EVALUATION OF HOLISTIC FACE PROCESSING

EVALUATION OF HOLISTIC FACE PROCESSING

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Abstract

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Holistic processing has been deemed a crucial part of human face processing. There are three tasks that are indexes of holistic processing and each is used by many researchers for the purposes of demonstrating that either their participants have intact holistic processing or that holistic processing is impaired or missing. The tasks that demonstrate holistic processing are the face inversion, composite face, and the whole-part tasks. In this dissertation, I evaluate the hypothesis that holistic processing is important for face identification. A secondary hypothesis that is evaluated is whether the three indexes of holistic processing are related and whether they are tapping the same underlying process. Chapter 2 tests the first hypothesis in a large group of young adults and shows that the composite face effect (an index of holistic processing) is not related to accuracy on two identification tasks. Chapter 3 tested both hypotheses and showed that none of the holistic indexes are related to one another and they are unrelated to face identification accuracy. In Chapter 4, a large group of older adults are tested on the composite face task and a face identification task, similar to Experiment 2 from Chapter 2. Unlike the results for young adults, older adults show a significant positive correlation between the composite face effect and identification accuracy even though older adults perform worse on the identification task.

Preface

The research described in Chapters 2-4 of this thesis was done in collaboration with my supervisors, Patrick Bennett and Allison Sekuler. In each project, I was responsible for designing and implementing the experiments, performing data analyses, and writing and editing the manuscripts.

The research described in Chapter 2 was published in *Psychological Science* under the title "Holistic processing is not correlated with face identification accuracy" (Konar, Bennett, & Sekuler, 2010, volume 21(1), page 38-43) and has been reprinted with permission from Sage Publishers.

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Chapter 1

General Introduction

All faces share the same basic structure: two eyes, vertically aligned and located on opposite sides of the midline, are positioned above a nose, which is located above a mouth. Nevertheless, human faces appear to be quite discriminable. Human faces differ from one another based on the shape and arrangement of many nameable features, such as eyes, nose, mouth, ears, face contours, hairstyle, and other unique markings. Despite their complexity, most human observers easily discriminate faces that differ in gender, age, and emotionality, and which are presented at different viewpoints, distances, and lighting conditions. The processes giving rise to this so-called face expertise are a topic of heated debate among face processing researchers. Currently researchers are trying to figure out whether human face expertise stems from the utilization of holistic/configural processing, piece-meal/featural processing, or a combination of both types of processing. Although there is support for both types of processing of faces, a lot of research and often-unqualified support has been geared toward the hypothesis that face recognition expertise is due to holistic processing.

1.1 Face inversion and holistic processing

The idea that our expertise in face recognition is a result of holistic processing was ignited by Yin (1969), who proposed that upright faces are unique objects that require special processing. Yin showed that the perception of faces was more affected by stimulus inversion than was the perception of other objects such as planes, houses, and bodies in motion. Participants were first presented with series of images of the four object types and were then tested in a two-alternative forced-choice task, where they had to identify the "old" or previously-viewed item. In general, participants made significantly more errors with inverted stimuli than with upright stimuli, but this effect of stimulus orientation was greater for faces than for other objects. Yin speculated that there are two factors that cause performance to be worse with inverted faces: a general factor, which affects performance with all objects, and a face-specific process. Yin reported that participants relied on a holistic strategy when processing upright faces, but failed to use this strategy for inverted faces and for other objects, which instead were processed using a piece-meal strategy. This lead to the notion that qualitatively different processes are used to perceive upright and inverted faces. Following Yin's study, measuring the effects of face inversion became a standard way of evaluating holistic processing, and many researchers posited that faces are a special set of objects that are processed by face-specific mechanisms (reviewed in Valentine, 1988).

The idea that face inversion is an index of holistic processing has been criticized. For example, Valentine (1988) conducted a comprehensive review of the literature on face inversion and failed to find strong evidence to support the notion that upright and inverted faces are processed qualitatively differently. More recently, Gaspar et al. (2008) and Sekuler et al. (2004) demonstrated that face inversion may be due to a lack of expertise with processing inverted faces and that this effect has nothing to do with holistic processing. Using the response classification technique, Sekuler et al. (2004) showed that participants rely on the eye and eyebrow regions to discriminate faces when upright and inverted, indicating that inversion in their task did not lead to a qualitative change in strategy. Gaspar et al. (2008) found that upright and inverted faces, which were embedded in low- or high-pass filtered noise, produced the same noise-masking functions indicating that there is no qualitative difference between the two orientations. These researchers found that despite observing the typical face inversion effect, observers relied on the same narrow band of spatial frequencies to identify upright and inverted faces.

Rossion (2008) reviewed and criticized the methods and interpretations of some of the above studies and claimed that there is sufficient evidence to demonstrate that upright faces are processed qualitatively differently from inverted faces. A parsimonious observer applying Okam's razor to the argument would be content to conclude that given plenty of evidence for a strong conclusion and plenty of evidence for an alternative, albeit simpler one, probably means that the simpler of the two conclusions is correct. Regardless of evidence countering the claim that inversion is an example of holistic processing, many researchers still use face inversion to demonstrate what they think is holistic processing.

1.2 Composite face effect

Young et al. (1987) discovered that two familiar faces, when combined in a particular way, created the perception of a new, unfamiliar face. Using faces of popular British celebrities and politicians, Young et al. created a composite face by combining the top half of one face with the bottom half of another. Aligning the bottom and top halves of the composite face made an impression of a new unfamiliar face. Misaligning the top and bottom face halves by displacing them horizontally made it easier for participants to identify who the two halves belonged to. The researchers found that participants were faster to identify the top or bottom face halves when they were misaligned than when they were aligned, an effect termed the Composite Face Effect (CFE). The standard interpretation of this finding is that holistic processing interferes with identification more in the in the aligned condition – when the the top and bottom halves are organized into a single, coherent face – than in the misaligned condition. In a second experiment, Young et al. (1987) found that the magnitude of the CFE was reduced when the composite faces were inverted, a result that suggests that face inversion disrupts holistic processing. The authors concluded that the the fact that the composite face effect was obtained with upright, but not inverted faces was direct evidence of the importance of holistic information in face discrimination.

In another experiment, Young et al. (1987) wanted to determine whether the composite effect (and hence holistic processing) could be shown for unfamiliar faces. This was prompted by findings that processing of familiar and unfamiliar faces is different (for example, Bruce and Young, 1986; Ellis et al., 1979). Although their participants showed the effect, there may have been a confound in this experiment. Despite using unfamiliar faces, participants had to learn the faces in order to match names to them, thereby making these faces familiar.

Young et al. (1987) constructed composite faces from familiar faces. Hole (1994) used a same-different task to give better evidence for whether holistic processing, as indexed using the CFE, is triggered by unfamiliar faces. Participants were required to determine whether the top halves of two, simultaneously-presented composite faces were the same or different. Hole found that the CFE – i.e., the difference between proportion correct, or reaction times (RT) for correct responses, in the aligned and misaligned conditions – was obtained with unfamiliar faces, but that the effect depended on stimulus duration. Specifically, a significant CFE was obtained when stimulus duration was 80 ms but not when it was 2000 ms. Hole speculated that, depending on the task, subjects can adopt different processing strategies that place different weights on feature-based or holistic processing. At short stimulus durations, holistic processing seemed to have a greater influence on performance than feature-based processing. On the other hand, when stimulus duration was longer, there was little evidence for holistic face processing. Hole (1994) concluded that these artificial tasks have to be validated with real-life processing of faces to deduce whether humans use feature-based or holistic processing. Hole's results suggest that holistic processing may not be the prominent strategy in naturalistic contexts or that this strategy is used in combination with piece-meal processing (see Riesenhuber et al. (2004) and Miellet et al. (2011) for examples where participants use either piecemeal or configural processing, depending on the task requirements).

More recent experiments that have used a modified version of Hole's method to test the CFE with face stimuli that do not have external features (e.g., hairline, ears) have validated Hole's (1994) results. Unlike Hole, Le Grand et al. (2004) presented two unfamiliar composite faces in two intervals separated by a 300 ms inter-stimulus interval. Participants were required to make same-different discriminations of the top halves of faces. The CFE was calculated using response time and proportion correct differences between aligned and misaligned conditions. Significant CFEs using both response time and proportion correct differences were observed in the healthy group of participants but not in a group of participants who were deprived of early patterned vision due to bilateral congenital cataracts. These findings provided support for the hypothesis that humans are not born with fully developed holistic processing and that there may be a critical period during which holistic processing develops or at least during which neural mechanisms underlying holistic processing require maintenance to develop normally. Results from this study and several others (for example, Carey and Diamond, 1977; Germine et al., 2011; de Heering et al., 2007) indicate that we gain expertise for holistic face processing early on and if the visual pathway is disrupted in any way, this can lead to a loss of normal face processing.

1.3 Whole-part effect

The whole-part effect (WPE) is thought to be an alternative index of holistic processing. This effect, which is similar to the object superiority effect (Homa et al., 1976; Davidoff and Donnelly, 1990), was first described by Tanaka and Farah (1993). In the whole-part task, participants memorized six face-name associations. To ensure retention of the associations, the six learning trials were repeated five times during the learning phase. The learning phase was immediately followed by a two-alternatives recognition test phase. The test phase was divided into full-face trials and part-face trials. During full-face trials, two full faces were shown where the target face was a learned face and the other was a foil that differed from the target by either the eyes, the nose, or the mouth. Participants matched the target face to a learned name, which was presented below the faces. During part-face trials, a set of features was presented: either two pairs of eyes, a pair of noses, or a pair of mouths. Participants matched a target feature with the learned name. The foil feature was from one of the other learned faces, hence did not match the learned face. A difference score between full-face and part-face accuracies is defined as the Whole-Part Effect or WPE. Participants' performance was best in the full-face condition. Tanaka and Farah interpreted this result as evidence that full-face trials confer an advantage when discriminating parts of faces compared to the part-face condition, where holistic processing is not active. When the stimuli were inverted, accuracy in the full-face and part-face conditions did not differ. This effect of stimulus orientation is similar to the failure to find a CFE with inverted faces, and it was again interpreted as evidence of a holistic process that is activated only by upright faces.

Although Tanaka and Farah's results can be interpreted as showing that there is something unique about whole faces, which allows for better discrimination of features that are embedded in full faces, there is an alternative interpretation based on the principle of encoding specificity (Tulving and Thomson, 1973). Tulving and Thomson proposed that participants perform best in situations that they have encountered before. Encoding specificity could play a role in Tanaka and Farah's findings given that participants only learned full-face name associations during the study phase of the experiment. According to the encoding specificity hypothesis, performance in the test phase is better on full-face trials than part-face trials because the full-faces are most similar to the conditions experienced in the study phase. Leder and Carbon (2005) tested the encoding specificity interpretation by using a complete experimental design in which half of the participants learned full-face name associations in the study phase and the other half learned part-face name associations. As would be predicted from encoding specificity, in the test phase, participants who learned part-face name associations were better at discriminating parts of faces while participants who learned full-face name associations were better in the full-face condition. Although these results are consistent with the predictions of the encoding specificity interpretation of the WPE, Leder and Carbon (2005) interpreted their results as further evidence of holistic processing.

1.4 Analysis of holistic effects

Researchers have argued that healthy adults develop holistic face processing but many individuals from special populations fail to develop it normally. For example, a recent study suggests that congenital prosopagnosics lack holistic processing (Avidan et al., 2011). All studies that examine holistic face processing in participants from special populations use one or more of the tasks mentioned above (i.e., face inversion, composite face, and whole-part tasks). Researchers often draw conclusions about the special population by demonstrating that these participants do not show the typical effects in comparison to the healthy young adults. However, before these tasks can be used as diagnostic tools, they have to be validated and their reliability has to be tested. This has not been done for any of the tasks that were developed since the seminal study by Yin (1969). Recall that face inversion was originally thought to be an index of holistic processing (Yin, 1969) but was critically reviewed and analyzed by some research groups who found that face inversion may be unrelated to holistic processing (for example Gaspar et al., 2008; Sekuler et al., 2004; Valentine, 1988). Despite the existence of evidence that raises the possibility that face inversion is not related to holistic processing, many researchers still assume that the inversion effect is an index of holistic processing. One approach to determine whether these tasks are tapping holistic processing is to determine whether the effects are associated. If the correlations between any of the three tasks (face inversion, composite face, and whole-part effect) are significant, then this will indicate that these tasks are tapping the same underlying process. On the other hand, if the effects are uncorrelated, then this may mean that none of the effects are tapping holistic processing or that each effect is tapping an independent holistic process unrelated to the others. This is the approach adopted in Chapters 2 and 3.

