Paper:
Towler, J. & Tree, J. (2018). Commonly associated face and object recognition impairments have implications for the cognitive architecture. *Cognitive Neuropsychology, 35*(1-2), 70-73.
http://dx.doi.org/10.1080/02643294.2018.1433155

The implications of highly associated face and object recognition impairments for the cognitive architecture

Towler, J. & Tree, J. J.

Geskin & Behrmann provide an extensive and scholarly meta-analysis of the extant cases of developmental prosopagnosia (DP) in order to ascertain how often impairments in face recognition and object recognition co-occur, mirroring an influential review of the acquired agnosias by Farah (1991) published in this journal. The authors conclude that for the appropriately tested cases, the majority of individuals with DP (approximately 80%) have substantial object recognition difficulties that co-occur with face recognition impairments. The authors suggest that this strong co-occurrence of face and object recognition difficulties in DP is revealing about the underlying cognitive architecture and that face and object recognition rely upon shared cognitive mechanisms. In the current commentary we agree with Geskin & Behrmann that the common co-occurrence of face and object (but not word) recognition deficits in DP is an interesting and important observation, and we also agree that face and object recognition are likely to share some common cognitive and neural mechanisms. We propose that this evidence for category-general recognition mechanisms needs to be carefully integrated with the strong evidence for category-specificity in visual processing. In this commentary we discuss what these category-specific and common shared mechanisms might be, and what such population-level statistics might tell us about the underlying cognitive architecture.

The use of population level statistics to infer cognitive structure can be traced back to the roots of individual differences psychometric research including the study of intelligence (e.g. Spearman, 1904). Such investigations utilise population-level statistics to infer properties of the underlying mental architecture, and correlations in performance on separate tasks across individuals suggest that such tasks recruit shared underlying cognitive or perceptual mechanisms. This approach has allowed for the discovery of general intelligence (*g*), as well as more specific cognitive domains relating to distinct abilities. The important discovery of *g* allows us to successfully predict that individuals with high *g* will perform well on a variety of cognitive tasks, and those with low *g* will perform poorly on a range of cognitive tasks. A different approach is taken within the field of cognitive neuropsychology when studying individuals with brain damage. Associations of impaired performance on multiple distinct tasks by neuropsychological patients are common and are generally understood to be because brain damage can result in impairments to domain-general systems or to multiple separate cognitive systems at one time. In this context, associations between different cognitive deficits in particular patient groups might reveal more about the physical pathology itself (e.g., spatially-extensive lesions) rather than about the inter-relatedness of the underlying cognitive systems. For these reasons associations between impairments are generally considered to be inferior evidence for understanding underlying cognitive structure (e.g., Shallice, 1988). Instead, neuropsychologists favour the logic underlying evidence of clear *dissociations* between abilities. If one ability is normal and another ability is selectively and severely impaired in the same patient then there must be some important degree of cognitive and neural separation between these two abilities. Within the classic neuropsychological framework we can take Geskin and Behrmann's observation that at least 20% of DPs do not have object recognition deficits, as strong evidence that aspects of face and object recognition ability dissociate in developmental cases and infer from this that there are separate cognitive and neural mechanisms underlying the development of these abilities.

Moreover, there are many other good reasons to believe in category-specificity in the cognitive and neural architecture (e.g. Kanwisher, 2010). Spatially and temporally distinct face- and object-selective brain activations have been observed with multiple experimental techniques (electroencephalography, functional magnetic resonance imaging, intracranial recordings). Causal links between category-selective brain regions and selective abilities have been strongly established through selective impairments due to brain damage (Susilo, Wright, Tree, & Duchaine, 2015), developmental disorder (Burns, Bennetts, Bate, Wright, Weidemann & Tree, 2017) and via brain stimulation techniques (e.g. Parvizi, Jacques, Foster, Witthoft, Rangarajan, Weiner, & Grill-Spector, 2012). Importantly, electrical stimulation of face-selective brain regions causes specific disruptions to face processing that appear to leave object processing intact. For these reasons we do not believe that Geskin & Behrmann's observations have any impact on the general conclusion that face and object recognition are largely separate abilities at the cognitive and neural levels other than to show the possible proportion of DP cases that demonstrate this important dissociation. However, we do agree with Geskin & Behrmann that the presence of a large proportion of individuals with co-morbid face and object recognition deficits is an important population-level phenomenon that is in need of an explanation.

