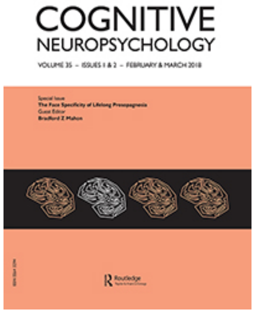

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Over time, the right results will emerge

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ABSTRACT

Scientific research involves going beyond the well-trodden and well-tested ideas and theories that form the core of scientific knowledge. During the time scientists are working things out, some results will be right, and others will be wrong. *Over time, the right results will emerge*. Lisa Randall (Frank B. Baird, Jr. Professor of Science, Physics Department, Harvard University)

We are grateful to all the commentators for the important and thoughtful comments raised in response to the Geskin and Behrmann (G & B) literature survey. The issues raised in the introduction to this Special Issue and in these commentaries not only address and challenge aspects of the G & B literature review, but contribute perspectives and extensions that go well beyond the scope of the review. As is evident from G & B and from the 13 commentaries, many aspects of congenital prosopagnosia (CP) remain controversial. Adopting the language of the quote above, the intention of the G & B survey, along with the commentaries and this response, is to establish a collaborative process from which the right results (and right theory) will emerge in time. We are grateful to the editor of this Special Issue, Dr. Brad Mahon, for his support and for facilitating this collaborative exchange in Cognitive Neuropsychology.

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Introduction

In this response, we extract common themes from the commentaries, address some inconsistencies, and face some of the challenges. The key result reported by Geskin and Behrmann (2018) is that roughly two thirds of individuals with congenital prosopagnosia (CP) have an associated deficit in object recognition, and the remaining one third have a deficit specific to face recognition. Although the numbers vary depending on how one counts and whether or not one derives estimates from the less definitive data, the preponderance of associations always outweighs the dissociations. In general, the commentaries note that the presence of both associations and dissociations and the higher frequency of associated over dissociated patterns are surprising. There is also general agreement that there is a pressing need for a satisfactory theoretical explanation.

The commentaries also raise a host of complicated issues including the criteria for the diagnosis of CP, whether the different patterns observed reflect different subtypes of CP, and whether we can uncover a neural mechanism that supports these patterns. There are also questions that address methodological challenges such as how to reconcile the findings at the group level with findings at the single individual level, what dependent measures to adopt, and what would constitute the right form of assessment of the participant's object recognition abilities. To address these myriad comments, we have clustered them along thematic lines.

Before proceeding, however, it is necessary to clarify the theoretical motivation that framed G & B in the first place. As Starrfelt and Robotham (2018) point out, G & B take as their starting point the perennial question of modular versus distributed representations (which Barton, 2018, humorously refers to as the "undead question"). G & B characterize the distributed view as one in which "object discrimination depends on dispersed regions spread across visual cortex, some of which may support the recognition of more than one stimulus class". Starrfelt and Robotham state that this is not a very strong claim, and go on to note that "it is hard to imagine any researcher that would disagree

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with the proposition that object and face recognition rely on some cortical regions which support both". Our reading of the literature is not as conclusive as theirs, and, indeed, this question continues to generate lively debate as is well reflected in the commentaries. Setting aside the functions of early and perhaps some mid-level regions of visual cortex as well as mnemonic and semantic functions, an alternative view that challenges the proposition that some cortical regions support both classes of object is set out in a recent retrospective on the quest for the "fusiform face area" (FFA) that states that, following the discovery of the FFA, "there was (now) a little piece of the brain that seemed to do just one thing: perceive faces" (Kanwisher, 2017). This view is also endorsed by Kanwisher in 2010 who stated that "at least a few brain regions are remarkably specialized for single high-level cognitive function", that researchers "have identified a number of cortical regions that respond selectively to single categories of visually presented objects: most notably, the FFA which responds selectively to faces", and that there are computational advantages that result from this functional specialization (Kanwisher, 2010, p. 11164; for related views, see McKone, Crookes, Jeffery, & Dilks, 2012; McKone, Kanwisher, & Duchaine, 2007; McKone & Robbins, 2010; Riddoch, Johnston, Bracewell, Boutsen, & Humphreys, 2008; Susilo, Wright, Tree, & Duchaine, 2015). Our contention is that the debate is far from resolved, and there is much room for additional, spirited exchange on the issue.

