Holistic face perception

Marlene Behrmann[1], Jennifer J. Richler[2], Galia Avidan[3], Ruth Kimchi[4]

[1]Department of Psychology and Center for the Neural Basis of Cognition, Carnegie Mellon University, Pittsburgh, USA
[2]Department of Psychology, Vanderbilt University, Nashville, USA
[3]Department of Psychology, Ben Gurion University of the Negev, Israel
[4]Department of Psychology, University of Haifa, Israel

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1. Introduction

Unlike most objects, for which recognition at the category-level is usually sufficient (e.g., "chair"; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976), recognizing faces at the individual-level (e.g., "Bob" rather than "Joe") is essential in day-to-day interactions. But face recognition, as a perceptual process, is not trivial: in addition to the fact that recognition must be rapidly and accurately accomplished, there is the added perceptual burden as all faces consist of the same kinds of features (eyes, nose and mouth) appearing in the same configuration (eyes above nose, nose above mouth). Thus, an obvious challenge associated with face recognition is the need to individuate a large number of visually similar exemplars successfully, while, at the same time, to generalize across perceptual features that are not critical for the purpose of identification, such as differences in illumination or viewpoint, or even in the age of the face and changes in hairstyle, amongst others. As evident, the cognitive demands of face perception differ from most other forms of non-face object recognition. Unsurprisingly, then, there are many instances where performance with faces differs from performance with other categories of objects. For example, inversion of the input disrupts recognition for faces disproportionately more than for other objects (Yin, 1969), and changing the spatial relations between features impairs face perception to a greater degree than is true for other objects (Tanaka & Sengco, 1997).

In light of these apparent distinctions, many have posited that faces are processed differently from other objects, and that the representations and/or processes that mediate face perception are qualitatively different from those supporting the recognition of other non-face object categories (Farah, Tanaka, & Drain, 1995; Farah, Wilson, Drain, & Tanaka, 1998; Tanaka & Farah, 2003). Specifically, according to some proponents, face processing is thought to require encoding as a whole or a Gestalt, and this is necessary in order to ensure that, during processing, the input matches a face template that enforces the first-order configuration of parts (e.g., eyes above nose, nose above mouth). Such (holistic or unified) representations are believed to facilitate the extraction of second-order configural information (e.g., spacing between features) that is coded as deviations from the template prototype (Diamond & Carey, 1986). This second-order spatial or configural information is, according to some researchers, particularly critical for distinguishing between objects that are structurally very similar; the class of faces is a paradigmatic example of a collection of homogenous exemplars (for review, see Maurer, Le Grand, & Mondloch, 2002). A possible corollary of the assumption that face representations are processed holistically is that the individual parts are not explicitly or independently represented. In its extreme version, this view assumes that faces are not decomposed into parts at all and, moreover, the parts themselves are especially difficult to access (Davidoff & Donnelly, 1990). Consistent with this is the claim that the face template may have no internal part structure; as stated, "the representation of a face used in face recognition is not composed of the faces' parts" (Tanaka & Farah, 1993). On such an account, there is mandatory perceptual integration across the entire face region (McKone, 2008), or, similarly, mandatory interactive processing of all facial information (Yovel & Kanwisher, 2004) (and for a recent review of holistic processing in relation to the development of face perception, see McKone, Crookes, Jeffery, & Dilks, 2012). Note that the notion of a unified face template bears similarity to the view espoused by Gestalt psychologists and the reader is referred to other chapters in this volume that articulate this concept in greater depth (Koenderink, 2013) and also that offer empirical evidence for the use of such a Gestalt and individual differences therein (de-Wit & Wagemans, 2013).

In this chapter, we focus specifically on the viability of a unified face template as implicated in face perception. We first review behavioral evidence suggesting that face recognition is indeed holistic in nature (Part 1), and we draw on data from normal observers and patient groups to support this point. In Part 2, we examine the nature of the mechanisms that give rise to holistic face recognition. Specifically, we argue that holistic face processing is not necessarily based on template-like, undifferentiated representations and, rather, we suggest that holistic processing can also be accomplished by alternative mechanisms such as an automatic attentional strategy and/or that it can emerge from the interactive processing of face configuration and features. We conclude by claiming that holistic processing is engaged in face perception but that the underlying mechanism is not likely to be that of a single, unified template.

