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The “parts and wholes” of face recognition: A review of the literature

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It has been claimed that faces are recognized as a “whole” rather than by the recognition of individual parts. In a paper published in the Quarterly Journal of Experimental Psychology in 1993, Martha Farah and I attempted to operationalize the holistic claim using the part/whole task. In this task, participants studied a face and then their memory presented in isolation and in the whole face. Consistent with the holistic view, recognition of the part was superior when tested in the whole-face condition compared to when it was tested in isolation. The “whole face” or holistic advantage was not found for faces that were inverted, or scrambled, nor for non-face objects, suggesting that holistic encoding was specific to normal, intact faces. In this paper, we reflect on the part/whole paradigm and how it has contributed to our understanding of what it means to recognize a face as a “whole” stimulus. We describe the value of part/whole task for developing theories of holistic and non-holistic recognition of faces and objects. We discuss the research that has probed the neural substrates of holistic processing in healthy adults and people with prosopagnosia and autism. Finally, we examine how experience shapes holistic face recognition in children and recognition of own- and other-race faces in adults. The goal of this article is to summarize the research on the part/whole task and speculate on how it has informed our understanding of holistic face processing.

Keywords: Face recognition; Holistic; Other-race face recognition; Autism

An axiom in face processing research is that a face is perceived not as a collection of discrete features (e.g., eyes, nose, and mouth), but as an amalgamation. The “whole” face emerges from its individual parts. Galton (1883) first observed that the face is “the sum of a multitude of small details, which are viewed in such rapid succession that we seem to perceive them all at a single glance” (p. 3). This fast, accurate, and seemingly effortless form of visual analysis is referred to as “holistic” perception and arguably distinguishes face recognition from other forms of object recognition. Most face researchers agree that faces are perceived holistically; however, behavioural methods meant to operationalize holistic representation and holistic processing[1] have proved to be empirically challenging.

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[1]We refer to a holistic face representation as the unitary whole-face memory, and holistic processing as the cognitive operation that mediates whole-face recognition.

In our 1993 Quarterly Journal of Experimental Psychology (QJEP) article, Tanaka and Farah introduced a task intended to probe holistic representations of face recognition. In the part/whole task, the participant studies a whole-face stimulus. Next, the participant's memory for a face part from the studied face is tested in isolation and within the context of the whole face. If a face part is integrated in memory as a whole-face representation, then recognition of its part should be superior when tested in the whole face than when tested alone. Consistent with this prediction, recognition of the part was better in the whole-face condition than when tested in isolation. Over the years, the part/whole task has gained traction as a valid and reliable test of holistic face processes, and the original paper has received over 1,000 citations since it was published . In the current review paper, we take a retrospective look at the contribution of the part/whole paradigm to our understanding of holistic face processing. We describe the value of the part/whole task for investigating the holistic recognition of the individual eye, nose, mouth features and how spatial configuration influences part recognition. We examine evidence for holistic and non-holistic approaches for developing models of face and object recognition. We examine the neural substrates of holistic processing and how these processes are compromised by brain damage. We also explore experiential factors in holistic face processing by investigating its developmental trajectory in children and the influence of other-race faces in adults. Our discussion begins by comparing the part/whole task to the other two gold standards of holistic face processing: the face inversion task and face composite task.

The face inversion and face composite tasks of holistic processing

Over the last several decades, the face inversion task has been shown to be one of the tried-and-true measures of holistic face processing. In the original face inversion task, faces and non-face objects were studied in an upright orientation and were then tested in both upright and inverted orientations (Yin, 1969). Yin's finding was that recognition of faces is disproportionately impaired by inversion relative to the recognition of other inverted, non-face objects. Although inversion disrupts the recognition of all objects, inversion produces a greater impairment in face recognition. From a psychophysical perspective, the face inversion effect is a striking phenomenon because upright and inverted faces are equivalent in their low-level visual properties (e.g., luminance, spatial frequency; Willenbockel et al., 2010), yet, turning a face upside down differentially affects its recognition relative to the recognition of other objects. Yin (1969) hypothesized that two factors account for the face inversion effect: a "general factor" of familiarity with mono-oriented objects and a "special factor" involving only faces. He speculated that in everyday face recognition, people form a detailed impression of a face that is recognizable in its upright orientation, but access to this information is blocked when the face is turned upside down. Like Galton, Yin suggested that upright faces trigger an impressionistic, holistic gestalt of a face, formed by the integration of the individual face parts into a unified whole. The face inversion effect has been replicated over the years and is one of the most robust findings in face recognition literature (see reviews by McKone & Yovel, 2009; Rossion, 2008).