Diagnosis

Consensus on the relevant diagnostic criteria

As noted in G & B, there is, as yet, no clear consensus on the criteria for diagnosing CP. Many commentaries allude to this challenge. Ramon (2018) but also Barton and Corrow (2016) and Dalrymple and Palermo (2016) highlight the need for formal diagnostic criteria, consistent terminology, and the systematic assessment of sub-processes involved in face recognition. Many commentaries also note the importance of specifying the tasks that should be employed for diagnosis; to date, these vary across studies, with some tasks tapping face recognition, others measuring face discrimination, and yet others assessing performance on old/new decisions (Robotham & Starrfelt, 2017). Van den Stock and de Gelder (2018) offer a host of useful suggestions regarding assessment tools. Additional suggestions for systematic approaches to diagnosis include assessing intra-individual consistency, adopting psychometric approaches (for example, careful evaluation of inter-item assessment and inclusion of a large number of items to ensure sufficient power), and exploiting other measures as obtained from gaze contingent and other eye-tracking paradigms and from information processing efficiency measures. Also, other methodological approaches such as the use of electrophysiology and of correlating well-established physiological signatures with behaviour are likely to be especially helpful in CP diagnosis (Eimer, 2018). Last, expanding the assessment repertoire by using personally familiar faces and personally familiar objects (Landi & Freiwald, 2017) and characterizing performance on tasks of facial expression and its dynamics (Ramon, 2018) will assist further in characterizing CP.

While there is growing consensus on the need for best practice diagnostics, there is still the question of what criteria to use when labelling an individual as CP. Rossion (2018) for example, challenges the use of the term "prosopagnosia" in CP from first principles. He notes that, historically, prosopagnosia clearly demarcated a specific disorder based on criteria for inclusion (severe difficulty in the recognition of individuals who were known prior to the brain damage and then encountered post damage) and exclusion (the deficit is visual in nature, but not accounted for by a low-level deficit or intellectual impairment). In contrast, nowadays any difficulty in individual face recognition seems to be classified as "prosopagnosia". Rossion proposes that these latter developmental difficulties in face recognition ought to be labelled "prosopdysgnosia" and ought to be distinguished from the acquired neurological syndrome of prosopagnosia.

We disagree and contend that the term "prosopagnosia" should continue to be applied to CP, albeit with stringent inclusion and exclusion of criteria, as laid out by Rossion (2018). Our view is that a longstanding, marked difficulty in familiar face recognition, which is not attributable to a fundamental visual, intellectual, language, or semantic deficit, warrants the label of "prosopagnosia". Moreover, as with the acquired neurological disorder, there is a neurological basis for CP too (see section below, entitled Neural Basis). To adhere to the stringent criteria, then, diagnostic tasks that rule out concomitant deficits in lower level or sensory vision and in intellectual function are crucial. It is the case that the face recognition disorder might be based on a mnemonic or perceptual deficit, and, to differentiate between these, a discrimination task using novel faces (with no associated semantics) is important, as well (for details on criteria, see Barton & Corrow, 2016; Dalrymple & Palermo, 2016).

Another point of contention (without a clear resolution in sight) concerns whether CP simply represents the lower end of the normal distribution—of course, performance that falls more than 2 standard deviations (*SD*s) from the mean of control individuals (and certainly 1.7 *SD*s) may simply reflect performance that is falling in the tail of the normal distribution. Determining whether CP is, in fact, a distinct pathology (Barton & Corrow, 2016) is essential but not trivial to accomplish. Although performance that, statistically, falls outside the normal distribution would suggest a different distribution, it is also possible that the behavioural scores of CP individuals may continue to fall in the tail of the normal distribution but that the scores of the CP and control individuals might derive from entirely different underlying computational and/or neural mechanisms. As we have conjectured, an abnormality in structural and functional connectivity in the distributed face network, especially in the connectivity to extended regions, may differentiate between CP and controls (Avidan et al., 2014; Behrmann, Avidan, Gao, & Black, 2007; Rosenthal et al., 2017; Thomas et al., 2009). We have also suggested that these neural differences might give rise to an abnormality in holistic or global processing (and potentially in feature representation as well; Avidan, Tanzer, & Behrmann, 2011; Behrmann, Avidan, Marotta, & Kimchi, 2005; Kimchi, Behrmann, Avidan, & Amishav, 2012; and for a recent investigation of this issue and evidence that the impairment in CP is perceptual rather than attentional in nature, see Gerlach, Klargaard, Petersen, & Starrfelt, 2017). Elucidating differences in the underlying mechanisms of CP and their specificity, and not only in the overt behaviour, may help resolve the conundrum of normality versus abnormality.