2. **Evidence that face recognition is holistic**

2.1. Normal observers

Several lines of empirical evidence have been offered in support of the view that face recognition is holistic. A particularly strong line of support derives from the 'part-whole effect', which refers to the finding that a particular facial feature (e.g., the nose) is recognized less accurately when tested in isolation (65% accuracy) than when presented in the context of the entire studied face (77%), an effect that is not observed for non-face objects (e.g., houses; isolated house parts 81% accuracy, whole-house 79% accuracy) (Tanaka & Farah, 1993). This finding has been taken as evidence that face parts (but not object parts) are represented together: thus, matching an individual isolated face feature is less accurate than matching an entire face because the stored representation corresponds to the entire face rather than to its individual parts. In anticipation of the argument we present later that face parts must be represented as well, we draw the reader's attention to the observation that, even in this classic study, participants must have access to parts to some extent (see 65% accuracy for isolated face part matching). Therefore, the conclusion that there is no decomposition of the face is not supported by the empirical results.

In addition to evidence from such part-whole effects, data obtained from another well-known paradigm, the composite task, is also often taken as strong evidence that faces – but not other objects - are represented as undifferentiated wholes. In the composite task[1] (Hole, 1994; Young, Hellawell, & Hay, 1987) (see Figure 1), participants are asked to judge whether one half (e.g., the top) of two sequentially presented composite faces are the same or different while ignoring the other, task-irrelevant face half (e.g., the bottom). Holistic processing is indexed by a failure to selectively attend to just the one half of the face: because faces are processed as wholes, the task-irrelevant face half cannot be successfully ignored and, consequently, influences judgments on the target face half. Thus, participants are more likely to produce a false alarm (say 'different') when the two top halves are identical and when their bottom halves differ than when both the top and the two bottom halves of the two faces are identical. Interference from the task-irrelevant half is reduced when the normal face configuration is disrupted by misaligning the face halves (Hole, 1994; Richler, Tanaka, Brown, & Gauthier, 2008), and, as one might expect from the holistic face view, is absent for non-face objects (Farah, et al., 1998; Richler, Mack, Palmeri, & Gauthier, 2011) (see Figure 2). Importantly, the magnitude of holistic processing as indexed by the interference in the composite task is a significant predictor of face recognition abilities more generally (DeGutis, Wilmer, Mercado, & Cohan, 2013; McGugin, Richler, Herzmann, Speegle, & Gauthier, 2012; Richler, Cheung, & Gauthier,

[1] Note that there are two versions of the composite task being used in the literature, and an ongoing debate over which is more appropriate (e.g., Gauthier & Bukach, 2007 versus Robbins & McKone, 2007). The interested reader might also wish to consult the recent exchange by Rossion (2013) and by Richler and Gauthier (2013). Details of this debate are beyond the scope of this chapter.

2011b), validating the presumed role of holistic processing as an important component of face recognition[2].

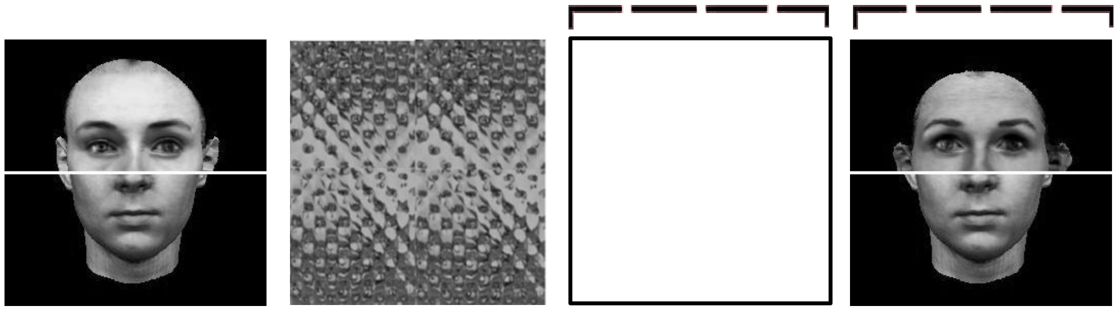


Figure 1. Example of a single trial from the composite task. Participants are asked to judge whether the cued face half (in this case, top) is the same or different between the study and test face while ignoring the other, task-irrelevant face half (in this case, bottom). Here, the correct answer is "different" because the top parts are different, even though the bottom parts are the same. Holistic processing is indexed by the extent to which the task-irrelevant bottom part interferes with performance on the target part as a function of alignment.