1.5 Holistic processing and aging

One group of people that often gets overlooked in face research is the older population. Statistics Canada estimates that over the next 25 years the number of seniors (those 65 and older) will double from the current 4.8 million Canadians. A similar trend is expected in other countries that experienced a baby boom after World War 2. As a larger percentage of the world population will be above 65 years, it is crucial now to learn more about physiological, neural, and behavioural changes that accompany healthy aging. All of the conclusions from the previous studies apply to young adults between the ages of 18 and 30 yet we know little about how the effects listed above change with age. Several studies demonstrated that there are significant changes to face processing as a function of age (for example, Boutet and Faubert, 2006; Grady, 2002; Resnick et al., 1995; Searcy et al., 1999). Grady (2002) showed that there are neural changes that accompany decrements in face processing abilities of older adults. Given that holistic processing is such a contested topic, it is surprising that only one study looked at whether holistic processing is preserved with age (Boutet and Faubert, 2006), and in that study the researchers found partial evidence that holistic processing is preserved with age. In Chapter 4 we tested a large group of older adults on the composite face task and the face identification tasks that were described previously in Chapter 2. The data in this chapter will elaborate on the question of whether holistic processing is preserved with age. The data also allows us to answer the question of whether holistic processing is related to face identification, which has not been tested in older adults.

1.6 Summary

Many face researchers have started using various tasks that supposedly tap holistic processing to test healthy participants and participants from special populations. There are many examples that healthy controls demonstrate Face Inversion Effect, Composite Face Effect, and Whole-Part Effect (FIE, CFE, and WPE) while participants from special populations fail to show these effects. However, before we start using these tasks as diagnostic tools, we need to determine whether the various holistic processing indexes are related to face identification in healthy individuals.

In Chapters 2 through 4 we evaluate the assumption that holistic processing is related to face identification by correlating different indexes of holistic processing with accuracy on face identification tasks. CFE is not correlated with several versions of a face identification task in Chapter 2.

Most face perception researchers assume that face inversion is an index of holistic processing. Similar assumptions are made about the composite face effect and the whole-part effect. One way to test this assumption is to test the relations between the various indexes of holistic processing. This approach is used in Chapter 3.

The world's population is aging rapidly. It is important to determine whether findings that are true in healthy young adults remain unchanged with age. Hence, in Chapter 4 we will evaluate the hypothesis that holistic processing is preserved with age and that holistic processing is related to face identification in older adults.

Bibliography

Avidan, G., Tanzer, M., Behrmann, M., 2011. Impaired holistic processing in congenital prosopagnosia. Neuropsychologia 49 (9), 2541–52.

Boutet, I., Faubert, J., 2006. Recognition of faces and complex objects in younger and older adults. Memory & Cognition 34 (4), 854–864.

Bruce, V., Young, A., 1986. Understanding face recognition. British Journal of Psychology 77 (3), 305–327.

Carey, S., Diamond, R., 1977. From piecemeal to configurational representation of faces. Science 195 (4275), 312–4.

Davidoff, J., Donnelly, N., 1990. Object superiority: a comparison of complete and part probes. Acta Psychologica 73 (3), 225–43.

de Heering, A., Houthuys, S., Rossion, B., 2007. Holistic face processing is mature at 4 years of age: evidence from the composite face effect. Journal of Experimental Child Psychology 96 (1), 57–70.

Ellis, H. D., Shepherd, J. W., Davies, G. M., 1979. Identification of familiar and unfamiliar faces from internal and external features: some implications for theories of face recognition. Perception 8 (4), 431–9.

Gaspar, C., Sekuler, A. B., Bennett, P. J., 2008. Spatial frequency tuning of upright and inverted face identification. Vision Research 48 (28), 2817–26.

Germine, L. T., Duchaine, B., Nakayama, K., 2011. Where cognitive development and aging meet: face learning ability peaks after age 30. Cognition 118 (2), 201–10.

Grady, C. L., 2002. Age-related differences in face processing: a meta-analysis of three functional neuroimaging experiments. Canadian Journal of Experimental Psychology 56 (3), 208–220.

Hole, G. J., 1994. Configurational factors in the perception of unfamiliar faces. Perception 23 (1), 65–74.

Homa, D., Haver, B., Schwartz, T., 1976. Perceptibility of schematic face stimuli: Evidence for a perceptual gestalt. Memory & Cognition 4 (2), 176–85.

Le Grand, R., Mondloch, C. J., Maurer, D., Brent, H. P., 2004. Impairment in holistic face processing following early visual deprivation. Psychological Science 15 (11), 762–768.

Leder, H., Carbon, C.-C., 2005. When context hinders! Learn-test compatibility in face recognition. The Quarterly Journal of Experimental Psychology: Section A 58 (2), 235–250.

Miellet, S., Caldara, R., Schyns, P. G., 2011. Local jekyll and global hyde: The dual identity of face identification. Psychological Science IN PRESS.

Resnick, S. M., Trotman, K. M., Kawas, C., Zonderman, A. B., 1995. Age-associated changes in specific errors on the benton visual retention test. The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences 50 (3), P171–8.

Riesenhuber, M., Jarudi, I., Gilad, S., Sinha, P., 2004. Face processing in humans is compatible with a simple shape-based model of vision. Proceedings. Biological Sciences 271 Suppl 6, S448–50.

Rossion, B., 2008. Picture-plane inversion leads to qualitative changes of face perception. Acta Psychologica 128 (2), 274–89.

Searcy, J. H., Bartlett, J. C., Memon, A., 1999. Age differences in accuracy and choosing in eyewitness identification and face recognition. Memory & Cognition 27 (3), 538–552.

Sekuler, A. B., Gaspar, C. M., Gold, J. M., Bennett, P. J., 2004. Inversion leads to quantitative, not qualitative, changes in face processing. Current Biology 14 (5), 391–396.

Tanaka, J. W., Farah, M. J., 1993. Parts and wholes in face recognition. The Quarterly Journal of Experimental Psychology. A, Human Experimental Psychology 46 (2), 225–245.

Tulving, E., Thomson, D. M., 1973. Encoding specificity and retrieval processes in episodic memory. Psychological Review 80 (5), 352 – 373.

Valentine, T., 1988. Upside-down faces: a review of the effect of inversion upon face recognition. British Journal of Psychology 79 (Pt 4), 471–91.

Yin, R., 1969. Looking at upside-down faces. Experimental Psychology 81, 141–145.

Young, A. W., Hellawell, D., Hay, D. C., 1987. Configurational information in face perception. Perception 16 (6), 747–759.

Chapter 2

The relation between face identification and the Composite Face Effect in young adults

Abstract

The current study tested the widespread assumption that holistic processing is important for the identification of upright faces. In two experiments, we show that (a) there are large individual differences in the magnitude of the composite face effect and face-identification accuracy and (b) the correlation between the magnitude of the composite face effect and face-identification accuracy is essentially zero. These findings are inconsistent with the claim that holistic processing, as indexed by the composite face effect, significantly influences accuracy in a face-identification task.

Citation: Konar, Y., Bennett, P.J., & Sekuler, A.B. 2010. Holistic processing does not predict face identification. Psychological Science, 21(1), 38-43.

2.1 Introduction

Holistic processing is thought to play a greater role in the perception of upright faces than inverted faces or other objects (Bartlett and Searcy, 1993; Diamond and Carey, 1986; Farah et al., 1995; Le Grand et al., 2004; Mondloch et al., 2007; Rossion and Boremanse, 2008; Tanaka and Farah, 1993; Young et al., 1987)[1]. The composite face effect (CFE) is a common measure of holistic processing (de Heering et al., 2007; de Heering and Rossion, 2008; Hole, 1994; Hole et al., 1999; Le Grand et al., 2004; Michel et al., 2006; Rossion and Boremanse, 2008; Schiltz and Rossion, 2006; Young et al., 1987). In a typical CFE task, half of one face is combined with the complementary half of another face, and subjects make judgements about one half of the composite face while ignoring the other half. If holistic processes are engaged automatically when perceiving faces, then the irrelevant portion of the face should interfere more when perceived as part of a single object than when perceived as a separate object. Results from many experiments are consistent with this prediction: Subjects perform worse on trials when top and bottom halves are aligned (and form a single face) compared to when they are misaligned. Hence, the CFE, defined as the difference between performance with aligned and misaligned faces, is assumed to be an index of holistic processing. The fact that stronger CFEs are obtained with upright than inverted faces has been taken as evidence that holistic processing plays a greater role in the perception of upright faces than inverted faces (Hole, 1994; Young et al., 1987).

Although it is widely assumed that holistic processing is critical for upright face perception, this assumption has not been tested directly. Furthermore, some recent studies call into question the idea that holistic processing always has a greater influence on the perception of upright than inverted faces. For example, recent findings (Gaspar et al., 2008; Sekuler et al., 2004) suggest that the differences in performance between upright and inverted faces may be due to quantitative factors (e.g., decreased processing efficiency for inverted faces compared to upright faces) rather than qualitative factors (e.g., holistic vs. part-based processing). Riesenhuber et al. (2004) suggested that the stronger effects of inversion obtained with faces that differ in configuration rather than individual features (Maurer et al., 2002) could be explained by differences in strategy rather than perceptual processing per se. Additionally, Jiang et al. (2006) proposed a biologically feasible quantitative model of face processing that accounts for a wide range of behavioral and functional magnetic resonance imaging data without explicitly coding

[1] We are using the word *holistic* to refer to holistic or configural processing.

either configural or featural cues.

The fact that identification accuracy for unfamiliar faces varies considerably across individuals (Bruce et al., 1999) provides us with a strategy for directly testing the assumption that there is a link between holistic processing and face perception. If holistic processing is particularly important for the recognition of upright faces, one would expect individual differences in face identification to be associated with individual differences in holistic processing. The current experiments examined this hypothesis by measuring the correlation between holistic processing, indexed by the CFE, and accuracy in face identification.

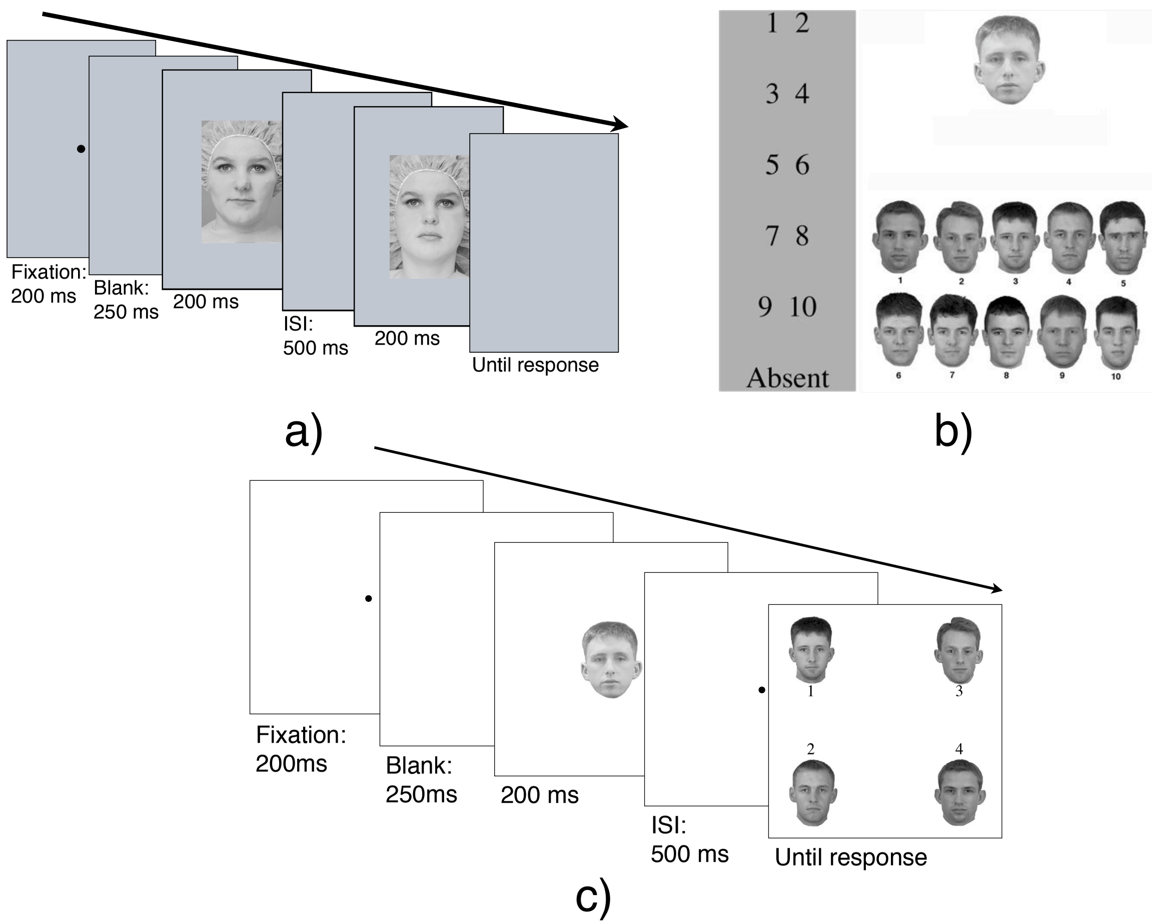


Figure 2.1: Illustrations of the stimuli and sequence of events in Experiments 1 and 2. The illustration in (a) provides an example of an aligned trial in the composite-face-effect task in Experiment 1. Stimuli were created by splitting gray-scale photographs of frontal-view faces (24 male and 24 female) horizontally across the middle of the nose and recombining top and bottom halves within gender (see Le Grand et al., 2004 for details). The two face halves were spatially aligned or misaligned: Aligned and misaligned stimuli were presented in separate blocks of 48 trials. The illustration in (b) provides an example of stimuli (right) and response options (left) for the version of the face identification task in Experiment 1 in which the target face was present on 50% of the trials. In another version, the "absent" option was not available because a correct match was always present. The stimuli were the same as those used by Bruce et al. (1999). For each trial, a target face and 10 selection faces were presented simultaneously. The illustration in (c) provides an example of a trial from the four-alternative forced-choice identification task used in Experiment 2. ISI = interstimulus interval.