A limitation of the face inversion task is that the disruption of holistic processes is inferred by inversion, but holistic processes are not directly manipulated in the paradigm. This problem is remedied in the composite face task developed by Young, Hellawell, and Hay (1987). In the original version, a composite face is created by combining the top and bottom halves of two celebrities' faces. In the example shown in Figure 1, the top half of Brad Pitt is fused with the bottom half of Tom Cruise (Figure 1a) to form a new composite face (Figure 1b, left). In the standard face composite task, the participant is asked to identify the celebrity in cued top (or bottom half) of the composite face. When the top and bottom face halves were aligned, participants showed difficulty attending to the cued half of the test face, as reflected in lower accuracy and slower response times. The poorer performance is attributed to holistic interference

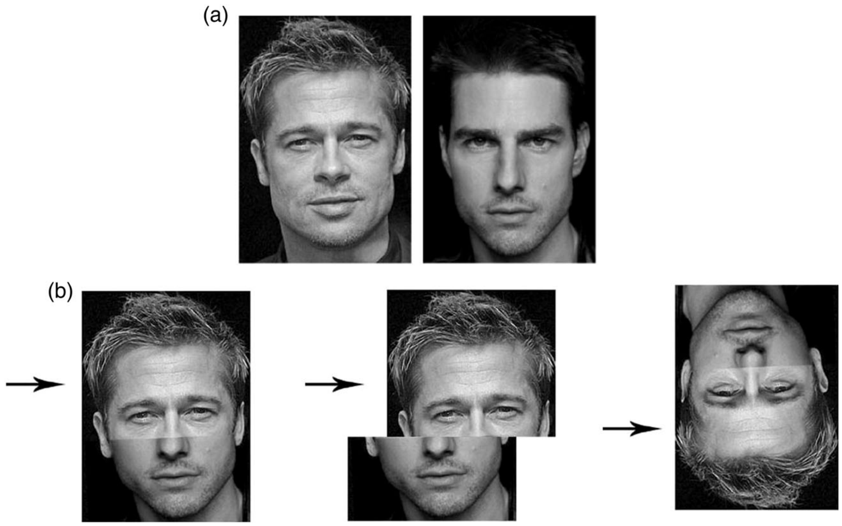

Figure 1. *Composite face task. (a) Original images of Brad Pitt and Tom Cruise. (b) In this example, a composite face is created by the joining the top half of Brad Pitt's face with the bottom half of Tom Cruise's face. Participants are asked to identify the face shown in the half of the composite face that is cued by the arrow while ignoring information in the uncued half. The test face is an intact composite face (left), misaligned composite face (middle face), or inverted composite (right face; figure from J. Tanaka & Gordon, 2011).*

caused by face information in the to-be-ignored half. However, when the top and bottom halves are misaligned (Figure 1b, middle) or if the composite face is inverted (Figure 1b, right), the interference effects are greatly reduced or abolished (Young et al., 1987). These results suggest that in a holistic face representation, it is difficult to selectively attend to information in a given region of a face without being influenced by information in other regions. Like the face inversion effect, the face composite effect has been demonstrated many times with both familiar (e.g., Young et al., 1987) and unfamiliar faces (e.g., Le Grand, Mondloch, Maurer, & Brent, 2004; Michel, Rossion, Han, Chung, & Caldara, 2006) and has been shown to be a robust indicator of holistic face processing.

There is an ongoing debate in the literature regarding the most appropriate methodological procedure for testing the face composite task (Richler & Gauthier, 2013; Rossion, 2013). Many researchers use the standard design in which holistic inference is calculated based on trials in which the faces are the "same" in the cued location and "different" in the uncued location (Le Grand et al., 2004; Michel et al., 2006), while others argue that in order to account for response biases, a complete design should be employed where the "same" and "different" faces appear equally often in the cued and uncued locations (Richler & Gauthier, 2013). Despite methodological differences, both versions of the face composite task demonstrate how difficult it is to restrict our attention to just one region of the face in deference to our perception of the whole face.