Although we suspect that Geskin & Behrmann's estimate of 80% comorbidity in face and object recognition impairments is likely inflated by methodological decisions and the appropriateness of the available empirical data, it is clear that the true proportion of co-occurrence is well above what would be expected by chance (e.g. Zhao, Li, Liu, Song, Wang, Yang, & Liu, 2016). In order to understand this association it is important to consider that despite the substantial evidence for the separation between face and object recognition systems, they are not *entirely* functionally separate abilities. Performance on face and object tests co-vary well-above chance, and it is an often replicated finding that approximately 10-20% of variance is shared between face and object recognition performance, with similar amounts of shared variance between other different object classes (e.g., Gauthier, McGugin, Richler, Herzmann, Speegle, & Gluick, 2014). Intriguingly, this shared variance appears to be relatively independent of *g* and therefore cannot be accounted for by general problem solving or executive factors. In addition, correlations in performance also tend to be much higher for tests that use the same object category for stimulus materials (e.g. faces, cars) even if the tasks have different cognitive demands (e.g. matching tasks and recognition tasks). Such observations indicate the presence of *both* category-general recognition systems/processes and category-specific mechanisms for faces and for different classes of object. These common systems might include memory encoding, storage, or retrieval processes that are generally required for recognition and episodic memory. Other common systems may include lower-level visual-perceptual processes that feed into both higher-level object specific and face-selective systems. If we assume that these types of system are partially separate and therefore have additive effects in terms of their impact on face recognition performance, then it logically follows that those individuals who have the worst face recognition impairments will likely have deficits in both category-specific and category-general systems. Conversely, individuals that demonstrate a clear dissociation between face and object recognition have problems restricted to face-selective systems.

We argue that the study of DP and other relatively-selective visual agnosias can reveal important clues about the underlying cognitive architecture. We have established that category-general mechanisms account for a relatively small amount of shared variance in recognition ability across the neuro-typical population. Yet according to Geskin & Behrmann's analysis, the DP population generally shows a much greater association between face and object recognition than might be expected. This conclusion is consistent with the emerging view that face processing is often less functionally specialised in DPs than in the general population (e.g. Towler, Fisher, & Eimer, 2017). Because individuals with DP have impaired face-processing systems, they may rely more strongly upon more general visual recognition mechanisms, and as a result often share more variance between face and object recognition. In contrast, neurotypical individuals without face processing impairments have developed efficient category-specific processing and may rely more strongly on separate category-specific systems for both faces and different object-classes. However, although it is often assumed that object recognition ability draws on a universally domain-general system in contrast to domain-specific face recognition ability, recent evidence suggests this assumption may be wrong. Individual differences research involving testing across multiple different object classes suggests they similarly share little association in the recognition performance for many types of object (Gauthier et al., 2014; Richler et al., 2017) – this low level of variance overlap is hard to reconcile with a single domain-general system for object recognition. Moreover, there is additional evidence that shows in some specific instances particular object categories may show much stronger association in performance (e.g., faces and bodies). Thus the pattern of performance comparing faces with various objects, and even performance comparing recognition across other different non-face categories is clearly complex – with varying degrees of association and dissociation in abilities. Thus casting further doubt on the idea that there is a universal domain-general system that can account for all variance in recognition ability. Importantly, such differences in ability do not appear to be easily accounted for by self-reported differences in visual experience alone, and that the likely cause of this variation may include heritable factors which impact on the capacity to learn about and take an active interest in different commonly occurring object categories (Shakeshaft & Plomin, 2015).