2.2 EXPERIMENT 1

2.2.1 Method

Subjects

Forty-eight Caucasian students from McMaster University participated ($M = 21$ years of age, range: 17-31 years). All subjects had normal or corrected-to-normal Snellen acuity and received partial course credit or monetary compensation ($10/hr).

Procedure

All experiments were controlled by a computer using Matlab (Version 5.2.1.1421), the Psychophysics and Video Toolboxes (Brainard, 1997; Pelli, 1997), and custom software. Each subject completed the CFE task first, followed immediately by the face-identification task.

CFE Task

We used Le Grand et al.'s (2004) composite faces. The width and height of the aligned faces subtended visual angles of 5.4° and 8.2°, respectively. In the misaligned condition, the faces subtended 8.2° × 8.2°.

Subjects determined, as quickly and accurately as possible, whether the tops of two faces were the same or different (Figure 2.1a). The bottoms differed on every trial and therefore provided no information about the correct response. CFEs based on reaction times (CFE_{RT}) were calculated, as in most studies (e.g., Hole, 1994; Le Grand et al., 2004), by subtracting the median reaction times for correct misaligned trials from those for aligned trials. CFEs based on d' levels (CFE_d) were calculated by subtracting d' for aligned trials from d' for misaligned trials. Thus, positive CFEs represent more interference in the aligned condition, and negative CFEs represent more interference in the misaligned condition.

Face-identification task

The stimuli were the same as those used by Bruce et al. (1999, Experiment 1). On each trial a target face and 10 selection faces were presented simultaneously (Figure 2.1b), and were displayed until the participant responded. On average, target faces subtended $5.8° \times 8.2°$, and selection faces subtended $4.5° \times 6.7°$. Subjects determined if the target was present in the selection set and, if so, selected its number with a computer mouse. Note that the face that matched the target was taken with a different camera under slightly different lighting conditions, so the task was not an image-matching task. The first 24 subjects were informed that the target was present on 50% of the trials and were instructed to select "absent" if the target was not in the selection set. For the second 24 subjects, the "absent" option was removed and subjects were informed that the target was always present in the selection set. There were 80 trials.

2.2.2 Results

The results are shown in Table 2.1. Both CFE measures were significantly greater than zero, indicating more interference in the aligned condition. Face-identification accuracy for the first 24 subjects fell within the range (i.e., 70%-82%) reported in previous experiments that used the same stimuli and procedure (Bruce et al., 1999; Megreya and Burton, 2006). Average accuracy was significantly greater in the second group of 24 subjects ($t(46) = 3.15,\ p = 0.003$).

Proportion correct was converted to z scores for each group separately, and then combined to form a single set of z scores. Figure 2.2 shows identification z scores plotted as a function of CFE_{RT} and CFE_d. The correlations between identification z scores and CFE measures were not significant (ID-CFE_d: $r = .02$, $t(46) = 0.15$, $p = .88$; ID-CFE_{RT}: $r = -.16$, $t(46) = -1.10$, $p = .27$). Similar results were obtained when the correlations were computed separately for the two sets of 24 z scores.

The effect of measurement error on the identification z scores and CFE correlations was estimated by applying a bootstrap to data from individual subjects to generate large numbers of CFE_{RT} and CFE_d scores. The distributions of the bootstrapped values were approximately normal, so we assumed that the CFE measures for each subject were distributed normally with a mean equal to the observed CFE score and a standard error that equaled the standard deviation of the bootstrapped scores. Proportion correct in the

Table 2.1: CFE_{RT} (ms), CFE_d, and identification accuracy (% correct).

Experiment and measure	M	95% CI	Range
Experiment 1			
Composite face effect: RT	69.1	(26, 112)	−232 to 410
Composite face effect: d'	0.57	(0.40, 0.74)	−0.46 to 1.78
Group 1 identification accuracy (%)	80.2	(75, 85)	48.7 to 100
Group 2 identification accuracy (%)	90.1	(87, 94)	68.7 to 100
Experiment 2			
Composite face effect: RT	41.8	(27, 57)	−154 to 342
Composite face effect: d'	0.53	(0.40, 0.67)	−2.42 to 1.57
Identification accuracy (%)	71.9	(70, 74)	46 to 88

Note: Composite face effects based on reaction times (RTs) were calculated by subtracting the median RTs (in milliseconds) for correct misaligned trials from those for aligned trials. Composite face effects based on d' were calculated by subtracting d' for aligned trials from d' for misaligned trials. See the text for more information. CI = condifence interval.

face identification task was assumed to follow a binomial distribution. A simulation constructed sets of CFE_{RT}, CFE_d, and identification-accuracy measures by drawing random numbers from normal and binomial distributions with parameters that were appropriate for each subject. Identification accuracy was converted to z scores, and the correlations between z scores and CFE measures were recorded. This process was repeated 4,999 times, and the simulated correlations were used to construct 95% confidence intervals for r. These confidence intervals estimate the uncertainty about the correlation, for these subjects, that is produced by measurement error. The 95% confidence interval for the correlation between identification and CFE_d was $[-.19, .18]$; the confidence interval for the correlation with CFE_{RT} was $[-.27, 0.01]$.

2.2.3 Discussion

Like others, we found evidence consistent with holistic processing in the CFE task, although the magnitude of the CFE varied significantly across subjects, and was even negative in some cases. We also replicated previous reports that identification accuracy in the current task is well below 100% and also varies considerably across subjects (Bruce et al., 1999; Megreya and Burton, 2006).

The correlation between identification and either CFE measure was not significant.

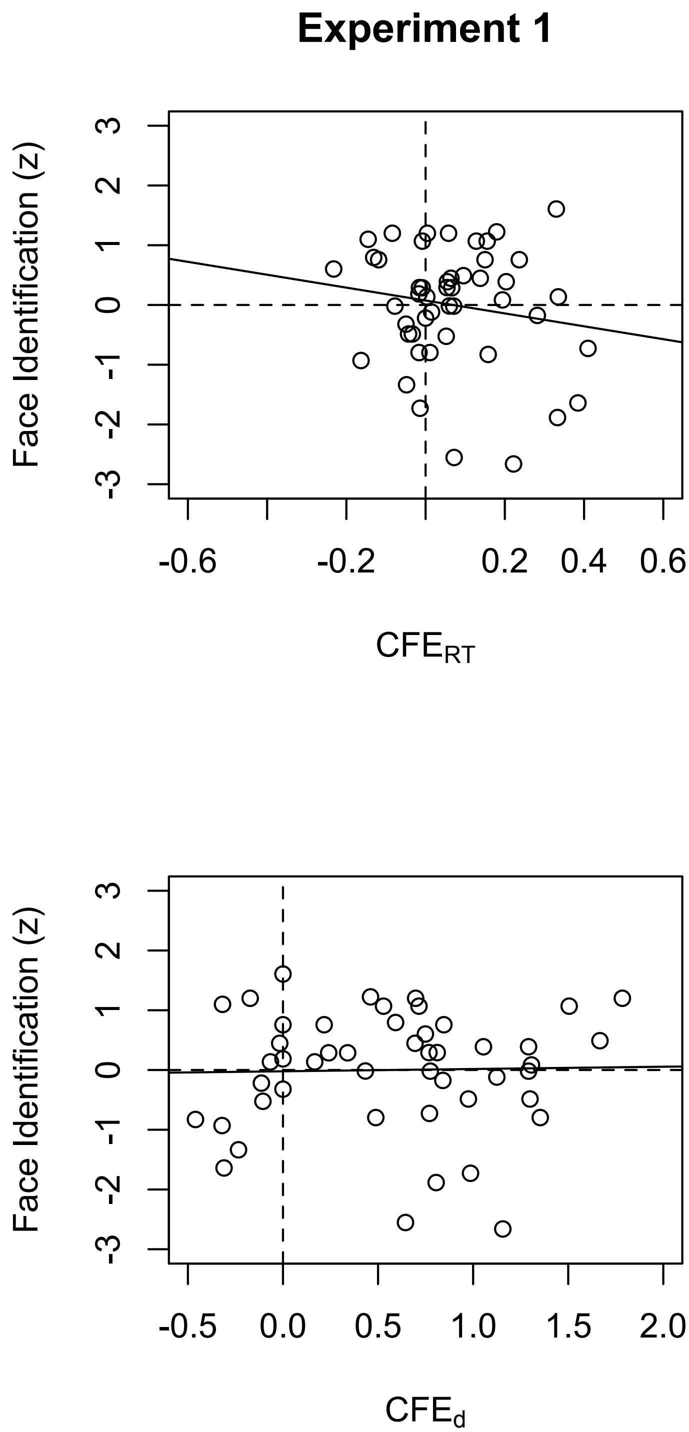


Figure 2.2: Face-identification accuracy (z scores) for individual participants in Experiment 1 as a function of the composite face effect (CFE) based on reaction times (RTs; top panel) and d' (bottom panel). The solid lines are regression lines.

Furthermore, the 95% confidence intervals suggest that the CFE probably accounts for less than approximately 10% of the variance in face identification, and that a negative correlation is nearly as likely as a positive correlation. (In the case of the CFE_{RT}, a small negative correlation may be more likely than a positive one.) The failure to find evidence for a correlation is surprising given the common assumption in the literature that holistic processing is important for perceiving upright faces.

2.3 EXPERIMENT 2

In Experiment 1, stimuli were presented briefly in the CFE task but remained visible in the face-identification task until a subject responded. Although the timing of these tasks was modeled after previous studies, holistic processing may have a greater effect on identification when faces are presented briefly (Goffaux and Rossion, 2006; Hole, 1994). Thus, our identification task may have minimized the impact of holistic processing. To address this concern, we modified the identification task by decreasing stimulus duration to match the duration used in the CFE task.

2.3.1 Method

Participants

A new group of 77 undergraduate students (17-25 years; $M = 19.3$) participated in both tasks. All participants received partial course credit or monetary compensation ($10/hour), and all had normal or corrected-to-normal Snellen acuity.

Procedure

As in Experiment 1, each subject completed the CFE task first, followed immediately by the face-identification task.

CFE task

The CFE task was the same as in Experiment 1, except that subjects completed three sets of aligned and misaligned trials. Sets of aligned and misaligned trials alternated during the experiment, and the order was counterbalanced across subjects.

Face-identification task

Faces from Bruce et al. (1999) were used to construct a four-alternative forced-choice identification task (Figure 2.1c). Duration of presentation of the target face was reduced to 200 ms, the same duration used in the CFE task. Faces subtended the same visual angles as in Experiment 1.

2.3.2 Results

The results are shown in Table 2.1. Both CFE measures were significantly greater than zero, and were similar to those obtained in Experiment 1. Face-identification accuracy was significantly lower than that in the first, Welch's $t(30) = -3.1$, $p = .004$, or second, Welch's $t(40) = -9.6$, $p < .001$, sets of 24 subjects in Experiment 1, although all subjects still performed at above-chance levels. As in Experiment 1, there was considerable variability across subjects on all three measures.

Figure 2.3 shows identification accuracy plotted as a function of CFE_{RT} and CFE_d. As in Experiment 1, the correlations between face identification and CFE were not significant, CFE_d $r = .05$, $t(75) = 0.45$, $p = .66$; CFE_{RT} $r = -.05$, $t(75) = -0.45$, $p = .65$). The effect of measurement error on these correlations was estimated using the approach outlined in Experiment 1. The 95% confidence interval for the ID-CFE_d correlation was $[-.07, .15]$, and for the ID-CFE_{RT} correlation was $[-.17, .03]$.

Inspection of Figure 2.3 shows that 1 subject had a very strong *negative* CFE_d. To investigate the effect this outlier had on our analyses, we calculated r after removing that subject's data. The ID-CFE_d correlation increased from .05 to .142, but still did not differ significantly from zero, $t(74) = 1.14$, $p = .22$. Simulations showed that the 95% confidence interval for r, after removing the outlier and adjusting for the effects of measurement error, was $[-.02, .23]$.