The part/whole face paradigm

Whereas the face composite task emphasizes holistic attention, the part/whole task emphasizes the effects of holistic processing in our immediate and long-term memories for faces. In the standard part/whole face paradigm, the participant learns a series of name–face associations (e.g., Joe, Bob, Fred). Afterwards, memory for the face parts from the study faces is tested in a two-alternative, forced-choice recognition task. The face part (e.g., Joe's nose) is tested either in isolation or in the context of the whole face (see Figure 2). The

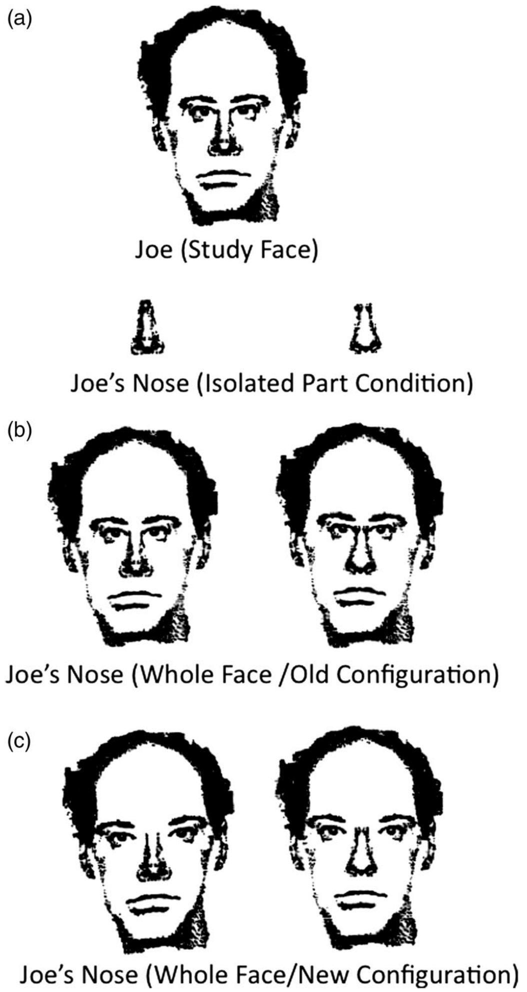

Figure 2. *Example of holistic recognition paradigm; Joe's nose feature is tested (a) in isolation, (b) in the whole face with studied configuration, and (c) in the whole face with a new configuration (figure from J. W. Tanaka & Sengco, 1997).*

important manipulation lies in the whole-face test condition, as the target and foil faces are identical with the exception of the critical part under examination. For example, as shown in Figure 2 (third row), recognition for Joe's nose is tested in a whole face. The non-target features of eyes and mouth are kept constant in the target and foil faces. If memory for the individual features of a face is integrated into the holistic face representation, recognition of the face part should be better when presented in the whole-face context than when tested in isolation. The difference in part and whole recognition is an index of holistic processing. The larger the difference in the whole face, old configuration condition, relative to the isolated part condition, the greater the holistic processing. Alternatively, if a face is remembered in terms of constituent parts (e.g., we remember Joe by his distinctive nose), recognition of the part should be no better when presented in the context of the whole face. Consistent with the holistic prediction, a reliable advantage is found when the face part is tested in the whole, old configuration face than when tested in isolation (J. W. Tanaka & Farah, 1993, Experiment 1) and whole, new configuration face (J. W. Tanaka & Sengco, 1997). The results indicate that our memory for a single part of a face is embedded in our memory for the entire face.

Interestingly, not all parts of a face are created equal in terms of holistic processing. Eyes and mouth features show the largest benefit from the whole-face context, whereas recognition of the nose is essentially the same whether tested in isolation or tested in the whole face.

It is possible that the whole-face advantage (i.e., superior recognition of face part when tested in the whole face relative to when tested in isolation) is not due to holistic processing per se, but was an artefact of an "encoding specificity" effect (Tulving & Thomson, 1973). Because the face part was studied and tested in the same whole-face context, the whole face is a better retrieval cue than the condition in which the part is encoded in a whole face, but tested as an isolated part (Gauthier, Klaiman, & Schultz, 2009; Mckone, 2004). But, encoding specificity is not the whole story behind the whole-face advantage. In follow-up studies, participants learned to identify scrambled or inverted versions of faces. Both scrambled and inverted manipulations directly disrupted holistic face processing. In the scrambled and inverted study conditions, recognition was no better in the whole face (scrambled or inverted) test condition than in the part test condition (J. W. Tanaka & Farah, 1993, Experiments 1 and 2). Nor was evidence of holistic processing found when house stimuli were studied and tested in the part/whole paradigm (J. W. Tanaka & Farah, 1993). Contrary to an encoding specificity account, recognition of an individual part only benefited from a previously studied context if the context was an upright face. If the part was tested in an inverted or scrambled face, or in a non-face object, there was no difference between the isolated part and whole-test conditions. These results demonstrate two points: First, the previously reported holistic advantage for upright faces was not an artefact of an encoding specificity effect, and, second, there is little evidence to suggest that inverted faces, scrambled faces, or houses are encoded holistically. In subsequent studies, the part/whole paradigm has been extended to investigate other types of holistic perception, such as bodies (Reed, Stone, Bozova, & Tanaka, 2003) and tactile patterns (Behrmann & Ewell, 2003).