Determination of an accompanying object recognition deficit

Setting aside the diagnostic issues in CP, there is still the question of how to evaluate whether there is a co-occurring deficit in object recognition. Barton (2018) largely agrees with the criteria used by G & B for assigning cases to the different categories based on object recognition status, but argues that Category 4 (object recognition performance that falls below 1.7 *SD*s from mean accuracy) should be set aside as contributing only marginal evidence. He also requests that researchers provide additional evidence to show that those with deficits in object recognition (Category 5) do not have an associated memory or general perceptual impairment. These caveats are all reasonable, and we concur entirely.

Garrido et al. (2018) note that G & B may have been too liberal in that, statistically, the likelihood of uncovering abnormal performance in CP in at least one test increases with the number of tests administered. Degutis and colleagues illustrate their point by showing that, based on four tests (two old–new recognition and two matching tasks), 50% of their control sample would meet the criteria for CP (although we do not know what the hit rate would be for fewer or more tests). This is an excellent point in general but may not hold under all circumstances. First, if 50% of the controls are classifiable as CP, this raises a question concerning the sensitivity of the measure itself. Second, as G & B show in Table 3, the use of more tests does not necessarily uncover a larger number of cases with object recognition deficits. As an example, the first column in Table 3 lists the number of cases without a deficit in object recognition identified by one test as 33 cases, by two tests as 14 cases, and by more than two tests as 0 cases. The use of more tests was not, in this instance, more likely to identify more cases of object impairment. It does appear, however, that at the other end of the spectrum, in those in whom a definite object recognition deficit is identified (column 3 of Table 3), the adoption of more than two tests does identify a larger number of cases than one or two tests: The use of one test identified 49 cases, two tests identified 41 cases, and more than two tests identified 69 cases. It remains a possibility that the larger number of cases in this column may be a result of a selection bias[1]—namely, individuals are assigned to this category/column first by the severity of the object recognition impairment. Because these individuals are most severely impaired, more tests inevitably result in more hits. In other words, the increase in hits with more tests may not be that surprising under these circumstances and may have no bearing on the sensitivity of adopting more tests in general—in a random sample of individuals or in the population at large, the axiom of more tests identifying more instances of abnormality may not necessarily hold.

Last, several commentators raised concerns about the disproportionate reliance on reaction time (RT) as the key dependent measure of object recognition ability. Starrfelt and Robotham (2018) argued that accuracy can be as sensitive as RT and that a dissociation (and presumably, also, an association) between objects and faces based on scores from the Cambridge Face Memory Test (CFMT)—and the object equivalent of this task, the Cambridge Car Memory Test—might suffice. However, Gerlach, Lissau and Hildebrandt (2018) and Rossion (2018) support the position taken by G & B (p. 6) in which accuracy alone is considered insufficient as a measure given that this might be achieved through prolonged RTs. Rossion notes that, unless there is an obvious motor or execution deficit, "if object (or face) recognition is abnormally slow, it must be impaired". We continue to hold that accuracy alone is an inadequate dependent measure, especially in neuropsychological populations, and we advocate for the measurement of RT (and any other dependent measures, as well). We provide many examples of why we think this is the case in G & B (p. 5). (Campbell & Tanaka, 2018, see below, also express concern about the absence of RT measures.)