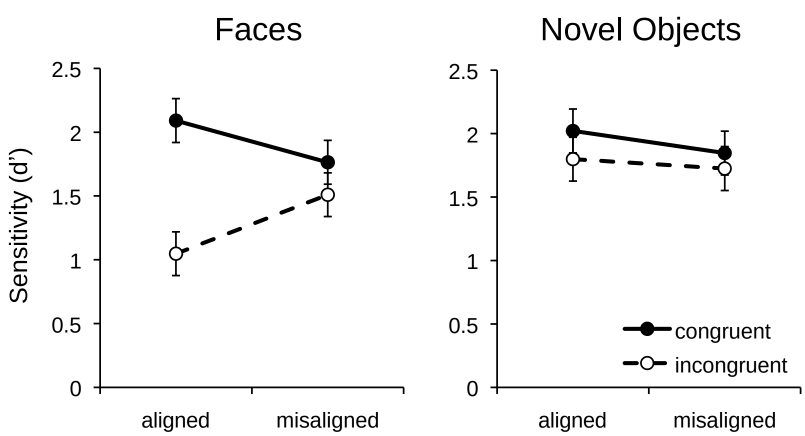


Figure 2. Re-plotted composite task data from Richler, Mack, Palmeri & Gauthier (2011, Experiment 2). Holistic processing is indexed by a congruency effect (better performance on congruent vs. incongruent trials) that is reduced or eliminated when parts are misaligned. As shown above, this effect is robust for faces (left panel), but is absent for non-face objects in novices (right panel).

[2] Studies that have not found support for this relationship have been criticized for the measure of holistic processing used (Konar, Bennett, & Sekuler, 2010) and erroneous interpretation of a correlation based on difference scores (Wang, Li, Fang, Tian, & Liu, 2012).

2.2. Prosopagnosia

Support for the claim that face processing is necessarily holistic (i.e., faces treated as an undifferentiated whole) is also gleaned from the findings that individuals who suffer from prosopagnosia and fail to recognize faces appear unable to process visual information in a holistic or configural fashion. In one of the earliest case studies, Levine and Calvanio (1989) argued that patient LH suffered from a deficit in configural processing, which they defined as "the ability to identify by getting an overview of an item as a whole in a single glance" (p. 160). This patient painstakingly analyses a stimulus such as a face detail-by-detail, over several visual fixations, noting the shapes of the features and their spatial relationships. Consistent with the failure to represent the whole, this patient was also impaired in the Gestalt completion tests of visual closure. Similar descriptions abound for other cases. In his popular book "The man who mistook his wife for a hat", Oliver Sacks reports the following incident concerning his patient, Dr P.

"Sacks noted that when Dr. P. looked at him, he seemed to fixate on individual features of his face—an eye, the right ear, his chin—instead of taking it in as a whole. The only faces he got right were of his brother— "Ach, Paul! That square jaw, those big teeth; I would know Paul anywhere!"—and Einstein whom he also seemed to recognize from characteristic features— Einstein's signature hair and mustache."

Considerable empirical evidence supports such anecdotes, with the central claim being that a breakdown in holistic processing or the ability to integrate the disparate local elements of a face into a coherent unified representation is causally related to the impairment in face processing (Barton, 2009; Rivest, Moscovitch, & Black, 2009). Indeed, it has been suggested that a key characteristic of patients with acquired prosopagnosia (AP) is the inability to derive a unified perceptual representation from the multiple features of an individual face (Ramon, Busigny, & Rossion, 2010; Saumier, Arguin, & Lassonde, 2001). Similar claims have been made about individuals with congenital prosopagnosia (CP). CP is a more recently recognized deficit in face recognition that occurs in the absence of frank neurological damage and altered cognition or vision and is apparently present even over the course of development. The growing consensus is that CP individuals are also unable to rapidly process the whole of the face (e.g., Avidan, Tanzer, & Behrmann, 2011; Behrmann et al., 2006; Lobmaier, Bolte, Mast, & Dobel, 2010; Palermo et al., 2011), and it appears that the patterns of impairment in face perception are extremely similar across the acquired and congenital groups of prosopagnosia (although performance in perceiving emotional expression may differ across the groups, e.g. Humphreys, Avidan, & Behrmann, 2007).