Although the presence of the whole face can facilitate the recognition of its parts, the converse situation is also possible where whole-face information can negatively affect the perception and memory of individual face parts (Leder & Carbon, 2005). In a twist on the part/whole task, participants learned to isolated face parts by name (e.g., Joe's nose) and were then tested for recognition of those parts in a whole face or in isolation. Part recognition was reliably worse when tested in the context of a whole face than when tested in isolation, demonstrating the presence of whole-face interference. That is, recognition of a face part was made more difficult because its identity was integrated into the context of the whole face. Informing participants in advance about the target feature had little effect on the magnitude of the interference, suggesting that holistic processing of the whole face was difficult to disregard, even when this strategy was not optimal for the task at hand.

Together, the foregoing studies demonstrate two sides of the holistic coin. On one side, holistic processing is facilitative when the encoding context of other face parts supports recognition of a specific face part. On the flip side, holistic processing can produce negative consequences for part recognition. Interference occurs when participants study a face part in isolation and are then tested for recognition of the part in a whole face, or when participants study a whole face and are tested for parts in a different whole face.

Holistic and analytic representation: A continuum, not a dichotomy

Whereas researchers have emphasized the holistic recognition of faces and the analytic recognition of objects, a more accurate characterization is that faces and objects contain a mixture of whole and part representations. It has been proposed that faces, objects, and words lie on a holistic–analytic continuum (Farah, 1992). On one end of the holistic–analytic continuum are faces whose individual parts (e.g., eyes, nose, and mouth) are integrated into a unitary face memory. Consequently, face recognition requires little decomposition of a face into its individual parts. On the other end of the holistic–analytic continuum are word forms whose identification requires that the words be decomposed into individual, constituent letter units. Objects (e.g., cars, birds, chairs) lie between faces and words along the holistic–analytic continuum and are composed of both whole and part information. Like faces, objects are susceptible to inversion effects (Yin, 1969), and individual letter parts are better recognized when shown in the whole word than when shown in isolation (Reicher, 1969) and in a normal face than in a face with scrambled face parts (Davidoff & Donnelly, 1990). Other studies have shown that in a part/whole task, novice participants demonstrate holistic effects for recognition house parts (e.g., doors windows; de Gelder & Rouw, 2000b), car parts (e.g., grills, headlights), and parts from biological cells (i.e., nuclei, mitochondria; J. W. Tanaka & Gauthier, 1997). Although the magnitude of part–whole difference for these objects was less than the holistic effect for faces, their recognition nevertheless benefited from the whole object context indicating that part information was integrated into the whole object representation.

Faces are not exclusively holistic, but contain a mixture of whole and part representations. For example, when observers are presented with a series of faces, they can erroneously recombine the features from one face with features of another face to form a novel face, suggesting that parts have a representational status that is separate from the whole (Cabeza & Kato, 2000). Similarly, the size of the face inversion effect is greater when faces differ in their configural information than when they differ in their features, indicating that face parts, like object parts, are less vulnerable to inversion (Macho & Leder, 1998; but see J. W. Tanaka, Kaiser, Hagen, & Pierce, 2014). Finally, in the part/whole task, participants performed above chance when recognizing isolated face parts, indicating that the facial features are stored as separate parts in memory (see Figure 2). Thus, empirical evidence indicates that face recognition is not exclusively holistic, nor is object recognition exclusively analytic. Instead, faces and objects contain a proportion of whole and part representations; relative to faces, objects contain a greater proportion of parts, and relative to objects, faces contain a greater proportion of wholes.

The neuroscience of part and whole face processing

Results from neurophysiological studies, with monkey and human participants, provide converging evidence for the representation of part and whole-face information. Neuroimaging and electrophysiological experiments with humans suggest the importance of the whole-face representation. Human neuroimaging studies show that normal, intact faces elicit a greater response in the middle fusiform gyrus (MFG), and the inferior occipital gyrus (IOG), than scrambled faces (Kanwisher, McDermott, & Chun, 1997) and inverted faces (Yovel & Kanwisher, 2004). Similarly, when applying the face composite task, a greater response is found in the MFG and IOG for holistically perceived aligned faces than for misaligned faces (Harris & Aguirre, 2008; Schiltz & Rossion, 2006). Studies measuring event-related scalp potentials (ERPs) show that upright faces produce a stronger brain response 180 ms after stimulus presentation than do inverted or scrambled faces (Rossion et al., 2000).