The right measures

G & B spend considerable time discussing the need to level the playing field when evaluating face and object recognition, and note the confounds that plague this endeavour, including the subordinate versus individual level of processing for objects versus faces, and the greater expertise for faces (although see Young & Burton, 2017, for a provocative discussion of this expertise point). So, what are the right measures? There is no easy answer, and, in the absence of a good theory of what processes are engaged in face and in object recognition, we may never really level the playing field. For example, Barton (2018) rightly points out that, even with the best of intention to equate the tasks, a dissociation between face and object recognition might arise for the following reason: Whereas face recognition might rely to a greater extent on a holistic process, object recognition might rely to a greater extent on a part-based process, and so preserved object recognition and impaired face recognition might simply reflect this distinction, and there is no way round it.

Along similar lines, Towler and Tree (2018) note that any attempt to equate the testing of face and object recognition might be confounded by the fact that, in general, multiple object categories share little overlap but some categories do show greater relatedness to faces (e.g., bodies and faces). Concluding whether there is a single mechanism for faces and objects might then depend on the objects chosen for assessment. The selection of a class of objects for comparison is also crucial insofar as expertise is implicated (Harel, Gilaie-Dotan, Malach, & Bentin, 2010; Martens, Bulthe, van Vliet, & Op de Beeck, 2017). Barton (2018) clearly makes the case that studies of CP ought to take expert-level processing into account when a category of objects is selected for comparison and that only a single individual thus far —O.H. (Weiss, Mardo, & Avidan, 2016), who is an expert in horse recognition—meets this criterion. The control of level of expertise notwithstanding, Campbell and Tanaka (2018) are still concerned about the conclusions that can be drawn from O.H.'s data. O.H. was tested on two different horse tasks. In the one test, horse recognition was tested across breed rather than across individual horses so individual-level recognition was not assayed. In the second test, although the task required discrimination between horses of the same breed, the task involved matching a target with one of two possible horses (one of which was identical to the target), and according to Campbell and Tanaka, this matching may be achieved on the basis of local feature matching. Thus, neither of the measures of horse recognition is equated with measures used to assay face recognition, and the poorer performance for faces might still result from the fact that individual faces may be more perceptually homogeneous, and, hence, constitute more "difficult" stimuli. As such, Campbell and Tanaka propose that, based on the existing data, O.H. be removed from Category 3 "CP with no object recognition deficit".

Campbell and Tanaka (2018), in a careful analysis of Category 3, argue further that G & B overestimated the number of "pure" CP cases (i.e., those without any associated object recognition impairment). The thrust of their argument concerns a confound in the comparisons between face recognition and object recognition. Specifically, they refer to the individual data scores that we computed from the Zhao et al. (2016) study. Zhao and colleagues had kindly shared their individual data with us, and so we were able to assign each of their 64 CP participants to one of the five categories based on their object recognition performance. In Zhao et al., a stimulus was shown (e.g., a car) for 33 ms and was then masked, and the participant was required to decide whether the stimulus was a pre-specified target (e.g., a Jeep) or not. The same was true for the face recognition task, with the participant deciding whether the stimulus was the pre-specified face of a well-known Chinese actor or not. Of the 46 participants assigned to Category 3 by G & B, 40 were participants from Zhao et al. who performed abnormally on the face measure and normally on the object measure (relative to their matched controls). In G & B, we had expressed some concern that the Zhao et al. measures of object recognition might have been too easy: "Note, however, that the Zhao et al. (2016) paradigm might have been relatively easy as 2/3 of their participants performed normally" (p. 10). We came to this conclusion on the basis of the distribution of the data rather than based on a principled explanation. Campbell and Tanaka, however, provide a principled explanation: Even if faces and objects are tested using the identical procedure, and even if the level of categorization is the same for the two tasks, the failure to control for perceptual similarity might still render the task more difficult for one category of stimuli than another. Specifically, the point is that the perceptual similarity between, for example, a pigeon and a warbler or a Jeep and a sedan, as in Zhao et al., is not equated with the perceptual similarity that exists between individual faces. In sum, just because testing is done with items from the same subordinate category, the perceptual demands of discriminating between exemplars can still vary greatly across categories. Campbell and Tanaka state that the best demonstration of a "pure" CP individual would be one who exhibits the spared ability to individuate structurally homogenous objects such as dogs of the same breeds or birds of the same species, together with the impaired ability to individuate faces. Campbell and Tanaka argue that the 40 participants from Zhao et al. do not meet the criteria for a "pure" face recognition deficit and suggest that G & B set them aside, leaving only six "pure" cases in Category 3 (also leaving out O.H.). If we accept this argument, we are left with 197 CP individuals for whom sufficient data exist for classification, of whom six are "pure" cases (Category 3) showing a dissociation, and 191 cases show an association of face and object recognition impairment (Categories 4 and 5). We note that Barton (2018) also expresses concern at the evidence from the Zhao et al. paper and, in light of the ambiguity of measurement, suggests that perhaps the "undead question" addressed by G & B should remain buried until more definitive evidence is accumulated.