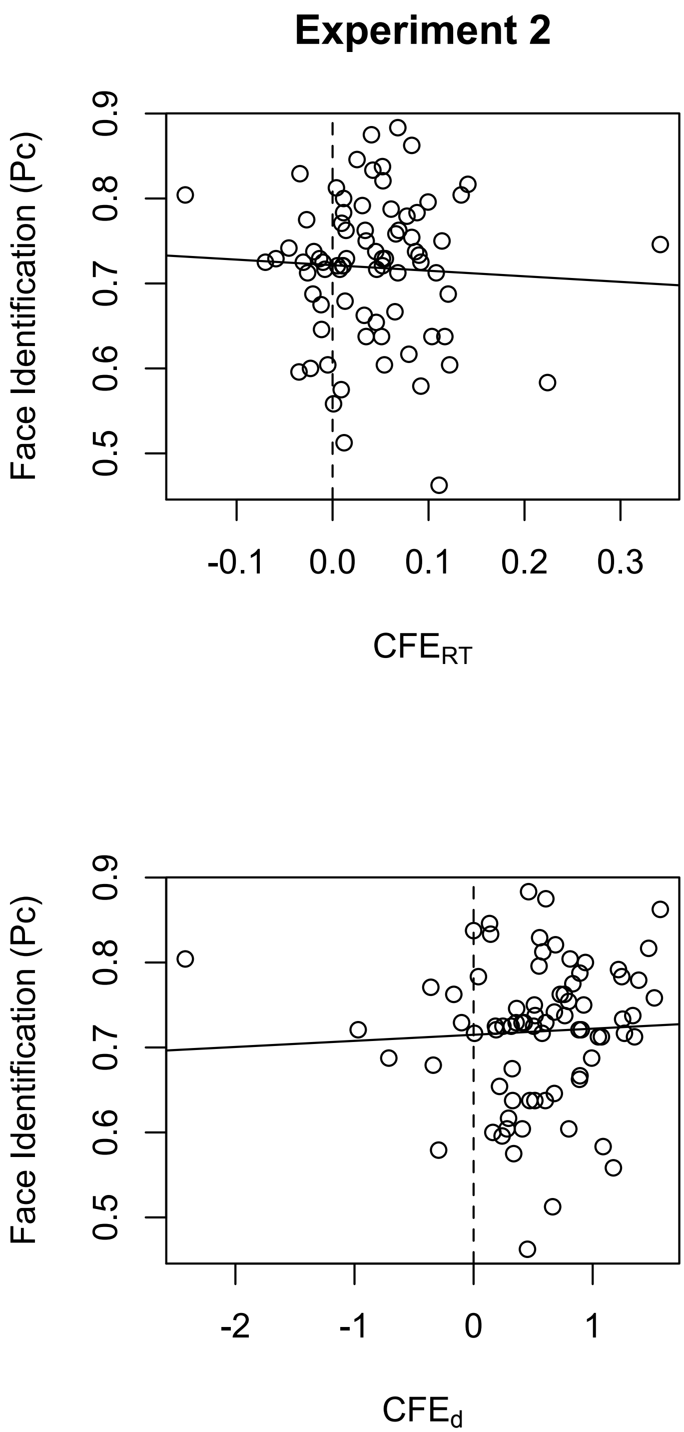


Figure 2.3: Face-identification accuracy (proportion correct, PC) for individual participants in Experiment 2 as a function of the composite face effect (CFE) based on reaction times (RTs; top panel) and d' (bottom panel). The solid lines are regression lines.

2.3.3 Discussion

As in Experiment 1, both CFE measures varied considerably across subjects, but the group averages were significantly greater than zero. Reducing the stimulus duration in the face-identification task, to enhance the influence of holistic processing on performance (Goffaux and Rossion, 2006; Hole, 1994), reduced accuracy on the task compared to Experiment 1, but the correlations between identification accuracy and both CFE measures remained nonsignificant. Furthermore, the 95% confidence intervals for r suggest that the CFE accounts for less than 10% of the variance in identification accuracy. Inspection of Figure 2.3 provides additional evidence of the weak relation between identification and the CFE, by highlighting the variability in face-identification even among subjects with relatively small CFEs. Among the 16 subjects who had a CFE_d between -0.3 and 0.3, for example, proportion correct on the identification task ranged from .58 to .85. Among the 23 subjects with CFE_{RT} between -25 ms and 25 ms, identification accuracy ranged from .51 to .81. Overall, Experiment 2, like Experiment 1, found no evidence for a significant association between CFE magnitude and face-identification accuracy.

2.4 GENERAL DISCUSSION

This study used an individual-differences approach to evaluate the common assumption that holistic processing is an important component of face identification. Two experiments found that face-identification accuracy and the size of the CFE varied considerably across subjects but that the correlation between identification and CFE measures did not differ significantly from zero. However, our analyses allow us to go beyond this statement about the null hypothesis and make a more interesting claim about the actual value of the correlation for our subjects. Our simulations, which estimated confidence intervals for r that incorporated the effects of measurement error, suggest that in our subjects, the correlations between identification and CFE_d was $[-.07, .15]$. Therefore, the current data suggest not only that the correlation does not differ significantly from zero but also that the true correlation between identification and CFE_d probably accounts for less than approximately 2.2% of the variance in identification accuracy. The correlation between identification and CFE_{RT} also was small, and the results did not depend significantly on the stimulus duration used in the identification task.

Given the widespread assumption that adults and even young children (de Heering et al., 2007) use holistic processing in face perception, we were surprised to discover such a weak association between the CFE, a common measure of holistic processing, and face identification. One interpretation of our results is that the holistic processes measured by the CFE do not constrain identification accuracy. Note that this interpretation does not necessarily imply that identification is not influenced by holistic processes or that the CFE is not a good measure of holistic processes. Instead, it implies that the holistic processes that produce the CFE may differ from those that constrain identification. In other words, face perception may be influenced by multiple forms of holistic processing, and phenomena that are thought to reflect the influence of holistic processing (e.g., the inversion effect, the composite face effect, and the part-whole effect) may be produced by distinct mechanisms.

Of course an alternative interpretation of our results is that holistic processing does not constrain face identification, at least as it was measured in our experiments. This hypothesis is consistent with evidence suggesting that the face-inversion effect for identification does not reflect a qualitative shift from holistic to part-based processing (Gaspar et al., 2008; Jiang et al., 2006; Riesenhuber et al., 2004; Sekuler et al., 2004). Note that such an interpretation does not mean that holistic processing never constrains face identification, but it does raise the question of when it exerts its influence. For example, holistic processing may be more important when faces must be identified from different viewpoints or when subjects identify familiar faces. Also, holistic processing might have a stronger influence on judgements about emotion, gender, or attractiveness. These caveats notwithstanding, we believe that the current findings indicate that the influence of holistic processing on face-identification may not be as significant, or automatic, as is commonly assumed.

Bibliography

Bartlett, J. C., Searcy, J., 1993. Inversion and configuration of faces. Cognitive Psychology 25 (3), 281–316.

Brainard, D. H., 1997. The psychophysics toolbox. Spatial Vision 10 (4), 433–436.

Bruce, V., Henderson, Z., Greenwood, K., Hancock, P. J. B., Burton, A. M., Miller, P., 1999. Verification of face identities from images captured on video. Journal of Experimental Psychology: Applied 5 (4), 339–360.

de Heering, A., Houthuys, S., Rossion, B., 2007. Holistic face processing is mature at 4 years of age: evidence from the composite face effect. Journal of Experimental Child Psychology 96 (1), 57–70.

de Heering, A., Rossion, B., 2008. Prolonged visual experience in adulthood modulates holistic face perception. PLoS ONE 3 (5), e2317.

Diamond, R., Carey, S., 1986. Why faces are and are not special: an effect of expertise. Journal of Experimental Psychology: General 115 (2), 107–117.

Farah, M. J., Tanaka, J. W., Drain, H. M., 1995. What causes the face inversion effect? Journal of Experimental Psychology. Human Perception and Performance 21 (3), 628–634.

Gaspar, C. M., Bennett, P. J., Sekuler, A. B., 2008. The effects of face inversion and contrast-reversal on efficiency and internal noise. Vision Research 48 (8), 1084–1095.

Goffaux, V., Rossion, B., 2006. Faces are "spatial"–holistic face perception is supported by low spatial frequencies. Journal of Experimental Psychology. Human Perception and Performance 32 (4), 1023–1039.

Hole, G. J., 1994. Configurational factors in the perception of unfamiliar faces. Perception 23 (1), 65–74.

Hole, G. J., George, P. A., Dunsmore, V., 1999. Evidence for holistic processing of faces viewed as photographic negatives. Perception 28 (3), 341–359.

Jiang, X., Rosen, E., Zeffiro, T., Vanmeter, J., Blanz, V., Riesenhuber, M., 2006. Evaluation of a shape-based model of human face discrimination using fmri and behavioral techniques. Neuron 50 (1), 159–172.

Le Grand, R., Mondloch, C. J., Maurer, D., Brent, H. P., 2004. Impairment in holistic face processing following early visual deprivation. Psychological Science 15 (11), 762–768.

Maurer, D., Grand, R., Mondloch, C., 2002. The many faces of configural processing. Trends In Cognitive Sciences 6 (6), 255–260.

Megreya, A. M., Burton, A. M., 2006. Unfamiliar faces are not faces: evidence from a matching task. Memory & Cognition 34 (4), 865–876.

Michel, C., Rossion, B., Han, J., Chung, C.-S., Caldara, R., 2006. Holistic processing is finely tuned for faces of one's own race. Psychological Science 17 (7), 608–615.

Mondloch, C. J., Pathman, T., Maurer, D., Le Grand, R., de Schonen, S., 2007. The composite face effect in six-year-old children: Evidence of adult-like holistic face processing. Visual Cognition 15 (5), 564–577.

Pelli, D. G., 1997. The videotoolbox software for visual psychophysics: transforming numbers into movies. Spatial Vision 10 (4), 437–442.

Riesenhuber, M., Jarudi, I., Gilad, S., Sinha, P., 2004. Face processing in humans is compatible with a simple shape-based model of vision. Proceedings. Biological Sciences 271 Suppl 6, S448–50.

Rossion, B., Boremanse, A., 2008. Nonlinear relationship between holistic processing of individual faces and picture-plane rotation: evidence from the face composite illusion. Journal of Vision 8 (4), 3.1–13.

Schiltz, C., Rossion, B., 2006. Faces are represented holistically in the human occipito-temporal cortex. Neuroimage 32 (3), 1385–1394.

Sekuler, A. B., Gaspar, C. M., Gold, J. M., Bennett, P. J., 2004. Inversion leads to quantitative, not qualitative, changes in face processing. Current Biology 14 (5), 391–396.

Tanaka, J. W., Farah, M. J., 1993. Parts and wholes in face recognition. The Quarterly Journal of Experimental Psychology. A, Human Experimental Psychology 46 (2), 225–245.

Young, A. W., Hellawell, D., Hay, D. C., 1987. Configurational information in face perception. Perception 16 (6), 747–759.

Chapter 3

Indexes of holistic processing are not related to each other or to face identification

Abstract

Face literature is replete with arguments that holistic processing is a required component of human face processing. We showed in Chapter 2 that holistic processing, as measured by the Composite Face Effect – a common index of holistic processing, was not related to face identification in young adults. We suggested that other indexes of holistic processing may be related to face identification. In this study we analyze three popular indexes of holistic processing (i.e., Face Inversion Effect, Composite Face Effect and Whole-Part Effect) to determine whether they are related to one another, and to determine to what degree each is related to face identification accuracy using correlation analyses. We found that none of the indexes of holistic face processing are related to one another nor to accuracies on two separate face identification tasks.

3.1 Introduction

Since the seminal studies by Yin (1969), face researchers have posited that holistic processing underlies face identification. Yin (1969) introduced the face inversion effect (FIE), which shows that it is harder for participants to identify or discriminate faces when they are rotated 180 degrees in the picture-plane. Some argue that when faces are rotated, participants switch from a holistic strategy to a part-based strategy (for example, see Rossion, 2008). Recently, the FIE has been investigated to determine whether it is indicative of holistic processing. Evidence suggests that observers use similar strategies to discriminate or identify upright and inverted faces (Gaspar et al., 2008; Riesenhuber et al., 2004; Sekuler et al., 2004). For example, Sekuler et al. (2004) used a classification image technique that samples noise in a stimulus that has a face embedded in it. They found that participants relied on similar pixels and regions of the face (area around the eyes and eyebrows) in upright and inverted orientation leading them to conclude that inverting a face does not lead to a qualitative change from holistic to piece-meal processing. These authors also found that, although the same pixels were used for face identification in both orientations, efficiency was much higher for upright faces, indicating that participants were more efficient in the use of the relevant pixels in the upright orientation compared to the inverted orientation. Gaspar et al. (2008) measured the FIE with faces embedded in different types of noise masks and found that the magnitude of the FIE was independent of the mask's spatial frequency content. This result is inconsistent with the claim that low spatial frequencies are especially important for holistic processing of upright faces (Goffaux and Rossion, 2006), or the more general claim that upright and inverted faces are identified using information conveyed by different bands of spatial frequencies. Finally, Riesenhuber et al. (2004) measured face discrimination using upright and inverted faces that varied primarily in terms of the characteristics of nameable features (i.e., the eyes and mouth) or the spatial configuration of these features. Similar FIEs were obtained when the two types of stimuli were presented in separate blocks or randomly intermixed, however, participants in the blocked procedure used different strategies depending on whether they saw the featural or configural manipulation first. This result contradicts previous findings that only featural changes produce Face Inversion Effects. Unlike the prediction from studies that failed to find FIEs for featural manipulations, Riesenhuber et al. (2004) showed that similar processes, not qualitatively different ones, are used to discriminate upright and inverted faces. Notwithstanding the ongoing debate about whether FIE is an index of holistic processing, it is useful to determine its relation to other holistic indexes given that it is a common task in face research that is used as a representative index of holistic processing.