Evidence also supports the status of parts in face processing. In macaque monkeys, the neural activity to combinations of face parts in the inferotemporal cortex (IT) can be predicted by summing neural activations of the individual parts. The IT neurons respond additively to faces. The response to a whole face is equal to the sum of the responses to the individual parts (Freiwald, Tsao, & Livingstone, 2009; Perrett, Rolls, & Caan, 1982). Intracranial recordings in humans indicate a selective tuning to face parts at recording sites located laterally and medially to the whole-face areas in IT (Mccarthy, Puce, Belger, & Allison, 1999). To test the holistic hypothesis, Harris and Aguirre (2008) presented participants with a face divided by a series of bars. The face-selective regions MFG and IOG were equally activated regardless of whether the face was holistically perceived in depth behind the bars or perceived as segmented strips of face parts. The authors speculated that the independent representations of face parts and wholes in face-selective MFG and IOG regions might reflect latency differences between part- and whole-face brain processes below the temporal threshold of functional magnetic resonance imaging (fMRI).

The notion of face parts and wholes is compatible with hierarchical models of vision, where activation of simple features feeds into the activation of complex features (Riesenhuber, Jarudi, Gilad, & Sinha, 2004; K. Tanaka, 1996; K. Tanaka, Saito, Fukada, & Moriya, 1991). According to a feed-forward approach, access to the local part information precedes access to the whole-face information. Reverse hierarchy models, however, allow for the opposite, where the global representation is accessed prior to activation of local parts (Ahissar & Hochetein, 1998; Hochstein & Ahissar, 2002), in which case whole-face access would take precedence over access to its parts. Indeed, as evidenced in patients with brain damage, the whole-face representation can be activated in the absence of activation of face parts (Rossion, Dricot, Goebel, & Busigny, 2011).

Prosopagnosia and holistic processing

Acquired prosopagnosia is a selective impairment in the ability to recognize individual faces due to brain damage of the visual cortex. The face recognition deficit often occurs in the presence of intact low-level visual processes and the ability to recognize non-face objects, indicating that the deficit is a result of damage to high-level visual representations. According to the holistic account, the source of the patient's face deficit is an impaired ability to integrate the features of a face into a coherent holistic representation (Busigny, Joubert, Felician, Ceccaldi, & Rossion, 2010). In a whole-to-whole or part-to-part matching task, patient H.J.A. showed better performance matching for face parts than for whole faces, whereas age- and IQ-matched control participants showed better performance for whole faces than for parts (Boutsen & Humphreys, 2002). Similarly, in another parts–wholes matching task, prosopagnosic patient G.G. and control participants were asked to study a whole face and select a part from the studied part presented in isolation or they studied a face part and were asked to identify the same part in a whole face. It was hypothesized that holistic interference should be observed in the part-to-whole and whole-to-part conditions relative to the part-to-part and whole-to-whole conditions. Whereas control participants demonstrated holistic interference effects in the whole-to-part and part-to-whole conditions, prosopagnosic patient G.G. performed equally well in both conditions, suggesting that her recognition of a face part is unaltered by other surrounding features of a face whether encoding the part in or retrieving it from memory (Busigny et al., 2010, Experiment 23). These studies provide convincing evidence that the prosopagnosic patient's inability to recognize faces is due to an impaired ability to form a holistic representation of a face.

Holistic processing has been examined in patients with developmental prosopagnosia. Like acquired prosopagnosia, developmental prosopagnosia is a profound and selective deficit in face recognition ability. Developmental prosopagnosia differs from the acquired prosopagnosia in that the deficit is not linked to either structural or functional organic brain damage. In a large-scale study, DeGutis, Cohan, and Mercado (2012) tested a group of developmental prosopagnosic (DP) individuals ($N = 38$) using the part/whole task. The researchers found that prosopagnosic participants showed an intact holistic advantage for the mouth, but a complete absence of a holistic advantage for the eyes. Whereas these individuals with developmental prosopagnosia evidence a preserved ability to apply holistic strategies for the mouth, they present a selective impairment in holistic recognition of the eyes. Given that the eyes are critical to identity recognition (Schyns, Bonnar, & Gosselin, 2002), failure to integrate the eyes into the whole face may explain the sources of face deficit in developmental prosopagnosia.