One last question arises—do we analyse the results of the data at the group or at the individual subject level? Towler and Tree (2018) argue that both levels are instructive: Population-level statistics (with a very large group as reviewed in G & B) allow one to infer properties of the mental architecture by examining correlations (and perhaps, going forward, by conducting factor analyses) that shed light on the components of the organization of the visual system. Thus, in the current context, the comorbidity of deficits in face and in object recognition at the population level requires an explanation. Associations at the single subject level, they argue, are less informative as the comorbidity of face and of object recognition might be more a function of the physical pathology than of the inter-relatedness of the computational system itself (also see below, the last section entitled Interpretation of Associations Versus Dissociations). Rossion (2018) strongly favours the study of individual cases and notes that G & B (and other researchers) tend to diminish the importance of single case reports. He further states that in-depth single case studies may even be the method of choice when patients are rare and the associated deficits differ across the single cases. Clearly, the single case versus group studies remains an ongoing point of contention.

Subtypes

Focused study of CP as a disorder is relatively recent, and, as the field matures, new questions come to the fore. One such question concerns the heterogeneity of the neural and psychological mechanisms that give rise to the face recognition deficit. Several commentators, such as Barton (2018) and Eimer

(2018) make a cogent argument in favour of identifying subtypes. Eimer offers up two possible subtypes: CP individuals who either do or do not have a domain-general sensory deficit. He bases this distinction on the finding that some CP individuals are less sensitive to contrast signals from the eye region of faces than is true for controls (Fisher, Towler, & Eimer, 2016), and this reduced sensitivity can impede both face and object recognition. In contrast, there may be other CPs in whom the deficit arises in post-perceptual detection or discrimination just of facial identity. These subtypes may be difficult to distinguish behaviourally, but could, in principle, be dissociated with electrophysiological markers (Fisher, Towler, & Eimer, 2015). Along these lines, Rosenthal and Avidan (2018) suggest that different subtypes may have different neural connectivity patterns (see below), which might be captured by characterizing the functional and structural connectivity between face-selective cortical regions.

Neural basis

Several commentaries highlight the future possibility of understanding the neural basis of CP given the advent of new technologies and analytic approaches. Rosenthal and Avidan (2018) propose the use of network science and graph theory to map the disrupted topology of complex visual networks in CP. Relative to controls, the CP group evinces two topological differences, hyperconnectivity in posterior connections and hypoconnectivity from posterior to anterior connections. These two patterns might be associated with different subtypes and such changes in connectivity might even be a benchmark for diagnosing CP (Rosenthal et al., 2017). Along similar lines, Nestor (2018) advocates the use of novel methodological tools to reveal differences in the representational basis of faces in CP versus controls through neurocomputational analyses and reconstruction of the face image from the multivariate neural signals.