We now consider the same sources of evidence gleaned from individuals with prosopagnosia as we did with the normal participants (part-whole and composite paradigms) and we consider some additional data from experiments that manipulate spatial configuration between face parts and spatial relations sensitivity). Rather few studies have directly examined the part-whole effect in prosopagnosia. In a variant of the standard part-whole task, two well-characterized APs showed a slight part-over-whole face advantage for eyes trials, in contrast to whole-over-part advantage found in controls, suggesting that these prosopagnosic individuals have severe holistic processing deficits, at least for the eye region (Busigny, Joubert, Felician, Ceccaldi, & Rossion, 2010; Ramon et al., 2010). Similar findings were obtained in a small group of congenital (or as they define them, developmental) prosopagnosics who showed a lack of a holistic advantage for both Korean and Caucasian faces (though CPs' overall holistic advantage for Caucasian faces was not significantly different from that of controls, who did show a significant advantage) (DeGutis, DeNicola, Zink, McGlinchey, & Milberg, 2011). Compatible with the finding is the result of an incomplete part-whole task (no isolated parts trials) in which a single patient was significantly worse at discriminating part changes in faces than controls, but not for houses (de Gelder & Rouw, 2000a). These data support the claim that the prosopagnosic individual did not benefit from the context of the face when making part judgments. A recent study has replicated the lack of benefit from the whole in CP but it appears that this may be specific to the eyes as trials in which the mouth was presented in context versus alone showed no differential performance across CP and controls (Degutis, Cohan, Mercado, Wilmer, & Nakayama, 2012). The differential reliance on mouth versus eye processing in prosopagnosia has been reported on several occasions (Barton, Cherkasova, Press, Intriligator, & O'Connor, 2003; Bukach, Le Grand, Kaiser, Bub, & Tanaka, 2008; Caldara et al., 2005).

As has been the case with normal individuals (see above), the composite face paradigm has been employed to explore the underlying processing in individuals with prosopagnosia. In contrast with normal individuals, in the context of a composite face paradigm, congenital prosopagnosic individuals performed equivalently with aligned and misaligned faces and were impervious to (the normal) interference from the task-irrelevant bottom part of faces (Avidan et al., 2011). Interestingly, the extent to which these individuals were impervious to the misalignment manipulation, was correlated with poorer performance on diagnostic face processing tasks (such as the Cambridge Face Memory Test; Duchaine & Nakayama, 2006). Consistent with these results, others have also shown that prosopagnosic (both AP and CP) individuals show reduced interference from the unattended part of the face in the composite face paradigm (Busigny et al., 2010; Ramon et al., 2010) (note, however, that, again, not every individual with prosopagnosia evinces the same profile and some appear to show the normal interference effects; Le Grand et al., 2006; Susilo et al., 2010). In general, these findings have been taken as evidence to support the notion that the severity of the face recognition impairment is directly related to the difficulty in attending to multiple parts of the face in parallel.

Individuals with prosopagnosia also show reduced sensitivity to the spacing between the features, implying a difficulty in representing the 'second order' relations between facial features. For example, Ramon and Rossion (2010) reported that patient PS, who suffers from acquired prosopagnosia, performed poorly on a task that required matching unfamiliar faces in which the faces differed either with respect to local features or inter-feature distances, over the upper and lower areas of the face. PS was impaired at matching when the relative distances between the features differed and this was true even when the location of the features was held constant (and uncertainty about their position was eliminated) (Caldara et al., 2005; Orban de Xivry, Ramon, Lefevre, & Rossion, 2008). Consistent with this, patients with prosopagnosia appear to adopt an analytical feature-by-feature face processing style and focus only on a small spatial window at a time (Bukach, Bub, Gauthier, & Tarr, 2006). The failure to focus on the eye region of the face (Bukach et al., 2006; Bukach et al., 2008; Caldara et al., 2005; Rossion, Kaiser, Bub, & Tanaka, 2009) as well as the relative distances between features (Barton & Cherkasova, 2005; Barton, Press, Keenan, & O'Connor, 2002), as mentioned above, may be a direct consequence of defective holistic processing (Rivest et al., 2009). Also, in a paradigm in which interocular distance or the distance between the nose and mouth were altered or the relative distances between features was changed, prosopagnosic patients perform more poorly when required to decide which of three faces was 'odd' (Barton et al., 2002).

Finally, we review those studies, which examine whether both configural and/or featural processing are affected in prosopagnosia. For example, studies that directly examined featural versus configural processing have found that while CPs show face discrimination deficits for faces that differ only in configural information (Lobmaier et al., 2010), whereas others report that CPs are impaired in discriminating both faces that differ only in configural information and faces that differ only in featural information (Barton et al., 2003; Duchaine, Yovel, & Nakayama, 2007; Yovel & Duchaine, 2006). However, Le Grand et al. (2006) found that three of their eight developmental prosopagnosic individuals were impaired in discrimination of faces that differed in the shape of internal features, four were impaired in discrimination of faces that differed in spacing, and one participant performed normally on both discrimination tasks. Taken together, these findings suggest that CPs can be impaired in processing featural information, configural information, or both. Whether the impairment in configural and featural processing versus configural processing alone reflects the heterogeneity in the population or whether the methodological differences in the various paradigms elicit somewhat different patterns of performance, remains to be determined.