Several research groups developed alternate ways of demonstrating that humans process faces holistically (e.g., Young et al., 1987; Tanaka and Farah, 1993). Young et al. (1987) found that it takes longer for participants to identify the top half of a face belonging to one individual when it is paired with the bottom half of a second individual. When the top and bottom face halves are misaligned horizontally, participants are faster at identifying who the face halves belong to. This phenomenon is called the composite face effect (CFE). It is argued that when faces are aligned, holistic processing takes over and interferes with the task of focussing on and identifying one face half. In other words, holistic processing is interfering with the task at hand. Most healthy participants are susceptible to this interference effect. The task has been used widely, even on clinical populations, such as prosopagnosic children and adults, and children with cataracts (e.g., Avidan et al., 2011; Busigny et al., 2010; Le Grand et al., 2004, 2006; Ramon et al., 2010).

In another common holistic processing task, created by Tanaka and Farah (1993), participants must determine whether a previously-learned face part (i.e., mouth, nose, or eyes) belongs to one of two faces: the full-face condition. The two faces share identical features except for the one being discriminated. On an alternative type of trial, participants simply have to discriminate whether a face part that was learned in a full face is on the left or the right side of fixation: the part-face condition. Performance usually is better when parts are embedded in a full face. Tanaka and Farah referred to this phenomenon as the whole-part effect (WPE), and argued that it occurs because holistic processing confers an advantage in the full-face condition compared to the part-face condition. Similar to the previous two tasks, the WPE is used extensively in face research and on special populations (e.g., Avidan et al., 2011; Busigny et al., 2010; Joseph and Tanaka, 2003).

The FIE, CFE and WPE are often used interchangeably in studies to make the claim that humans process faces holistically. Researchers make the implicit assumption that these three effects are related. For example, Maurer et al. (2002) describe the CFE and WPE as related demonstrations of holistic processing. Like Maurer et al. (2002), many researchers assume that any of the three tasks can be used for the purpose of testing holistic processing. Implicit in this assumption is the idea that the three measures of holistic processing ought to be correlated. To our knowledge, no one has tested this assumption. In this chapter we will test the assumption that the three indexes are related by testing the same group of participants on the three tasks and calculating correlations between the three effects.

In Chapter 2 (Exp. 2) we showed that in a large group of 77 young adults, who were tested on a common CFE task and on a perceptual face identification task, there was no relationship between the CFE and face identification accuracy. In Chapter 2 we proposed that other indexes of holistic processing may have stronger relations with face identification. Some evidence for this comes from Richler et al. (2011), who used an alternative version of the composite task that had an increased task difficulty. They found that their index of holistic processing was correlated with a memory-based face identification task, but not with a perceptual face identification task.

In this study we will test a modified hypothesis that three common indexes of holistic face processing (i.e., FIE, CFE, and WPE) are correlated with face identification accuracy. To anticipate our findings, we did not find significant correlations between CFE, WPE, and FIE, and none of the holistic indexes were significantly correlated with accuracies on two face identification tasks.

3.2 Experiment 1

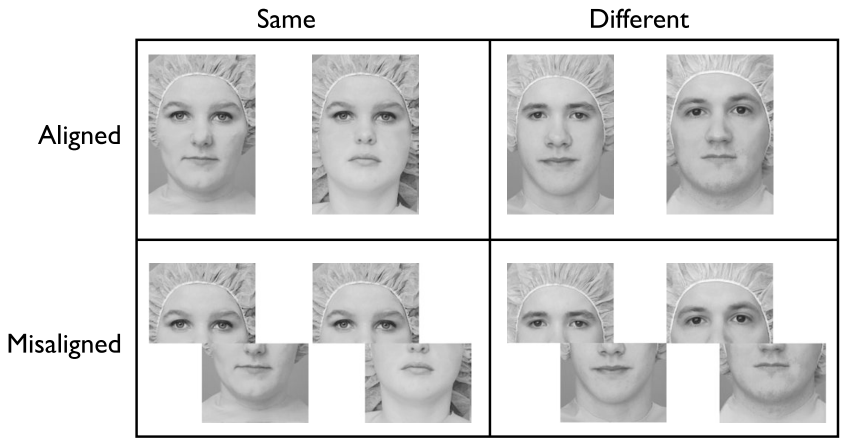
3.2.1 Participants

We tested a group of forty young adults (14 male), mean age was 22.43 years (range of 18 – 30 years). Thirty nine participants were compensated ($10/hr) and one participant did the study for course credit. All participants had normal or corrected-to-normal Snellen visual acuity.

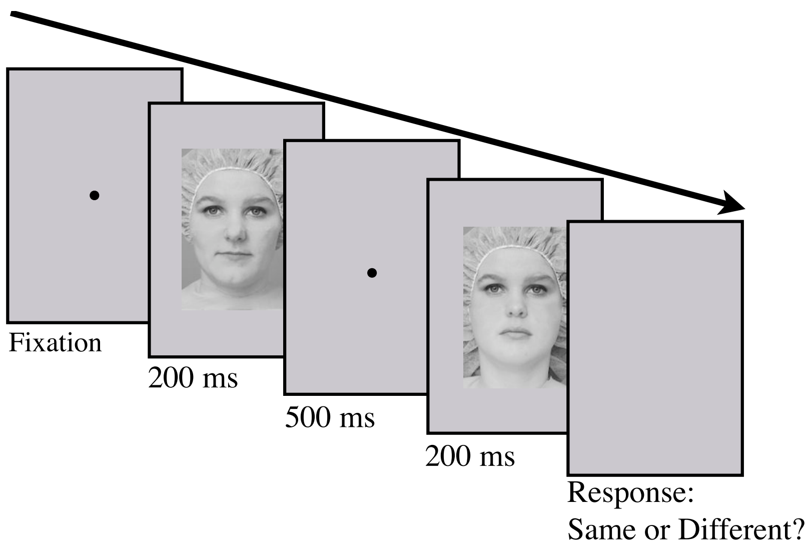
3.2.2 Tasks

Composite face task

The composite face task was identical to the one reported previously in Chapter 2 (Exp. 2). Briefly, there were 24 male and 24 female face pairs in aligned and misaligned conditions, half of which shared the same top halves. Every pair of stimuli had different bottom halves of faces. The aligned stimuli subtended $5.4° \times 8.2°$ and misaligned stimuli subtended $8.2° \times 8.2°$ of visual angle at a distance of 100 *cm* (see Figure 3.1 for examples). The task consisted of 96 trials, half in aligned and half in misaligned conditions. Participants completed the task twice.



(a) Conditions in the CFE task



(b) Sample trial of the CFE task

Figure 3.1: Example of stimuli and a trial on the CFE task.

Face identification

The stimuli and procedure were modeled after Chapter 2 (Exp. 2). The face identification task was modified so that half of the 80 target faces and the faces that were always presented along with each target were tested in the upright orientation and the second half were tested inverted, counterbalanced across participants. To shorten the study's duration, instead of testing participants on the task three times, all participants were tested twice and trials were randomized for the retest. Face identification (labelled "Face ID") performance was obtained from the upright orientation. The FIE was calculated as a difference between response accuracy (i.e., proportion correct) in the Face ID task using upright and inverted faces. See Figure 3.2 for examples of the stimuli and a trial sequence.

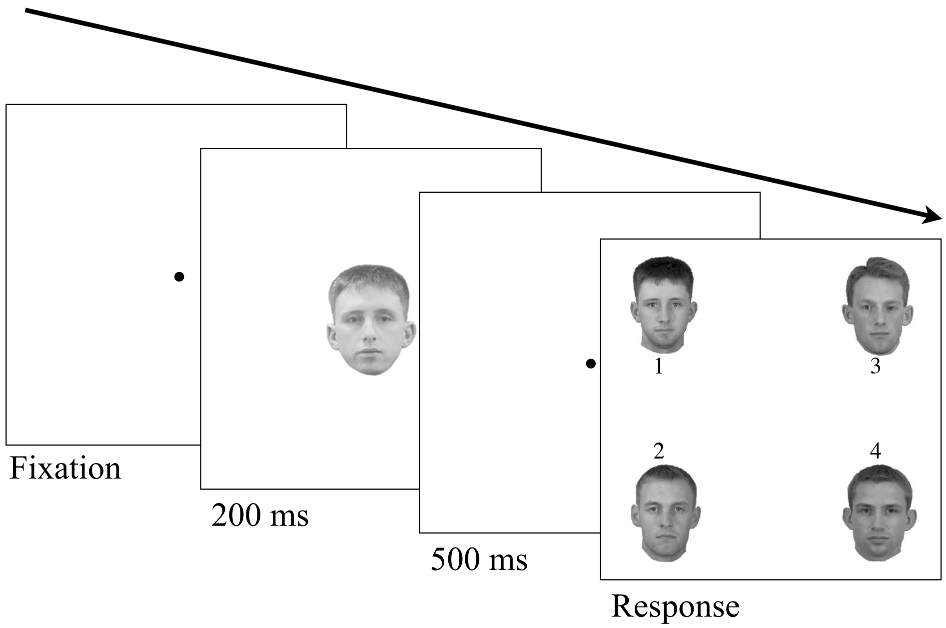


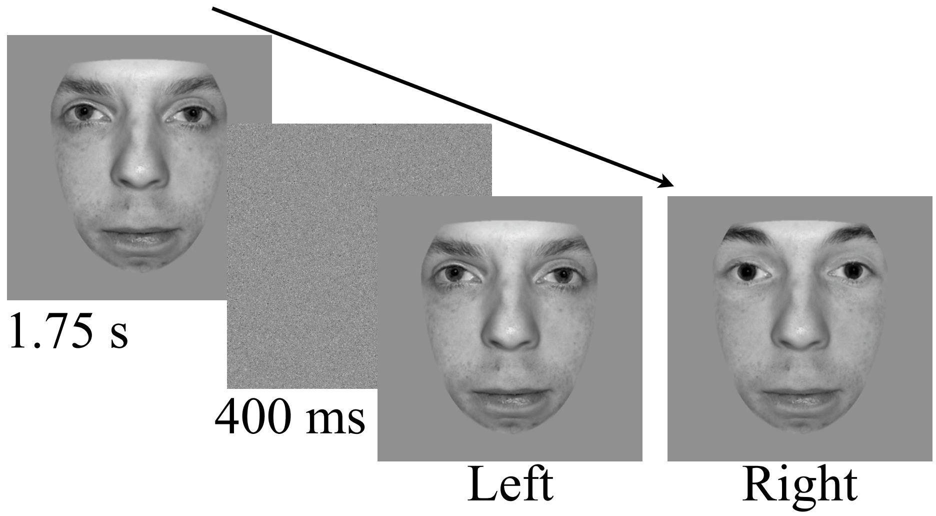
Figure 3.2: Trial example for the face identification task. The choices stayed up on the screen until participants made a response between "1" and "4". Performance was measured in separate blocks of trials using upright and inverted faces.

Whole part task

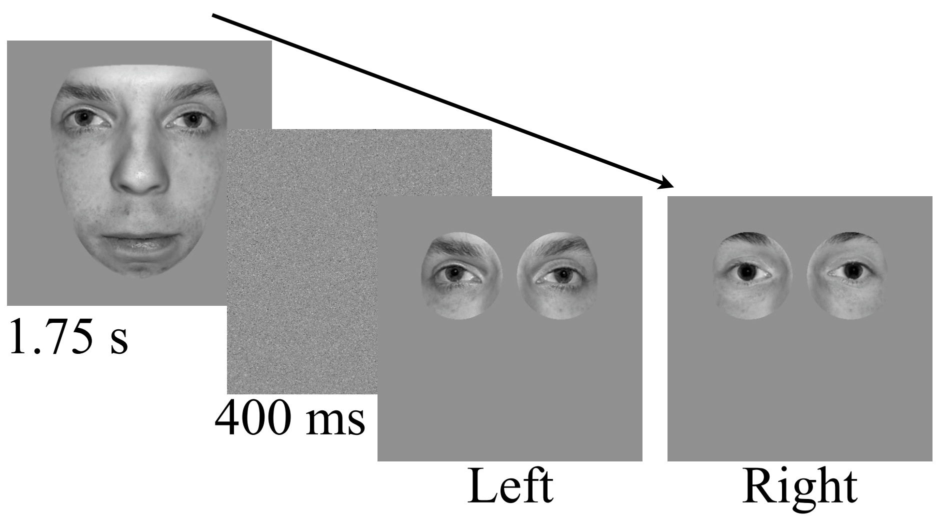
The WPE task was modeled after Boutet and Faubert's (2006, Exp. 4) procedure. The stimuli were derived from 14 original digital face photographs of individuals who gave their consent to use their faces as stimuli in later experiments. The images were processed through FaceGen's PhotoFit function in order to create 3D models of the faces. Once the 3D models were created, we ensured that each face was forward-facing before saving colour 2D bitmap images for use as stimuli. The images were then processed with Gimp (an open-source Photoshop alternative) to make sure that the pupils were perfectly circular (FaceGen tended to generate slightly oval pupils when generating a 3D model of a face). These 14 images were used as templates to create a single stimulus set, which consisted of seven full-face targets and seven full-face distractors.