To the extent that fine-grained neural studies have been conducted, there is no obvious consensus on what constitutes the biological fingerprint of CP. For example, Grill-Spector and colleagues (Grill-Spector, Weiner, Kay, & Gomez, 2017; Witthoft et al., 2016) have shown that the population receptive field size (pRFs) across the ventral stream was smaller in CP than in controls, as measured using functional magnetic resonance imaging (fMRI). Some of these same authors have also reported no qualitative differences in ventral temporal lobe white-matter tracts associated with face processing, but, instead, have reported significant differences in the mean diffusivity and in the structure–behaviour relationship specifically in white-matter local to the region known as "mFus-faces" (Gomez et al., 2015; see also Song, Zhu, Li, Wang, & Liu, 2015). It is not obvious how restricted pRFs and white matter abnormalities in the vicinity of face-selective cortex are related, and, as reported in G & B, there are now multiple studies reporting different patterns of white matter abnormalities in CP. Thomas et al. (2009) reported a relationship between the structurally compromised inferior longitudinal fasciculus (which projects between posterior occipital and anterior temporal lobe) in the right hemisphere and the severity of the face impairment in CP, and this is consistent with the claim that the anterior temporal cortex and its connectivity are critical for intact holistic face processing (Collins & Olson, 2014). Yet others have argued that a key difference between CP and controls is evident in both core and extended regions as well as in the right parahippocampal cortex (Rivolta et al., 2014), and de Gelder and colleagues have reported reduced category-selective responses in posterior cortex, which affects both face and body processing and recognition (Righart & de Gelder, 2007; Van den Stock, van de Riet, Righart, & de Gelder, 2008). It is not clear whether these various structural and physiological changes are related to each other and whether these different findings index different subtypes of CP. There is much to be done, and a biological fingerprint for CP or multiple such fingerprints for different subgroups of CP remains elusive at present.

According to Gray and Cook (2018), clues to the underlying neural difference in CP and controls may also be gleaned from noting that genetic or environmental factors that predispose one to CP also increase the risk of developing other recognition disorders. They speculate that individuals with CP do not inherit CP per se but, rather, that they inherit the susceptibility to altered structural development of occipitotemporal cortex. They go on to suggest that this predisposition may result in the co-occurrence of CP with other (independent) occipitotemporal neurodevelopmental disorders such as body agnosia and/or developmental object agnosia. On this view, forms of developmental agnosia affecting faces, bodies, and objects constitute independent conditions, and so we might expect to see all possible pairwise impairments of these three categories. Their proposal is interesting and plausible but the absence in CP of a co-occurring deficit in word recognition, which certainly has an occipitotemporal substrate, may require some qualification of their hypothesis.

Interpretation of associations versus dissociations

The last and most controversial topic across the commentaries relates to the core proposal of G & B that the predominant pattern of an association in CP between impaired face and object recognition offers evidence of a single domain-general mechanism. In this context, G & B also formulate a mechanism whereby the less frequent dissociation may also arise (p. 17). This proposal bears some resemblance to that initially proposed by Farah (1992) but with an added elaboration regarding hemispheric specialization. The account concerns the hemispheric specialization for the different visual classes and the fact that the pattern of specialization differs across different individuals. Thus, in individuals in whom the deficit for face and object recognition are associated, both visual classes engage the same cortical region/s in the same (likely right) hemisphere. A perturbation of right-hemisphere function would therefore result in the associated deficits for the two classes. Word recognition would be spared with preservation of the left hemisphere and the well-established visual word form area. In those individuals in whom face and object recognition are dissociated, we would predict that the representation of faces is strongly lateralized to the right hemisphere, and the representation of words is strongly lateralized to the left hemisphere, and that object recognition is mediated bilaterally by both hemispheres. While left-hemisphere functions may be spared with preserved object and words processing, right-hemisphere face processing would be adversely affected (also see Nestor, 2018; and Rosenthal & Avidan, 2018). This profile would give rise to the dissociation of faces and objects, with the sparing of word recognition.

The claim of a single mechanism in CP for face and object recognition was challenged in the commentaries in several ways. As noted above, Eimer (2018) expresses concern that the association may result from a third shared factor such as a low-level sensory disorder or even from a high-level working memory or executive disorder. Ensuring that neither of these alternatives holds is critical. If indeed, a shared mechanism is causally responsible for the face and object association in CP, Eimer predicts that there should be an association between face and object recognition in all cases of CP. This is not the case, of course, and, as described in the preceding paragraph, G & B set out a scenario in which not all cases would evince this association.