3. Why is face recognition holistic?

3.1. The holistic account

Much of the literature on holistic face processing in normal observers has focused on effects of stimulus manipulations, such as spatial frequency filtering (Cheung, Richler, Palmeri, & Gauthier, 2008; Goffaux, 2009; Goffaux & Rossion, 2006), face race (e.g., Michel, Rossion, Han, Chung, & Caldara, 2006; Mondloch et al., 2010) and orientation (e.g., Robbins & McKone, 2003; Rossion & Boremanse, 2008). Such results are often explained by a holistic representation account in which manipulations that disrupt first-order configuration (e.g., inversion, misalignment) result in patterns that are no longer consistent with the face template, and so are encoded more similarly to other objects. This latter encoding style permits selective attention to parts (i.e., no composite effect), as parts are not integrated in the representation, and, additionally, eliminates any advantage of a whole-face context when matching parts because part representations themselves are explicitly available (no part-whole effect).

Importantly, however, although the results from the part-whole and composite task are consistent with a processing mechanism that might be optimized for faces versus other objects, there is surprisingly little direct empirical evidence that this is the result of holistic *representations* per se. Indeed, there are several results that are incompatible with the notion of template-like face representations created during encoding. For example, when a face composite task and a novel object composite task are interleaved, novel objects are processed holistically in some conditions. Specifically, participants exhibit difficulty in selectively attending to parts of novel objects when they are preceded by an aligned face (that is processed holistically) but not when they are preceded by a misaligned face (that is not processed holistically; Richler, Bukach, & Gauthier, 2009). This result is difficult to explain by invoking a face template – how would a holistic face representation created during encoding influence processing of a subsequent object that does not share the same configuration of features?

Other work showing that holistic processing can be modulated by experimentally induced attentional biases is also difficult to reconcile with the idea of a face template. For example, holistic processing of faces is larger when each trial of the composite task is preceded by a task that requires attention to the global elements of an unrelated, non-face hierarchical stimulus like Navon compound letters (Navon, 1977) versus a task that requires attention to the local elements of the compound letter (Gao, Flevaris, Robertson, & Bentin, 2011; Macrae & Lewis, 2002). Similarly, Curby et al. (2012) found that inducing a negative mood – a manipulation that is believed to promote a local processing bias (Basso, Schefft, Ris, & Dember, 1996) - led to a decrease in holistic processing measured in the composite task relative to inducing a positive or neutral mood. Thus, as is evident, promoting global vs. local attentional biases can obviously influence holistic processing, but there is no simple explanation for how such manipulations would alter the use of a face template, or disrupt face representations. For example, although it is conceivable that these global/local manipulations operate on a template representation, such that a global bias enhances the Gestalt representation and a local bias draws attention to features, it is unclear how the latter would work if the face features were not independently represented in the first place. The key distinction then is between an underlying holistic template, which serves as the representation of a face versus a mechanism that allows for rapid processing of the disparately represented features in tandem.

Finally, according to the holistic representation view, inverted faces do not fit the face template (first-order configuration is disrupted), and so should (and could) never be processed holistically (e.g., Rossion & Boremanse, 2008). Thus, the holistic representation view posits a qualitative processing difference between upright and inverted faces. However, a growing body of work suggests that performance differences between upright and inverted faces are quantitative, such that upright faces and inverted faces are processed in qualitatively the same way, but that upright faces are processed more efficiently than inverted faces (Loftus, Oberg, & Dillon, 2004; Riesenhuber, Jarudi, Gilad, & Sinha, 2004; Sekuler, Gaspar, Gold, & Bennett, 2004). Inversion effects (and their loss in patients with prosopagnosia) have also been documented for non-face objects, especially those that have a canonical orientation (de Gelder, Bachoud-Levi, & Degos, 1998; de Gelder & Rouw, 2000b). Consistent with this more graded account of inversion effects, results from a composite task show that both upright and inverted faces are processed equally holistically, but overall performance is better and faster for upright faces (Richler, Mack, et al., 2011)[3].

One interesting consequence of the difference in processing efficiency for upright versus inverted faces is that holistic effects require longer presentation times to be observed for inverted faces (Richler, Mack, et al., 2011). Interference from task-irrelevant parts are observed for upright faces presented for as little as 50ms (Richler, Mack, Gauthier, & Palmeri, 2009; Richler, Mack, et al., 2011), and the modulation of this interference due to misalignment that characterizes holistic processing occurs with presentation times of 183ms. In contrast, although performance is above chance for inverted faces presented for 50ms and 183ms, there is no evidence for holistic processing of inverted faces until presentation times of 800ms (Richler, Mack, et al., 2011).