Stimuli were created with a custom MATLAB script. Half of the faces were treated as donors of features (eyes, noses, and mouths) and the other half were the recipients, whose features were used as donors for other recipients. Once all the features were cropped out from all the faces, donors and recipients were chosen randomly to generate new face stimuli. All participants were tested using a single set of faces that were created using this procedure. Three distractors per target were generated with this approach, where each distractor differed from the target on one feature only, either the eyes, the nose, or the mouth. An example of the stimuli, in which the eyes are the discriminable feature, are shown in Figure 3.3 (page 36). The stimuli were presented at a distance of 60 cm. The monitor's resolution was 1280×1024 and the refresh rate was 75 Hz. The stimulus background luminance was 94 cd/m^2. The inter-pupilary distance was on average $\sim$ 3.6 cm, which subtended 3.4 ° of visual angle. All faces were cropped with a mask that was created by adding three Gaussian masks. Each individual Gaussian mask was oval in shape and was used to crop out a different region of the face: the first mask cropped out the lower face parts (i.e., chin and cheeks) and neck; the second mask cropped out features on the side of the face (i.e., ears and sideburns); the last mask was used to crop out the hair on top of the head. This composite mask was chosen so as to encapsulate the relevant distant features (from eyebrows to mouths) and to trim off the shape of the head (forehead, ears, neck and chin). There were two reasons for the choice of this mask: researchers assume that internal features of a face are optimal for triggering holistic processing, and, in the context of the whole-part task, the external features are constant between target and distractor, thus they are uninformative and can be removed.

Participants performed a sequential matching task where they learned a face in the first interval and then decided which of two faces in the second interval was the one they learned. The learning stimulus was always a full face while the test stimuli were either full faces or part faces on half the trials. The learning face was shown for 1.75 s, followed by a noise mask, which was shown for 400 ms, and then by a test interval that stayed on until a response was registered. The noise mask was created by randomizing the rows and columns of the first interval stimulus pixels. Two types of trials were used during the task: full-face and part-face trials. During the full-face trials, the test interval showed two faces, one of which was identical to the learned face. The distractor face differed from the correct face by one of the manipulated features: eyes, nose, or mouth. During part-face trials, the test interval showed a set of features from two faces, either two sets of eyes, two noses, or two mouths. Only one of the features was identical to the learned face's features. The WPE task was blocked with half the participants starting with the upright orientation and half with the inverted orientation. Each target was viewed three times by a participant in either orientation, once accompanied by a distractor that differed by the eyes, once by the nose, and once by the mouth. There were a total of 42 trials in each orientation (14 trials per feature).



(a) Example of a full face trial on the WPE task



(b) Example of a part face trial on the WPE task

Figure 3.3: Example of stimuli and trials in the upright orientation on the WPE task. Faces were rotated by 180° on inverted trials.

Cambridge Face Memory Test

We used an on-line[1] version of the CFMT (Duchaine and Nakayama, 2006). Procedure and methods were identical to the ones described in Duchaine and Nakayama (2006). The online stimuli were generated in FaceGen. The task consisted of three practice trials where participants had to locate Bart Simpson's face in a three-face array. Next, participants memorized 1/3 profile (left- and right-facing) views and a front facing view of a face for 3 s and then performed a three alternative forced-choice (AFC) face matching task. This task was done on six faces for a total of 18 trials. Next, as a reminder of all target faces for the next step, participants were shown the same set of six faces simultaneously for 20 s in the front-view orientation. Participants then proceeded to do a three AFC identification task. They were informed that they would be shown an array of three faces on each trial, and that one of the faces would be a face they had studied in the previous phase of the experiment. There were 30 trials, and on each trial the faces in the test array varied either in orientation, lighting, or both. Participants were shown the same set of six faces simultaneously for 20 s in the front-view orientation. This time there were 26 trials and all stimuli were embedded in Gaussian noise. Orientation and lighting were manipulated as before. Participants completed a total of 72 trials on the complete CFMT. See Figure 3.4 for an example trial.

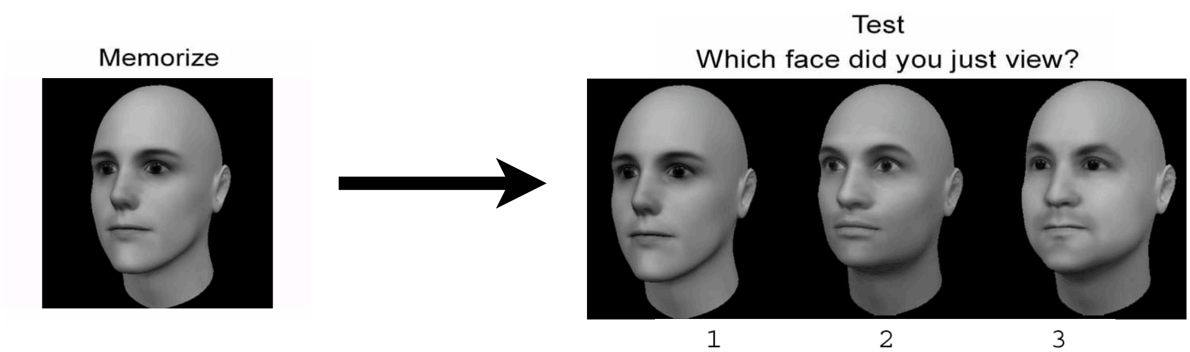


Figure 3.4: Trial example for the Cambridge Face Memory Test. All stimuli for this version of the task were created in FaceGen.

[1]As of August 2011, the on-line version, which was located at http://www.faceblind.org/facetests/fgcfmt/fgcfmt_intro.php, is no longer available.

3.2.3 Procedure

The CFE and WPE tasks were completed first; the order of the two tasks was counterbalanced across subjects. We tested both holistic tasks first to avoid contamination of native face processing strategies by exposure to the face identification tasks. The WPE task was tested once and the CFE task was tested twice. Then participants completed the Face ID task with separate blocks of upright and inverted stimuli, counterbalanced between participants. Finally, all participants completed the online version of the Cambridge Face Memory Test (CFMT; Duchaine and Nakayama, 2006).

3.2.4 Results

All analyses were done in R (R Development Core Team, 2010).

Whole Part Effect

WPE was measured by taking a difference between proportion correct on trials where the learning and test stimuli were whole faces and where the learning stimulus was a whole face but the test stimuli were parts: $WPE = Learn_{full}\_Test_{full} - Learn_{full}\_Test_{part}$.

We analyzed WPE as a function of stimulus orientation (upright vs inverted) using a within-subjects ANOVA. There was no significant effect of orientation ($F(1, 39) = 2.91$, $p = 0.096$). Two-tailed t tests indicated that neither the WPE for upright faces ($M = 0.03$, $t(39) = 1.56$, $p = 0.13$) nor for inverted faces ($M = -0.01$, $t(39) = -0.61$, $p = 0.54$) differed significantly from zero.

Composite Face Effect

CFE_d was defined as the difference between d' in the aligned and misaligned conditions (see Chapter 2 for more details). Recall that the CFE task was completed twice by each participant. Both values of CFE_d were significantly above zero, ($M = 0.46$, $t(39) = 3.65$, $p < 0.001$; $M = 0.43$, $t(39) = 3.59$, $p < 0.001$), and a within-subjects ANOVA revealed that the two values of CFE_d did not differ significantly, $F(1, 78) = 0.03$, $p = 0.87$.

The two mean CFE_ds in this experiment (0.46 and 0.43) did not differ significantly from the CFE$_d$s from blocks one and two in Chapter 2 (0.58 and 0.51), $t_{Welch}(84.6) = 0.74$, $p = 0.46$ and $t_{Welch}(76.0) = 0.53$, $p = 0.60$, respectively. A Spearman's correlation test showed no significant correlation between the two CFE$_d$ measures, $\rho = 0.14$, $S = 9159.23$, $p = 0.39$. The analyses in the following sections used average CFE$_d$ from blocks 1 and 2.

3.2.5 Face identification and inversion

Response accuracy (proportion correct) was analyzed with a 2 (block) × 2 (orientation) ANOVA. There were significant main effects of block ($F(1, 39) = 15.91$, $p < 0.001$) and orientation ($F(1, 39) = 89.31$, $p < 0.001$), but the block × orientation interaction was not significant ($F(1, 39) = 2.74$, $p = 0.11$). The main effects reflect the fact that accuracy was higher with upright faces than inverted faces, and higher in block two than block one. The correlation between accuracy in the two blocks was significant for both upright ($\rho = 0.38$, $S = 6600.8$, $p = 0.02$) and inverted ($\rho = 0.4$, $S = 6394.39$, $p = 0.01$) faces. Essentially identical results were obtained when the analyses were performed on arcsin-transformed data.

The mean proportion correct obtained with upright faces (averaged across two blocks) was 0.71 (range = [0.55, 0.98]), which was similar to the performance of 0.72 (range = [0.46, 0.88]) reported in Chapter 2 (Exp. 2). The mean proportion correct (averaged across two blocks) for inverted faces was 0.55 (range = [0.36, 0.80]). Face Inversion Effect (FIE) scores were calculated as a difference between upright and inverted proportions correct for each block separately. The FIE scores from the two blocks were significantly correlated, $\rho = 0.50$, $S = 5329.7$, $p = 0.001$ (two-tailed).

Given that the correlation between blocks for both orientations was significant, we calculated a single FIE by averaging the proportions correct for each orientation separately and calculating a difference between upright and inverted scores. FIE scores above zero are expected given that performance ought to be higher on upright faces and lower on inverted, and in fact the mean FIE of 0.17 (range = [-0.05, 0.40]) was significantly greater than zero, $t(39) = 9.45$, $p < 0.001$, one-tailed. The average FIE scores were used in subsequent tests.

3.2.6 Cambridge Face Memory Test

Performance on the web-based CFMT (M = 0.85, range = [0.69, 0.99], SD = 0.11) was similar to that reported in Duchaine and Nakayama (2006) (M = 0.80, range = [0.60, 1.00], SD = 0.11) and Wilmer et al. (2010) (means ranged between 0.72 and 0.80, SDs ranged between 0.11 and 0.14).

3.2.7 Relations between variables

There was large between-subjects variability on each task, which allowed us to evaluate Spearman's ρ correlation coefficients between the three holistic processing indexes and the two face identification tasks. These coefficients are summarized in Table 3.1 (p. 41).

The CFMT, which is a memory-based face identification task, was significantly correlated with average proportions correct on the perceptual face identification task ($\rho = 0.31$, $S = 7441.51$, $p = 0.03$, one-tailed).

The table reveals that CFE_d, WPE, and FIE were not significantly correlated. There are several reasons why the relations between holistic indexes are so low and in some cases negative. It is possible, for example, that the tasks are unrelated and are tapping distinct underlying processes. Another reason for the weak relations may be that the tasks have low reliability, which therefore attenuates the correlation between effects.

Table 3.1 also has correlations that test the second hypothesis, namely that indexes of holistic processing are related to face identification. None of the holistic processing indexes (CFE_d, WPE, and FIE) were significantly correlated with the perceptual or the memory-based face identification accuracies. That WPE did not correlate significantly with either face identification accuracy could be due to the fact that we did not obtain a significant group WPE. It is also possibile that holistic processing, as indexed by either CFE, WPE, or FIE, is not necessary to perform well on face identification tasks. However, low task reliability can also lead to non-significant correlations between holistic indexes and face identification accuracies.

Table 3.1: Correlation matrix of Experiment 1 effects for 40 participants. All values are Spearman's ρ correlation coefficients. Significance levels are '.' ≤ 0.1, '*' ≤ 0.05, '**' ≤ 0.01, and '***' ≤ 0.001, 2-tailed. 'Face ID' refers to the average proportions correct on the perceptual face identification task. FIE scores are based on the same scores as Face ID, hence, the correlation between these two measures is not reported as the two measures are based on the same Face ID scores.

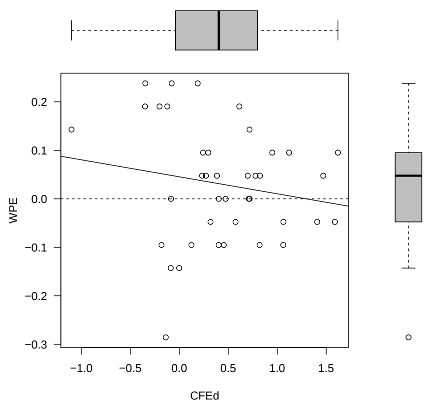
	CFEd	WPE	FIE	Face ID
CFEd				
WPE	-0.16			
FIE	-0.12	0.17		
Face ID	-0.10	0.12		
CFMT	0.03	0.01	0.16	0.31.