Other studies have shown that Caucasian DP individuals fail to show a whole-face advantage for own-race Caucasian faces, relative to other-race Korean faces, indicating that race-specific experience has little effect on holistic face processing abilities (DeGutis, DeNicola, Zink, McGlinchey, & Milberg, 2011). De Gelder and Rouw (2000a) found that individuals with DP failed to use the holistic context to detect part changes in whole faces, yet benefited from the whole object context for detecting part changes in houses. Thus, patients with acquired and developmental prosopagnosia exhibit impairment in their ability to perceive whole faces, and the holistic deficit seems to be particular acute in the eye region of the face.

Holistic face processing deficits in autism?

Autism spectrum disorder (ASD) is defined as a developmental disorder that is characterized by delayed language, repetitive and ritualistic behaviours, and deficit in social–emotional communication. Although not a diagnostic characteristic, many persons with autism show deficits in their perception and recognition of face identity (Behrmann, Thomas, & Humphreys, 2006; Wallace, Coleman, & Bailey, 2008), in recognition of familiar faces (Boucher & Lewis, 1992), and in immediate recognition of novel faces (Blair, Frith, Smith, Abell, & Cipolotti, 2002; Klin et al., 1999).

As a possible explanation of this face deficit, it has been hypothesized that individuals with ASD are "local" processors who show a bias for perceptual details of a stimulus at the expense of their global organization (Behrmann et al., 2006; Iarocci, Burack, Shore, Mottron, & Enns, 2006; Jemel, Mottron, & Dawson, 2006). It is plausible that a local strategy would put individuals with ASD at a distinct disadvantage for face processing tasks, where recognition is dependent on encoding whole-face information (Weigelt, Koldewyn, & Kanwisher, 2012).

Researchers have employed the part/whole task to measure holistic processing in people with ASD (Faja, Webb, Merkle, Aylward, & Dawson, 2009; Wolf et al., 2008). Joseph and Tanaka (2003) found that typically developing children show holistic effects for eyes and mouths, whereas children with ASD exhibit a holistic effect only for mouths. In contrast, Faja et al. (2009) reported an overall holistic effect for adults with ASD equal to that of non-ASD adults, and adults with ASD showed a stronger holistic effect for the eye features. The authors speculated that the eye bias might reflect a compensatory face strategy of focusing on the eyes, compared to the children tested in the other studies (Joseph & Tanaka, 2003; Wolf et al., 2009). In another training study, J. W. Tanaka et al. (2010) found that children with ASD improved in their holistic recognition of eyes after two months of a computerized face exercise. Finally, Lopez, Donnelly, Hadwin, and Leekam (2004) showed that participants with ASD, like TD individuals, were flexible in their encoding strategies and could be cued to either the part or whole-face level of analysis. While it is clear that individuals with ASD do not suffer an overall deficit in holistic face processing, there are data to support a more selective deficit in their capacity to process holistic information in the eye region (J. W. Tanaka & Sung, 2013).

The spaces in between: Configural information in a holistic face representation

A distinction can be drawn between the featural and configural properties of a face. Featural properties refer to the discrete parts of the face (e.g., eyes, nose, mouth), whereas configural properties refer to the distances that separate the features[2] (e.g., inter-ocular distance, distance between nose and mouth; Mondloch, Le Grand, & Maurer, 2002; see Bruyer, 2011, for a comprehensive review of configural face processing studies). An important question is whether featural and configural information make distinct contributions to the face recognition process. In support of the featural–configural distinction, it has been shown that children acquire sensitivity to the features of a face earlier in development than sensitivity to the configuration (Mondloch et al., 2002), configural information is more vulnerable to inversion (Freire, Lee, & Symons, 2000), and configural information is more susceptible to the effects of visual deprivation than featural information (Le Grand, Mondloch, Maurer, & Brent, 2001). However, more recent papers indicate that the featural–configural distinction is not as straightforward as previously believed. For example, even at very young age, children are able to discriminate the spacing between the eyes as accurately as their ability to discriminate eye features (Quinn, Lee, Pascalis, & Tanaka, in press), and inversion has relatively little effect on the perception of the eye spacing and eye features (J. W. Tanaka et al., 2014). This work suggests that configural information in the eye region of the face is highly conserved during development and when a face is turned upside down. Moreover, in their critical review paper, Burton, Schweinberger, Jenkins, and Kaufmann (2015) argued that the contribution of configural information to face recognition processes is overestimated in the literature, where large changes in configural information have little effect on face recognition.