The interaction between presentation time and holistic *processing* challenges the holistic *representation* account for several reasons. First, the holistic representation account would not predict that presentation time should influence holistic processing – faces either are or are not encoded into the face template, and, consequently, holistic processing should be all or none. Second, the fact that presentation time influences holistic processing suggests that parts are, in fact, being encoded independently: above chance performance in the composite task only requires encoding of the target part, whereas interference indicative of holistic processing in the composite task requires that the irrelevant part be encoded as well. Accordingly, one interpretation of these results is that at 50ms and 183ms only the target part of inverted faces could be encoded, resulting in successful performance but no interference. Longer presentation times are required to encode both parts of inverted faces, so more time is required to observe interference. In contrast, although they may be encoded separately, both the target and distractor part in upright faces can be encoded within 50ms (Curby & Gauthier, 2009), leading to interference from holistic processing at the fastest presentation times.

While compelling, the evidence for independent part representations based on the interaction between holistic processing and time in Richler, Mack et al. (2011) is certainly speculative. However, other findings also suggest that individual face features can be used in face recognition (e.g., Cabeza & Kato, 2000; Rhodes, Hayward, & Winkler, 2006; Schwarzer & Massaro, 2001), indicating that part representations are accessible. Indeed, participants can recognize previously learned faces with above chance accuracy when the face parts are presented in a scrambled configuration, a condition in which recognition must rely on feature information alone because configural information has been removed. Although recognition performance is better in a blurred condition where facial configuration is maintained but facial featural information is "blurred out" compared to

[3] This study also shows that the results of studies that find reduced holistic processing of inverted faces are driven by differences in response bias between upright and inverted faces. Interested readers are encouraged to see Richler, Palmeri, & Gauthier (2012) and Richler & Gauthier (2013) for discussion of this issue.

the scrambled condition, above chance performance in the scrambled condition implies that feature representations are available and can be used, as well (Schwaninger, Lobmaier, Wallraven, & Collishaw, 2009; see also Hayward, Rhodes, & Schwaninger, 2008). In fact, at the extreme, face discrimination performance can be guided by a single feature in the absence (or near absence) of configural variability (Amishav & Kimchi, 2010).

3.2. Holistic processing as an automatized attentional strategy

If faces are not encoded as unified representations, and face parts can be encoded independently, then what mechanism gives rise to differences in performance between faces and objects, and how can we account for the interference effects that are unique to faces and are described as holistic processing? Studies comparing holistic processing of faces and failures of selective attention that can be found for other objects converge to show that while failures of selective attention to object parts are malleable and responsive to changes in task demands and strategy (Richler, Bukach, et al., 2009; Wong & Gauthier, 2010), holistic processing of faces is automatic and impervious to top-down strategic manipulations (Richler, Cheung, & Gauthier, 2011a; Richler, Mack, et al., 2009). This has led to the suggestion that holistic processing of faces is the outcome of a perceptual strategy of attending to all object parts together and that this strategy becomes automated with extensive experience (Richler, Wong, & Gauthier, 2011). Unlike objects where parts are interchangeable and largely independent (e.g., one can replace the arm-rests of a chair without affecting the shape of the cushions), face parts often change together: face parts move together during speech or changes in emotional expression. Thus, although we can volitionally attend to all parts of a chair, this attentional strategy becomes increasingly automatized in cases where we learn that the higher-order statistics are particularly useful. Importantly, although an attentional strategy may influence encoding, it does not require that the individual face parts attended to simultaneously are integrated at the level of the resulting representation.

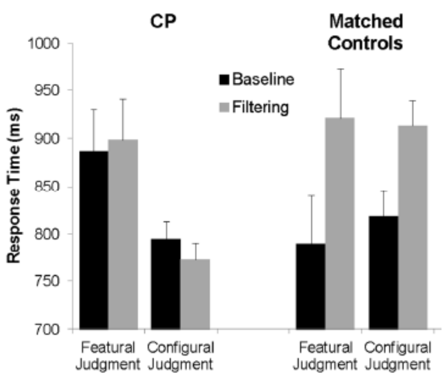
The results from the interleaved face and object composite tasks described earlier can be accommodated by this account: the holistic processing strategy that was automatically engaged for the aligned face could not be "turned off" in time to process the subsequent object, leading to holistic processing of that object as well (Richler, Bukach, et al., 2009). Additionally, although holistic processing is robust to strategic, top-down control, it can be modulated by perceptually-driven manipulations of attentional resources (Curby et al., 2012; Gao et al., 2011). This suggests that holistic processing itself is the outcome of an attentional strategy, and may explain the fact that we see impaired holistic processing in CP for non-face stimuli, as well.