It is clear then that some individuals have generally high levels of object experience accompanied by low levels of general object recognition ability, and that these individuals also tend to have poor face recognition performance (Gauthier et al., 2014). Our interpretation of this complex pattern of evidence is that such associations must emerge as a result of the efficiency of the underlying category-general visual *learning* mechanisms. Within the intelligence literature a similar phenomenon is known as Spearman's law of diminishing returns; and we propose that a law of diminishing returns in the underlying general visual learning mechanisms can explain the strong association between face and object recognition impairments in DP. According to this framework the root cause of DP for these cases may be impairments in *both* category-general and face-selective visual learning mechanisms that can combinatorially disrupt the development of face-selective systems. Face recognition is the most apparent symptom of impaired visual recognition learning abilities for such individuals because it constitutes a visual category that all typical individuals acquire rich visual experience during the lifespan, and therefore have the most opportunity to achieve higher levels of performance and category-specificity. Geskin & Behrmann's central observation that for DPs there is a disproportionately higher association between face and object recognition relative to the general population neatly falls out of the principles of this framework. Namely, that there is a single general visual learning ability – *v,* which can account for these associations (Gauthier, et al., 2014). However, because we have already pointed out that correlations in performance across different types of face and non-face object can vary in degree (even after experience is held constant), we remain cautious about whether there is a *single* underlying category-general learning mechanism. Taken together, it seems likely that there are multiple underlying learning mechanisms which impact differentially on different categories of object. These multiple learning mechanisms may include distinct perceptual and memory-related processes and will impact on different object categories to the extent that they place different demands on visual attention, perception and memory, and encourage individuals to engage in deeper levels of processing with particular kinds of object.

In our view, in order to account for patterns of association and dissociation in cognitive performance we have to assume the existence of both general learning mechanisms (*g,* types of *v*) and domain-specific representational systems (faces, words, cars, bodies, etc.). It is important to note that psychologists have not given up on the concept of *g* in the face of evidence that some individuals with pervasive developmental disorders have severely low *g* but islets of preserved or enhanced cognitive ability in specific domains (that would otherwise be strongly correlated with *g*). Within our framework, cognitive and neural category-specificity is the product of both domain-specific and category-general learning abilities that are constrained by heritable factors and extensive visual experience over development. This proposal asks only that we give up on extreme notions that *either* category-specificity or general visual learning ability can fully account for the developmental of cognitive and neural systems underlying visual recognition across the population. Geskin & Behrmann's review draws our attention to the need for theories that can explain human performance both at the level of individuals and populations. We suggest that developmental cognitive neuropsychologists should aspire to integrate neuropsychological and individual differences approaches within their psychological and neurological frameworks.

References

Burns, E. J., Bennetts, R. J., Bate, S., Wright, V. C., Weidemann, C. T., & Tree, J. J. (2017). Intact word processing in developmental prosopagnosia. *Scientific Reports*, *7*, 1683. http://doi.org/10.1038/s41598-017-01917-8

Farah (1991). Cognitive Neuropsychology: Patterns of Co-occurrence Among the Associative Agnosias: Implications for Visual Object Representation. Cognitive Neuropsychology, 8(1).

Gauthier, McGugin, Richler, Herzmann, Speegle, & Gulick (2014). Experience moderates overlap between object and face recognition, suggesting a common ability. *Journal of Vision,* 14(8):7.

Kanwisher, N., (2010). Functional specificity in the human brain: a window into the functional architecture of the mind. PNAS, doi:10.1073/PNAS.1005062107.

Parvizi, Jacques, Foster, Witthoft, Rangarajan, Weiner, Grill-Spector (2012). Electrical stimulation of human fusiform face-selective regions distorts face perception. J. Neurosci., 32, 14915-14920.

Richler, Wilmer, & Gauthier (2017). General object recognition is specific: Evidence from novel and familiar objects. Cognition, 166, pp. 42-55.

Shallice, T. (1988). From Neuropsychology to Mental Structure. Cambridge, UK: Cambridge University Press.

Spearman, C. (1904). "General Intelligence," Objectively Determined and Measured. *The American Journal of Psychology, 15*(2), 201-292. doi:10.2307/1412107

Susilo, T., Wright, V. Tree, J. J. & Duchaine, B. (2015). Acquired prosopagnosia without word recognition deficits – Cognitve Neuropsychology, 32 (6), 321-339.

Towler, J., Fisher, K., & Eimer, M. (2017). The cognitive and neural basis of developmental prosopagnosia. *The Quarterly Journal of Experimental Psychology*. http://doi.org/10.1080/17470218.2016.1165263

Zhao, Y., Li, J., Liu, X., Song, Y., Wang, R., Yang, Z., & Liu, J. (2016). Altered spont aneous neural activity in the occipital face area reflects behavioral deficits in develop mental prosopagnosia. Neuropsychologia, 89, 344-355