The part/whole task provides a good test of the claim that featural and configural information are processed independently in face perception and recognition. Note that in a holistic representation, the distinction between featural and configural

[2]In addition to its parts and spatial configuration, other properties of a face include surface information about skin texture and pigmentation, and local information such as eye colour. Work by Leder and Bruce (1998) has examined local properties and has found that they are less vulnerable to inversion effects.

information disappears; that is, information about the features of a face and their spatial distances is integrated as a unitary whole-face representation. Therefore, a prediction of the holistic hypothesis is that modifying one type of information (e.g., changing the spatial distance between the eyes) should alter recognition of other information (e.g., perception of the eye and mouth features). Using the part/whole task, J. W. Tanaka and Sengco (1997) asked participants to study a version of a face in which the eyes were either spaced close together or far apart. At test, part recognition was tested in three conditions: (a) in isolation, (b) in the studied whole-face configuration, and (c) in a new whole-face configuration. For example, if participants studied a version of Joe with his eyes close together, they would be tested for parts of Joe's face shown in isolation, in the studied whole-face configuration with Joe's eyes close together, and in a new configuration of Joe's face with his eyes far apart (see Figure 2c). Part recognition was best when tested in the old configuration, suggesting that participants were sensitive to configural distances that separate the features of a face. However, part recognition was better in the new configuration than in isolation. Thus, preserving the global configuration of a face facilitates the recognition of its constituent parts. Critically, changing the spatial distance between the eyes impaired recognition of the nose and mouth features—features whose spatial locations were not directly changed. These findings provide persuasive evidence that featural and configural properties are integrated in a holistic representation. Local configural changes of one feature (e.g., interocular distance) alter the recognition of all features whose configuration was not directly perturbed. Thus, contrary to Burton et al.'s (2015) assertions, configural information is encoded in face memory in a part/whole task, and modification of spatial relationships disrupts face recognition processes.

Does long-term face recognition rely on holistic processes?

The average person will encounter thousands, if not hundreds of thousands, of faces over the course of their lifetime. Although it is not known exactly how many faces are encoded and stored in long-term memory, the durability of our face memories is remarkable. People that we have not seen from our past are still recognized 50 years later (Bahrick, Bahrick, & Wittlinger, 1975). Young et al.'s (1987) findings with celebrity faces and the face composite task (see Figure 1) indicates that memories of familiar faces are represented holistically. However, it remains an open question how holistic processes are involved in the encoding and retrieval of our long-term memory for faces. If holistic processing is important for face recognition, those who excel in holistic face processing should perform well on face recognition tasks, and those who are poor at recognizing faces should exhibit less holistic face processing abilities.

Using the face composite task, Richler, Cheung, and Gauthier (2011) found a reliable correlation between performance on the face composite task and face recognition scores as measured by the Cambridge Face Memory Task (but see Konar, Bennett, & Sekuler, 2010). As further support for the holistic view, Wang, Li, Fang, Tian, and Liu (2012) found that the face composite task and the part/whole task correlated with face recognition performance. Curiously, in their study, the correlation between performance on the composite task performance and performance part/whole was relatively weak, suggesting that the two tasks tap into difference aspects of holistic processing. However, in a subsequent study, DeGutis, Wilmer, Mercado, and Cohan (2013) found a strong association between face composite and part/whole performance after regressing out object recognition performance.

Although evidence for holistic face processing has been well established in perceptual and immediate memory paradigms, less is known about the time course of holistic representations over longer time intervals. In order to measure the robustness of holistic face memories in long-term memory, Heptonstall, Tanaka, and Hoven (2013) trained participants to identify 12 novel faces (six male, six female) by name (e.g., Joe) to a criterion of 100% accuracy. Half of the participants were trained to recognize upright faces, and the other half were trained to recognize inverted faces. Next, their memory for the eyes, nose, and mouth features was tested in isolation, and within the whole face. Participants who learned the upright faces demonstrated a significant whole-face advantage that was maintained two weeks after training. In contrast, participants who learned inverted faces performed poorly and showed no evidence of holistic processing. These results provide strong evidence that familiarized faces are encoded and retained in long-term memory as whole faces, and they suggest that the durability of face memories is a consequence of holistic processing.

Does early experience influence holistic face processes?