The idea that holistic processing of faces can be understood within the context of domain-general attentional processes is supported by a composite task study by Curby, Goldstein, & Blacker (2013). In that study, face parts were always presented in an aligned format. Square regions surrounding the two face halves were either the same color and aligned, or different colors and misaligned. Remarkably, this manipulation led to a decrease in holistic processing that was similar in magnitude to that observed when face parts themselves are misaligned. In other words, discouraging the grouping of face parts by disrupting classic Gestalt cue of common region reduced holistic processing in the same manner as physically misaligning the face parts.

3.3. Holistic processing as interactivity between features and configuration

Another possible way in which interactivity might emerge is one in which the features themselves are processed independently (Macho & Leder, 1998; Rossion, Prieto, Boremanse, Kuefner, & Van Belle, 2012), and holistic processing is the result of interactive processing of features and configuration (Amishav & Kimchi, 2010; Kimchi & Amishav, 2010; Wenger & Townsend, 2006). Support for this view comes from a study based on the Garner's speeded classification task (Garner, 1974). In this paradigm, observers classify faces based on a single dimension that could be either configural (inter-eyes and nose–mouth spacing) or featural (shape of eyes, nose, and mouth) while ignoring the other dimension which remains constant in some blocks (baseline) or varies independently in others (filtering) (see Figure 3a). Critically, the relationship between the two dimensions is inferred from the relative performance across these two conditions. Equal performance in the baseline and filtering conditions indicates perfect selective attention to the relevant dimension, and the dimensions are considered separable. Poorer performance in the filtering than in the baseline condition – Garner interference – indicates that participants could not selectively attend to one dimension without being influenced by irrelevant variation in another dimension, and the dimensions are considered integral. Using this paradigm, Amishav & Kimchi (2010) documented that normal participants exhibited symmetric Garner interference: they could not selectively attend to the features without interference from irrelevant variation in the configuration, nor could they attend to the configuration without interference from irrelevant variation in the features and both 'interference' effects were comparable in magnitude. These findings indicate that features and configuration are perceptually integral in processing of upright faces and cannot be processed independently. Interestingly, when only face features were manipulated, participants were able to attend to variation in one feature (e.g., nose) and ignore variation in another feature (e.g., mouths), providing further support for the notion that features are perceptually separable. However, when faces were inverted, an asymmetrical Garner interference was observed such that participants could attend the features while ignoring configuration but not vice versa, thus showing evidence for the dominance of featural information in inverted compared to upright face. Taken together, these experiments provide support for the notion that holistic processing, indexed by the combined integration of features and their configuration, is dominant only for upright faces.

B.



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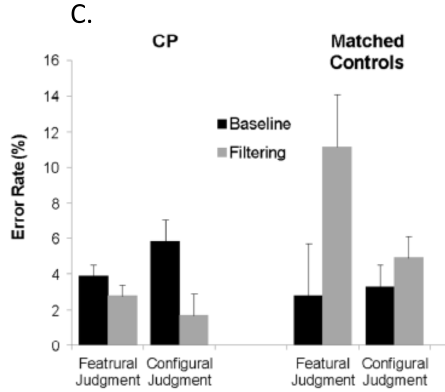

Figure 3. (A). The stimulus set used in Amishav and Kimchi (2010) and Kimchi at el., 2012. Faces in each row (Faces A and B and Faces C and D) vary in their configural information (inter-eyes and nose–mouth distance) but have the same components (eyes, nose, and mouth). Faces in each column (Faces A and C and Faces B and D) vary in their components (eyes, nose, and mouth) but have the same configural information (inter-eyes and nose–mouth distance). Reprinted from Amishav and Kimchi (2010).

Mean RTs (B) and error rates (C) as a function of task (featural judgments, configural Judgments) and condition (baseline, filtering) for the CP participants and matched controls. Error bars represent the standard error of the difference between responses in the baseline and filtering tasks. As evident from both dependent measures, the matched controls show slower RT and more errors in the filtering tasks when making both featural and configural judgments, reflecting the symmetrical interference. The absence of a performance difference for the CPs for either the featural or configural judgments reflects the perceptual separability of the features and the configuration. Adapted from Kimchi et al. (2012).