3.2.8 Discussion

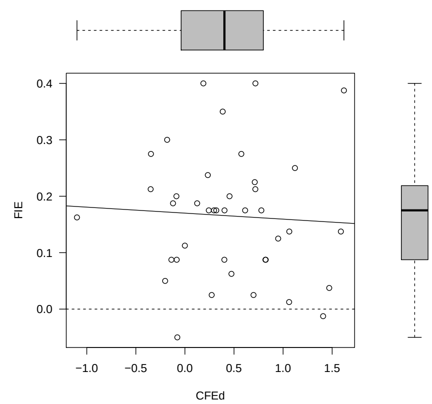
In this experiment we tested the prediction that an alternative index of holistic processing, namely the Whole-Part Effect, is related to face identification accuracy to a greater degree than CFE. Although we failed to find a significant group WPE, there was large variance on the task, which allowed us to test the relationship between individual WPE scores and other measures.

It is unclear why we failed to find a significant group WPE. One reason for this may be due to the use of a different stimulus set. In Boutet and Faubert's (2006, Exp. 4) study all stimuli had faces with hair, ears, and necks whereas we used stimuli that had these features removed by a mask. The face outlines in Boutet and Faubert's study should not be responsible for the whole-part effect since targets and distractors share face outlines, therefore the outlines should not aid in the task of discriminating between internal features (eyes, noses, and mouths). Nevertheless, it is possible that the presence of the face outline affects the way people perceive and remember faces. This will be addressed in Experiment 2.

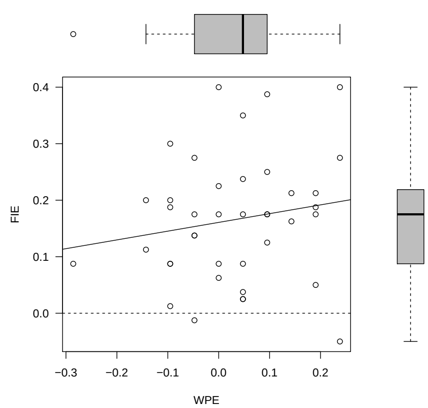
Holistic indexes are assumed to be related given that they supposedly tap the same holistic face processes (for example, see Maurer et al., 2002). To our knowledge, this assumption has not been tested. The first thing to note from Experiment 1 is that for this group of 40 participants there were no significant correlations between any of the three holistic indexes: composite face, whole-part, and face inversion effects (see Table



(a) CFE_d versus WPE for upright faces



(b) CFE_d versus FIE



(c) WPE versus FIE

Figure 3.5: Scatterplots of relations between holistic indexes: CFE_d, WPE, and FIE

3.1). This is a surprising finding given the assumption in the literature that all of these indexes are good measures of holistic processing. The lack of significant correlations between the three indexes indicates that the three effects may measure different aspects of "holistic face processing". An alternative explanation may be that the correlations between all holistic effects are low and not significant because the tasks are not reliable.

To summarize, we failed to replicate Boutet and Faubert's results: we did not find a significant group WPE. On the other hand, we found a significant group CFE_d and FIE. The individual differences approach in this experiment did not find any significant relationships between WPE, CFE_d and FIE and none of the holistic indexes were significantly correlated with accuracies on the two face identification tasks. In the next experiment we will attempt to obtain a group WPE by using a set of faces that retain the face outline and will retest the relations between all effects.

3.3 Experiment 2

In Experiment 1, the failure to find significant relations between holistic measures may be partly due to the fact that we did not find a significant group WPE. The only difference between the WPE task in Experiment 1 and the one reported by Boutet and Faubert (2006, Exp. 4), on which our task is based, was that their stimuli had a generic face outline (i.e., hair, ears, and neck) during a trial. To test whether the face outline is essential to obtain a group WPE, we designed a new set of stimuli for the WPE task that included the missing features (see below). All other tasks were the same as in Experiment 1.

3.3.1 Participants

A new group of 40 McMaster undergraduates (13 male) was tested; 35 participants did the study for course credit and five received monetary compensation ($10/hr). The mean age was 18.82 with a range of 17 – 24 years. All participants had normal or corrected-to-normal Snellen visual acuity.

3.3.2 Method

All participants were tested using the same procedure as in Experiment 1: Participants were tested on the holistic tasks first (CFE and WPE, counterbalanced across participants), followed by the perceptual face identification task, which also tested inverted stimuli, and finally the online CFMT task. The only difference between the two experiments was the type of stimuli that were used in the whole-part task (see an example below on page 45). The composite face task, the perceptual face identification task and the online Cambridge Face Memory Test were identical to the those in Experiment 1.

Whole-Part Task

The faces used in the current experiment were the same as those used in Experiment 1's WPE task, except they were embedded in a generic face outline, obtained via Google Images[2]. The internal stimuli and the external contour were blended to look seamless using Gimp's smudge tool. When the stimuli were presented on the screen, the inter-pupillary distance was maintained the same as in Experiment 1. This resulted in stimuli that were larger than the ones in Experiment 1 due to the fact that the external features were no longer masked in the new stimuli. Importantly, the internal features and distances between the features were identical across the two experiments (see Figure 3.6 on page 45).

3.3.3 Results

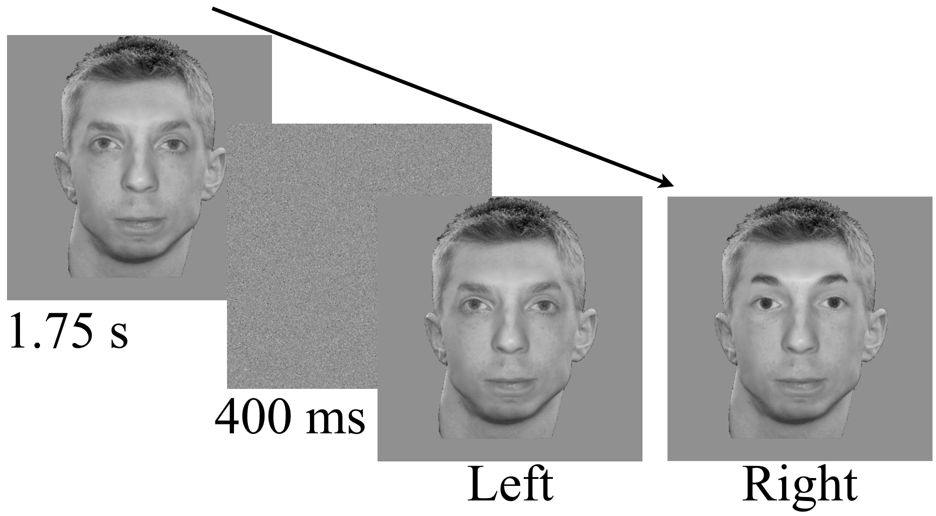
Whole Part Effect

We analyzed WPE as a function of stimulus orientation (upright vs inverted) using a within-subjects ANOVA. Unlike the result in Experiment 1, there was a significant effect of orientation, $F(1, 39) = 8.36$, $p = 0.006$, with the mean WPE being greater for upright faces. The WPEs for upright faces were significantly different from zero ($M = 0.09$, $t(39) = 4.82$, $p < .001$) but the WPEs for inverted faces did not differ from zero ($M = 0.004$, $t(39) = 0.15$, $p = 0.88$), both tests two-tailed. These results are consistent with previous studies that found that the WPE was significantly lower for inverted faces than upright faces (Boutet and Faubert, 2006; Goffaux and Rossion, 2006; Tanaka and Farah, 1993).

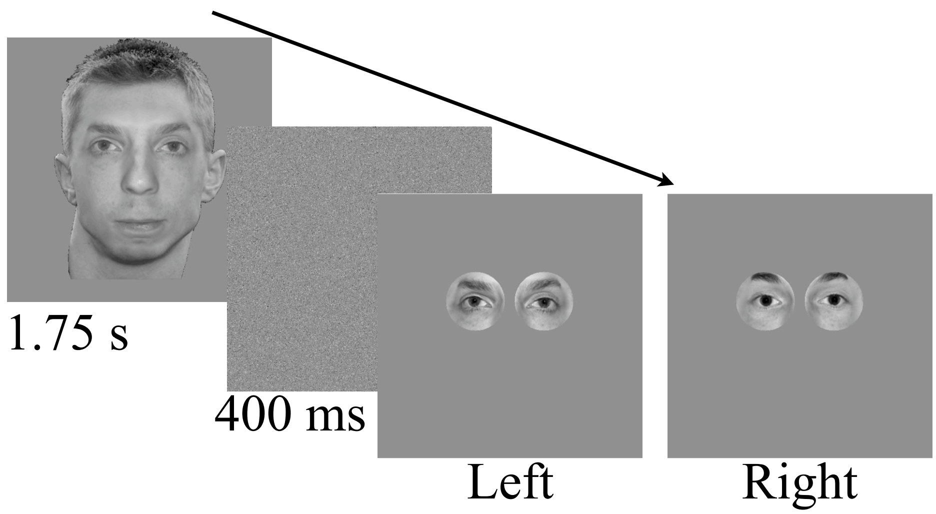
Composite Face Effect

As in Experiment 1, we conducted a within-subjects ANOVA on both blocks of the CFE_d. There was no effect of block ($F(1, 78) = 0.003$, $p = 0.96$) indicating that average performance on the two tests was equivalent. Similar to Experiment 1's results, group CFE_d was greater than zero in the first ($M = 0.35$, $t(39) = 2.54$, $p = 0.008$) and second

[2]The male face that was used in this Experiment was obtained at the following address `http://media.onsugar.com/files/2011/03/11/0/1506/15069278/ec/short3.jpg`



(a) Trial example of full faces in the WPE task



(b) Trial example of part faces in the WPE task

Figure 3.6: Example of stimuli and trials in the upright orientation on the WPE task in Experiment 2. Faces were rotated by 180° on inverted trials.

($M = 0.34$, $t(39) = 2.9$, $p = 0.003$) blocks, both one-tailed tests. As was done in Experiment 1, we used the average data from both blocks for subsequent analyses.

A separate 2 (experiment) × 2 (block) ANOVA was conducted to test whether CFE_d scores differed between the two experiments. The main effects of experiment ($F(1, 78) = 0.70$, $p = 0.41$), block ($F(1, 39) = 0.02$, $p = 0.88$), and the interaction effect ($F(1, 78) = 0.01$, $p = 0.94$) were not significant. These results indicate that performance on the two experiments was similar and that within each experiment there was no difference between

CFE_ds from blocks one and two.

3.3.4 Face identification and inversion

Proportion correct was analyzed with a 2 (block) × 2 (orientation) within-subjects ANOVA. There were significant main effects of block ($F(1, 39) = 4.37$, $p = 0.04$) and of orientation ($F(1, 39) = 82.3$, $p < 0.001$), but the block × orientation interaction was not significant ($F(1, 39) = 0.7$, $p = 0.41$). The same results were obtained when the ANOVA was conducted on arcsine transformed proportions correct.

The mean proportion correct on upright faces (averaged across two blocks) was 0.68 (range = [0.41, 0.89]), which was similar to the performance in Experiment 1 (0.71, range = [0.55, 0.98]). The mean proportion correct (averaged across two blocks) for inverted faces was 0.52 (range = [0.29, 0.71]), which was similar to the performance in Experiment 1 (0.55, range = [0.36, 0.80]). We calculated a single FIE for each participant by averaging the proportions correct for each orientation separately and then calculating a difference between upright and inverted scores. The mean FIE of 0.16 (range = [-0.08, 0.36]) was significantly above zero, $t(39) = 9.07$, $p < 0.001$ (one-tailed test), and this was similar to the results from Experiment 1 ($M = 0.17$; range = [-0.05, 0.40]). The average FIE scores were used for subsequent analyses.

3.3.5 Cambridge Face Memory Test

Performance on the web-based CFMT ($M = 0.77$, range = [0.54, 0.99]) was similar to the previously reported values in Experiment 1 ($M = 0.85$, range = [0.69, 0.99]) and to values from Duchaine and Nakayama (2006) and Wilmer et al. (2010).

3.3.6 Relations between variables

As in Experiment 1, there were large individual differences on all effects, which allowed us to conduct correlation analyses on the relations between all effects. Table 3.2 (p. 47) has a summary of correlations between CFE_d, WPE, FIE, and the two face identification tasks. Similar to Experiment 1's results the only significant correlation was between response accuracy in the perceptual and the memory-based face identification tasks (i.e., FID and CFMT). As in Experiment 1, CFE_d, WPE, and FIE were not significantly correlated with each other, nor were they correlated with performance in either face identification task.

Table 3.2: Correlation matrix of Experiment 2 effects for 40 participants. All values are Spearman's ρ correlation coefficients. Significance levels are '.' ≤ 0.1, '*' ≤ 0.05, '**' ≤ 0.01, and '***' ≤ 0.001. 'Face ID' refers to the average proportions correct on the perceptual face identification task. FIE scores are based on the same scores as Face ID, hence, the correlation between these two measures is not reported as the two measures are based on the same Face ID scores.