Another, perhaps more damning critique is that CP may have no bearing on the question of modular versus distributed systems for visual recognition. Rossion (2018) and Starrfelt and Robotham (2018) recognize that the property of modularity may emerge only in a fully mature brain, and thus the study of CP is moot on this point. The thinking is that typical development results in the topographic configuring of separate systems in the ventral occipito-temporal cortex over the course of experience (Arcaro, Schade, Vincent, Ponce, & Livingstone, 2017). Therefore, only in the mature system can brain damage lead to highly specific recognition impairments, including prosopagnosia. Moreover, the frequent cases of CP with impaired object recognition may be a consequence of the abnormal early development and resulting abnormalities in the underlying system following an early perturbation. Starrfelt and Robotham appeal to the position of D'Souza and Karmiloff-Smith (2011) who claimed that modularity is the end state of development, and not its starting point. In essence, the G & B survey might have no bearing on our understanding of the organization of the mature visual recognition system. Even if this were true, there is still some merit to studying CP qua CP. One compelling reason to do so, for example, is to understand the absence of plasticity in CP. The failure to acquire normal face recognition in CP contrasts dramatically with cases of extreme neurological challenge in childhood, such as those who undergo lobar resection and still acquire normal face recognition (Liu & Behrmann, 2017; Liu et al., submitted manuscript). What is it, then, about CP that precludes normal face acquisition?

The last (and, if possible, even more damning) critique, which is not levelled just at G & B directly but at the field more generally, relates to conceptual claims about the relative weight of dissociations versus associations. Gerlach et al. (2018) is concerned that the definition of a dissociation is not sufficiently strong—their point is that most studies from which CPs are assigned to Category 3 ("pure" CP, dissociation) employ liberal means for determining the presence of a dissociation. Gerlach et al. stipulate that a dissociation must be based on positive evidence—an individual's performance on task X, in addition to being outside the normal range, must also differ significantly from the same individual's performance on task Y. Additionally, the degree of correlation between the two tasks X and Y in the normal population must be taken into account—if this is high, then the dissociation between tasks X and Y in CP becomes even more powerful theoretically. Gerlach et al. (2018) also call for distinguishing between a classical and a strong dissociation (Shallice, 1988), with the former suggesting a qualitative difference in the mechanisms engaged for face and object recognition, and the latter more indicative of a quantitative difference between face and object recognition.

Garrido et al. (2018 argue that dissociations do carry more weight and value than associations in elucidating the underlying mechanisms and that G & B have incorrectly considered the associations in CPs to be more revealing than the dissociations. Degutis et al. also state that they find the G & B stance in favour of a common mechanism account puzzling because no account of how a dissociation might arise is offered. However, in multiple locations, G & B argue that *both* the associations and dissociations must be accounted for. This is clear in the statement that "Furthermore, although dissociations have generally been considered to carry more theoretical weight than associations, a theory based on explaining the distribution of all the data will probably provide the best account of the phenomenon" (p. 20). Additionally, G & B do offer a means whereby dissociations can arise, and this is by virtue of individual differences in cerebral lateralization for faces, objects and words (see p. 18 and above in the section entitled Interpretation of Associations and Dissociations). Last, Degutis and colleagues suggest that the association may be a product of a lesion or aberration that affects neighbouring regions rather than resulting from damage to a single domain-general mechanism, but this would not obviously account for the preservation of word recognition in CP. The regional proximity account also cannot easily explain how, if the mechanisms are truly segregated, virtual reality training to improve cognitive map formation had a positive transfer effect in a case with CP and concurrent topographical difficulties, resulting in post-training improved face recognition (Bate, Adams, Bennetts, & Line, 2017).

Gray and Cook (2018) offer an intriguing theoretical rapprochement in which they state that CP is the result of neither category-specificity nor domain-generality but, rather, may be the outcome of impairments in both domain-general and more modular mechanisms and that these, in combination, disrupt the development of face-selective systems.

Conclusion

This response has highlighted discrepancies and areas of overlap between the commentaries and G & B but also across the commentaries themselves. Some points of view and novel approaches offered strong support for the positions taken by G & B, whereas others have prompted re-evaluation of some of the claims in G & B. Clearly there remains much to be done to characterize CP well and to elucidate the nature of the underlying psychological and neural mechanisms that give rise to this intriguing disorder. It may be the case, however, that a purely empirical, bottom-up approach in the absence of a sound theoretical framework will not yield the desired clarity. But, we hope that through productive exchanges and insightful commentary, the right results and the right theories will emerge.

Note

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