In a recent study, Kimchi et al. (2012) adopted Amishav and Kimchi's (2010) version of Garner's speeded classification task and applied it to individuals with congenital prosopagnosia, along with matched control participants. This study replicated the finding that normal observers evince symmetric Garner interference for upright faces as revealed by the failure to selectively attend to features without being influenced by irrelevant variation in configuration, and vice versa, indicating that featural and configural information are integral in normal upright face processing (see Figure 3b,c). In contrast, the prosopagnosics showed no Garner interference: they were able to attend to configural information without interference from irrelevant variation in featural information, and they were able to attend to featural information without interference from irrelevant variation in configural information. The absence of Garner interference in prosopagnosics provides strong evidence that featural information and configural information are perceptually separable and processed independently by individuals with congenital prosopagnosics implying that, in contrast with normal observers, these individuals do not perceive faces holistically.

The finding that information about the parts and information about the configuration of a face are available is also noted in fMRI and electrophysiological recording that indicate the existence of both whole-, and part-based representations in face-selective regions of the human and monkey brain (Harris & Aguirre, 2008, 2010) suggesting that part-based and holistic neural tuning are possible in face-selective regions such as the right fusiform gyrus, further suggesting that such tuning is surprisingly flexible and dynamic. Similar findings have been uncovered in studies with non-human primates (Freiwald, Tsao, & Livingstone, 2009). Holistic processing is largely attenuated when only high spatial frequencies are preserved in the stimulus (Goffaux, 2009; Goffaux & Rossion, 2006) (but see but see Cheung et al. 2008, who found equal holistic processing for LSF and HSF faces). However, a face in high spatial frequencies is still well detected as being a face by the observers, suggesting again that detecting a face (and presumably activating the template representation of an upright face) may not be enough to involve holistic processing. More recently, evidence indicated that holistic processing might depend on the availability of discriminative local feature information (Goffaux, Schiltz, Mur, & Goebel, 2012).

Before we conclude, we draw some speculative observations about the mechanisms we have considered and their possible generality. We have articulated a perspective in which face parts are processed holistically and in which, over the course of experience, this integrated processing becomes more automatized. Similar mechanisms may play out in other visual domains as well at both lower and higher levels of the visual system where context (co-occurrence of other information) is present. For example, similar discussion about holistic processing are present in the literature about crowding and the need and difficulty to extract individual components from the multiplicity of items; debates about the inability to attend to only a part and whether this affects the perception of the whole are rife in that field too (Oliva & Torralba, 2007). Finally, discussions about context in scene perception have a similar flavor and so we tentatively suggest that similar mechanisms in which higher-order statistics are derived from the input, especially with greater experience, may be at play throughout the visual system (e.g., Bar & Aminoff, 2003).

4. Conclusions

There is abundant behavioral evidence that face recognition is holistic based on effects that are observed in faces but not non-face objects in normal observers, and that are absent in patient groups characterized by face recognition deficits. But there remains disagreement about what mechanisms are responsible. Of course, what it means for face recognition to be “holistic” need not be all-or-none. Here we have argued against the holistic representation view that, in the extreme, posits that faces are represented as undifferentiated wholes with no explicit representation of individual features. However, “more-than-features” can take on more graded meanings. For example, spatial relations between face features may be explicitly represented and used in addition to information about the features themselves.

It is also important to note that the alternatives to the extreme holistic representation view that we have proposed here - automatic attentional strategy account and the interactive account -are not mutually exclusive. For example, proponents of the view that holistic processing is the result of interactivity between features and configuration often describe face features as being processed in parallel (Kimchi & Amishav, 2010; Macho & Leder, 1998; see also Fific & Townsend, 2010), which may be consistent with the notion that attention is automatically deployed to the entire face at the same time (Richler, Wong, et al., 2011). Importantly, certain aspects of these two accounts need to be empirically reconciled. For example, the classic finding in the composite task (used to support the automatic attentional strategy account) is that participants cannot selectively attend to one face half (e.g., Richler, et al., 2008), but in the Garner paradigm (used to support the interactive account) participants are able to make classification judgments based on one feature while successfully ignoring other features (Amishav & Kimchi, 2010). Moreover, the failures of selective attention documented in the composite task are also observed for inverted faces (Richler et al., 2011c), but interactivity of features and configuration assessed in the Garner paradigm are specific to upright faces (Kimchi & Amishav, 2010). Thus, the two paradigms lead to different conclusions about whether processing differences between upright and inverted faces are qualitative vs. quantitative. One potential reason for these discrepancies is that the coarse parts used in the composite task (full face halves) contain both feature changes (e.g., a different bottom part will have a different mouth) but also subtle configural changes, whereas in the Garner paradigm used by Amishav & Kimchi (2010) feature and configural information are fully isolated and manipulated independently. An exciting avenue for future research is to explore how these two lines of work and the theoretical accounts they support come together to explain normal face perception.

5. **References**

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