Previously, it has been speculated that very young children adopt a piecemeal approach to face recognition, where they see individual parts of a face but not the entire gestalt. As they mature, children switch to a holistic approach where face parts and their configuration are combined in a unified representation (Carey & Diamond, 1977). The part/whole paradigm provides the ideal test for the encoding switch hypothesis. Results from developmental studies indicate that children as young as 6-year-olds show strong effects of holistic processing, where memory for parts in upright faces is better when tested in the whole-face context than when tested in isolation (Pellicano & Rhodes, 2003; J. W. Tanaka, Kay, Grinnell, Stansfield, & Szechter, 1998). Although overall performance improves with age, the magnitude of the holistic effect (i.e., difference in the part/whole performance) remains stable over time. When faces are inverted, the recognition performance of young children and older children declines, indicating that inversion disrupts holistic processing in both groups (Pellicano & Rhodes, 2003; J. W. Tanaka et al., 1998). In summary, the converging developmental evidence indicates that by early childhood, holistic face processes are well established.

Holistic processes and the other-race effect

Race is treated as a proxy for racial experience; that is, all things begin equal, we typically have more experience and familiarity with individuals from our own race than with people from a different race. In face recognition, differential racial experience leads to advantages and biases as demonstrated by the other-race effect (ORE) where people are better recognizing faces from their own race than faces from other races (Meissner & Brigham, 2001). However, perceptual exposure to other-race faces does not necessarily lead to a reduction in the ORE. Caucasian adults who reported having extensive contact with African (Chiroro & Valentine, 1995) or Asian (Ng & Lindsay, 1994) individuals nevertheless showed a robust ORE. Similarly, Korean children adopted between 2 and 26 months of age by Caucasian families and raised in a Caucasian environment do not show a reverse ORE for Asian faces (De Heering, De Liedekerke, Deboni, & Rossion, 2010). In addition to perceptual experience, motivation to individuate people from the other race seems to be an important factor for ameliorating the ORE (Levin, 2000), although the source of the ORE is still an open question.

According to the holistic account, increased perceptual experience and motivation to individuate faces from a particular race promote holistic processing. Specifically, people are more inclined to employ holistic strategies when recognizing own-race faces than other-race faces. To test the holistic account of the ORE, Caucasian and Asian participants were asked to recognize features of Caucasian and Asian faces presented in isolation, and in the whole face (J. W. Tanaka, Kiefer, & Bukach, 2004). The main finding was that Caucasian participants recognized own-race faces more holistically than Asian faces, whereas Asian participants demonstrated holistic recognition for both own-race and other-race faces. The differences in holistic recognition between Caucasian and Asian participants mirrored differences in their relative experience with own-race and other-race faces.

Using the face composite task, Michel et al. (2006) provided converging evidence for the holistic account of the ORE. In their study, Caucasian and Asian participants were asked to recognize the upper half of an own-race or other-race composite face. Recognition was more disrupted when the composite stimulus was a same-race face than an other-race face, suggesting that same-race faces are processed more holistically than other-race faces. The developmental and other-race research indicates the generality and specificity of holistic processing with respect to face experience. In children, the accumulated experience with faces over the course of young and older childhood seems not to modulate the magnitude of the holistic face processing (i.e., young children evidence the same degree of holistic processing as older children). In contrast, extensive exposure to faces of a familiar race in adulthood accentuates relative to faces from a less familiar race.

SUMMARY AND CONCLUSIONS

Although it is well accepted that faces are perceived and recognized as a whole stimulus, the concept of holistic processing has been challenging to operationalize in the laboratory. In the part/whole paradigm, memory for a face part is tested when shown in isolation or in the whole face. The part-face and whole-face test items are informationally equivalent, such that the test items differ only with respect to the critical target feature. Despite their equivalence, recognition of a face part is superior when tested in a whole face than when tested in isolation. These results provide compelling evidence that memory for an individual face part is integrated in a holistic face memory. Critically, the holistic advantage appears to be restricted to normal face recognition because the benefits of the whole stimulus disappear for inverted faces, scrambled faces, and non-face objects.

As demonstrated by the part/whole task, faces are not exclusively recognized holistically nor are objects exclusively recognized non-holistically. Instead, faces and objects contain a mixture of whole and part representations; relative to objects, faces contain a greater proportion of wholes, and relative to faces, objects contain a greater proportion of parts. The parts/whole task has elucidated the contribution of specific facial features (e.g., eyes, nose, mouth) to and the effects of configural spacing on holistic face recognition. The task has also been valuable for identifying the neural substrates of holistic face processing and what happens to holistic processing when the face system is compromised due to prosopagnosia or autism. Finally, the part/whole measure has shed light on the role that holistic processes play in mediating the recognition of own- and other-race faces. In summary, the part/whole task has supplied the necessary scientific precision and experimental rigour to validate Galton's (1883) initial observation that when it comes to face recognition the "whole is *truly* (our italics) greater than the sum of its parts".

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