what is typically found between face and non-face object recognition tests (e.g. $r = 0.37$ in Dennett et al., 2012), a result difficult to reconcile with the notion that a single test could capture domain-general object recognition. Moreover, individual pairwise correlations varied widely by category-pair (from $r = 0.00$ for cars and leaves to $r = 0.54$ for leaves and butterflies), suggesting that the contributions of domain-general mechanisms to everyday object recognition may differ sharply from one category to another (McGugin, Richler, et al., 2012; Van Gulick et al., 2015).

Indeed, one might ask whether domain-general mechanisms necessarily contribute at all to individual differences in object recognition. In theory, the modest associations found between object recognition tests might have nothing to do with object recognition *per se*, but might instead reflect more general differences in IQ, attentiveness, or motivation. A key aim of the present work was to verify whether any individual differences in domain-general object recognition exist. A second, related aim was to ask whether individual differences in domain-general object recognition are underestimated by correlations among familiar object categories. In theory, dissociations in performance between object categories could result not only from domain-specific object recognition mechanisms, but also from domain-specific non-perceptual knowledge (e.g. names of car makes and models) gained through domain-specific experience with familiar objects (e.g. extensive research on cars prior to buying one).

Our first two studies test a pair of predictions drawn from the hypothesis that nontrivial individual differences in object recognition exist: (A) measures of object recognition performance that minimize the impact of individual differences in domain-specific experience will correlate relatively highly, via cleaner isolation of domain-general object recognition mechanisms, and (B) associations between such measures will not be substantially explained by measures that are known to load highly on IQ. We tested prediction A in Studies 1 and 2 via different approaches. In Study 1, we created object recognition tests for three novel object categories (Novel Object Memory Tests; NOMTs). The use of novel categories, with which everyone should be similarly unfamiliar, should minimize the impact of individual differences in domain-specific experience. In Study 2, we attempted to minimize the impact of category-specific experience by averaging performance across tests of familiar categories. In both Studies 1 and 2, we then tested prediction B by asking whether controlling statistically for performance on IQ-loaded measures would substantially reduce or eliminate associations between object recognition tests. To preview our results, both predictions held: our efforts to reduce the impact of category-specific experience yielded higher correlations, and these correlations were remarkably impervious to controls for multiple IQ-related measures, thereby supporting the existence of individual differences in domain-general object recognition mechanisms.

Studies 1 and 3 tested two simple predictions of the further hypothesis that the same domain-general mechanisms contribute to recognition of both unfamiliar (novel) and familiar object categories. In Study 1, we examined correlations between novel object recognition and face recognition. Plausibly, recognition in both of these cases may be relatively free of domain-specific experience variation. In the case of face recognition, performance might be relatively free of experience variation if most persons reach a saturation point in their experience whereby only genetic variation remains (this would be consistent with the high heritability found in existing twin studies: Shakeshaft & Plomin, 2015; Wilmer et al., 2010). In the case of novel object recognition, everyone should be similarly inexperienced. If domain-specific experience variation were relatively absent, and if the same underlying mechanisms were used in familiar and unfamiliar object recognition, then performance should correlate highly between faces and novel objects. The correlations we found, however, were weaker than those among NOMTs, tentative evidence that recognition of familiar versus unfamiliar object categories may rely on at least partially distinct mechanisms. In Study 3, we asked whether the NOMTs' relatively low correlation with face recognition is unique to faces, or whether similar results can be obtained using cars, a category that in past work has shown a degree of dissociation from other object categories that is similar to that for faces (McGugin, Richler, et al., 2012; Van Gulick et al., 2015). Cars provide an interesting test case. On the one hand, car recognition is as heritable as face recognition (Shakeshaft & Plomin, 2015), potentially motivating an experience-saturation hypothesis similar to the one mentioned above for face recognition. On the other hand, car recognition is highly correlated with both self-reported car experience and objectively assessed, car-related semantic knowledge, suggesting that statistical controls for one or both might isolate a relatively pure object recognition capacity. Again, however, the correlation of car recognition with NOMTs was weaker than those among NOMTs, even after controlling for experience and semantic knowledge, further evidence that recognition of familiar versus unfamiliar object categories may rely on distinct mechanisms. To summarize, face and car recognition both correlate relatively little with novel object recognition compared with the inter-correlations between NOMTs. This result suggests that domain-general