	CFEd	WPE	FIE	Face ID
CFEd				
WPE	-0.01			
FIE	-0.01	0.01		
Face ID	-0.11	-0.26		
CFMT	-0.18	0.13	0.25	0.56***

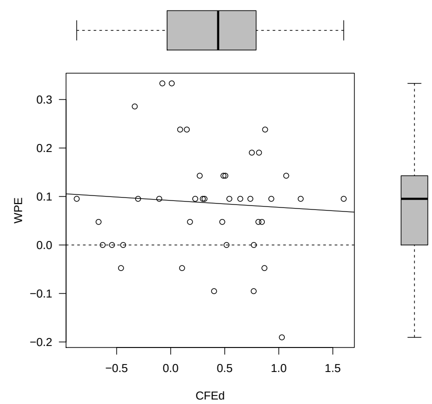
3.3.7 Comparison of Experiments 1 and 2

WPE as a function of experiment

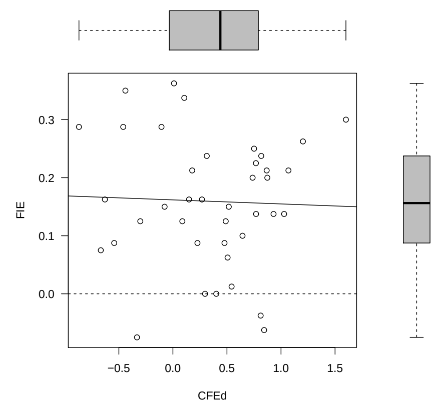
Although we did not anticipate a benefit of using whole faces as stimuli (i.e., non-masked faces with hair, ears, necks), other researchers found significant whole-part effects when using such stimuli (e.g., Tanaka and Farah, 1993; Boutet and Faubert, 2006). There was an increase in the whole-part effect for upright faces when stimuli were whole faces (Experiment 2). This was confirmed by an ANOVA with experiment as a between subjects variable, $F(1, 78) = 4.73$, $p = 0.03$. On the other hand, there was no difference between WPEs for inverted faces across the two experiments, $F(1, 78) = 0.27$, $p = 0.6$.

CFE, FIE and face identification accuracies

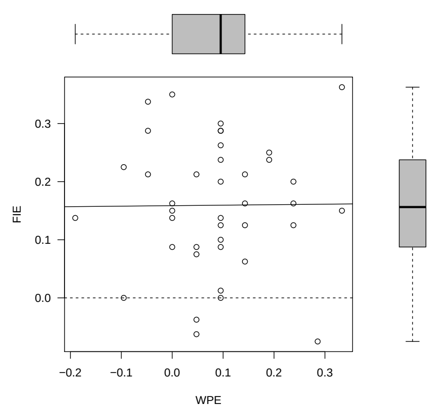
CFE_d, FIE, and accuracy on the perceptual face identification task were not different between the two groups of participants (all F's < 2.13, p's > 0.15). CFMT was different between experiments, with the second group of participants ($M = 0.77$) performing worse



(a) CFE_d versus WPE for upright faces



(b) CFE_d versus FIE



(c) WPE versus FIE

Figure 3.7: Scatterplots of relations between holistic indexes: CFE_d, WPE, and FIE

than the first group ($M = 0.85$), $F(1, 78) = 13.65$, $p < 0.001$. This finding may be due to the fact that the second group of participants were, on average, younger than the first group of participants. The mean age (range) of participants in Experiment 1 was 22.43 years (range [18, 30]) and that of participants in Experiment 2 was 18.82 years (range [17, 24]). Evidence from 60,000 online participants indicates that performance on the CFMT task improves with age and peaks around age 30 (Germine et al., 2011). The performance of our two groups of participants fit well with the results from Germine et al.'s study, who found that 18 year olds perform at around 78% and 22 year olds perform at around 82% on the online CFMT task.

3.3.8 Discussion

In Experiment 2, the whole-part task was modified from Experiment 1 to include a generic face outline. Full faces with external features, such as hair, ears, and neck turned out to be necessary to produce a group Whole-Part Effect. Finding a group WPE in Experiment 2 indicates that there is an interaction between the informative internal and uninformative external features. Simultaneously, results from Experiment 1 suggest that occluding too many parts of a face significantly decreases the magnitude of the WPE.

Finding a significant group WPE in Experiment 2 did not change the conclusions from Experiment 1: None of the holistic indexes were significantly correlated and all Spearman's ρ coefficients were essentially zero (see Table 3.2). Our correlation analyses also showed that accuracies on the perceptual face identification tasks are not correlated with CFE_d, WPE, or FIE. These results are consistent with the findings presented in Chapter 2 and suggest that face identification accuracy is not associated with common measures of holistic processing.

Performance on the CFE task and on the face identification task (upright and inverted orientations) was similar to the one in Experiment 1. However, the younger group of participants in this experiment performed worse on the memory-based CFMT than the group in Experiment 1. These results are consistent with Germine et al.'s (2011) findings, who showed a steady increase in CFMT performance with a peak at around 30 years in a large group of 60,000 online participants.

3.4 General Discussion

In this study we addressed the following two questions:

1. Is there a relation between holistic processing indexes: the Composite Face Effect, the Whole-Part Effect, and the Face Inversion Effect? and
2. Is there a relation between these holistic indexes and face identification accuracy?

The answer to the first question is that there are no significant relationships between any of the three holistic indexes, CFE_d, WPE and FIE. We were concerned that in Experiment 1 the lack of significant correlations between WPE and the other two indexes may have been masked by a lack of a significant group WPE.

By modifying the stimuli from Experiment 1, we found a group WPE that was significantly above zero and was of a magnitude that was previously reported: 9% compared to 9% in Tanaka and Farah (1993, Exp. 2) and 10% in Goffaux and Rossion (2006) (the mean WPE of 17% in (Boutet and Faubert, 2006, Exp. 4) was bigger than the one we observed). However, this did not result in more positive relations between WPE and the other two indexes. In fact, the correlation coefficients between the holistic indexes decreased.

The necessity to include uninformative external face features in the stimuli to obtain a group WPE was unexpected. It should be noted that other researchers have successfully obtained group WPEs with stimuli that lack external features, although their stimuli differed slightly from ours. Goffaux and Rossion (2006) used faces that lacked hair, ears, and necks but retained a natural face shape which differed across trials but was unique within a trial. Given that the face shape was consistent within a trial, it is expected that this shape should not aid in the discrimination of parts because the correct face and the distractor are identical except for the changed feature. Nonetheless, they obtained a group WPE of 10%. Results from Goffaux and Rossion's study indicate that the face shape is necessary to obtain a group WPE. On the other hand, our results indicate that the removal of the face shape (along with ears and necks) eliminates the WPE.

The lack of correlation between FIE and the other two indexes of holistic processing may be because FIE is not an adequate index of holistic face processing. Several researchers have criticized the use of face inversion as an index of holistic processing (e.g., Gaspar et al., 2008; Riesenhuber et al., 2004; Sekuler et al., 2004). Their results show that FIE can be induced by feature and configuration manipulations of faces (Riesenhuber et al., 2004), that similar spatial frequencies are used for upright and inverted face identification (Gaspar et al., 2008), and that participants rely on similar high-contrast facial information (i.e., eyes and eyebrows) to identify upright and inverted faces (Sekuler et al., 2004). Our results of a lack of correlation between FIE and the other two indexes (i.e., CFE and WPE) support the idea that FIE is not an index of holistic processing. Alternatively, the lack of association may be caused by relatively low reliability of measures of holistic processing.

To answer the second question of whether holistic processing indexes are related to face identification accuracy, we correlated CFE_d, WPE, and FIE with accuracies on the memory-based and the perceptual face identification tasks in both experiments. In each experiment, we found that none of the holistic processing indexes are related to face identification accuracy. This result is consistent with the finding from Chapter 2 where we tested the relationship between CFE_d and accuracy on a perceptual face identification task. Our findings indicate that the decades long assumption that holistic processing aids adults in face identification must be revisited. Further, these results suggest that adults do not rely exclusively on processes that are tapped with the tasks that are assumed to be indexing holistic processing. Perhaps, featural processing or a combination of the featural and holistic processing plays a bigger role in how adults identify faces.

The question of which processes underlie face identification and recognition remains open. An attempt to answer this question comes from a recent study by Miellet et al. (2011), who found that young adults alternate between at least two strategies when identifying faces. The researchers found that the strategies changed between featural/piecemeal and holistic, and that strategy choice was dependent on the location of initial fixation on a face. Their findings suggest that holistic processing should not be expected to be the default strategy and the current findings support this idea given that none of the holistic indexes correlated with performance on the identification tasks. Changing strategies throughout a task can lead to poor internal reliability, which leads to correlation attenuation when comparing different effects. In the future, researchers will have to analyze the holistic indexes more thoroughly to determine whether participants' strategies remain constant throughout the task.

Bibliography

Avidan, G., Tanzer, M., Behrmann, M., 2011. Impaired holistic processing in congenital prosopagnosia. Neuropsychologia 49 (9), 2541–52.

Boutet, I., Faubert, J., 2006. Recognition of faces and complex objects in younger and older adults. Memory & Cognition 34 (4), 854–864.

Busigny, T., Joubert, S., Felician, O., Ceccaldi, M., Rossion, B., 2010. Holistic perception of the individual face is specific and necessary: evidence from an extensive case study of acquired prosopagnosia. Neuropsychologia 48 (14), 4057–92.

Duchaine, B., Nakayama, K., 2006. The cambridge face memory test: results for neurologically intact individuals and an investigation of its validity using inverted face stimuli and prosopagnosic participants. Neuropsychologia 44 (4), 576–85.

Gaspar, C., Sekuler, A. B., Bennett, P. J., 2008. Spatial frequency tuning of upright and inverted face identification. Vision Research 48 (28), 2817–26.

Germine, L. T., Duchaine, B., Nakayama, K., 2011. Where cognitive development and aging meet: face learning ability peaks after age 30. Cognition 118 (2), 201–10.

Goffaux, V., Rossion, B., 2006. Faces are "spatial"–holistic face perception is supported by low spatial frequencies. Journal of Experimental Psychology. Human Perception and Performance 32 (4), 1023–1039.

Joseph, R. M., Tanaka, J., 2003. Holistic and part-based face recognition in children with autism. Journal of Child Psychology and Psychiatry 44 (4), 529–42.

Le Grand, R., Cooper, P. A., Mondloch, C. J., Lewis, T. L., Sagiv, N., de Gelder, B., Maurer, D., 2006. What aspects of face processing are impaired in developmental prosopagnosia? Brain and Cognition 61 (2), 139–58.

Le Grand, R., Mondloch, C. J., Maurer, D., Brent, H. P., 2004. Impairment in holistic face processing following early visual deprivation. Psychological Science 15 (11), 762–768.

Maurer, D., Grand, R., Mondloch, C., 2002. The many faces of configural processing. Trends In Cognitive Sciences 6 (6), 255–260.

Miellet, S., Caldara, R., Schyns, P. G., 2011. Local jekyll and global hyde: The dual identity of face identification. Psychological Science IN PRESS.

R Development Core Team, 2010. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Ramon, M., Busigny, T., Rossion, B., 2010. Impaired holistic processing of unfamiliar individual faces in acquired prosopagnosia. Neuropsychologia 48 (4), 933–44.

Richler, J. J., Cheung, O. S., Gauthier, I., 2011. Holistic processing predicts face recognition. Psychological Science 22 (4), 464–71.

Riesenhuber, M., Jarudi, I., Gilad, S., Sinha, P., 2004. Face processing in humans is compatible with a simple shape-based model of vision. Proceedings. Biological Sciences 271 Suppl 6, S448–50.

Rossion, B., 2008. Picture-plane inversion leads to qualitative changes of face perception. Acta Psychologica 128 (2), 274–89.

Sekuler, A. B., Gaspar, C. M., Gold, J. M., Bennett, P. J., 2004. Inversion leads to quantitative, not qualitative, changes in face processing. Current Biology 14 (5), 391–396.

Tanaka, J. W., Farah, M. J., 1993. Parts and wholes in face recognition. The Quarterly Journal of Experimental Psychology. A, Human Experimental Psychology 46 (2), 225–245.

Wilmer, J. B., Germine, L., Chabris, C. F., Chatterjee, G., Williams, M., Loken, E., Nakayama, K., Duchaine, B., 2010. Human face recognition ability is specific and highly heritable. Proceedings of the National Academy of Sciences of the United States of America 107 (11), 5238–41.

Yin, R., 1969. Looking at upside-down faces. Experimental Psychology 81, 141–145.

Young, A. W., Hellawell, D., Hay, D. C., 1987. Configurational information in face perception. Perception 16 (6), 747–759.

Chapter 4

The relation between face identification and the Composite Face Effect in older adults

Abstract

Several studies have shown that face identification accuracy is lower in older than younger adults. This effect of aging might be due to age differences in holistic processing, which is thought to be an important component of human face processing. Currently, however, there is conflicting evidence as to whether holistic face processing is impaired in older adults. The current study therefore re-examined this issue by measuring response accuracy in a 1-of-4 face identification task and the composite face effect (CFE), a common index of holistic processing, in older adults. Consistent with previous reports, we found that face identification accuracy was lower in older adults than in younger adults tested in the same task. We also found a significant CFE in older adults that was similar in magnitude to the CFE measured in younger subjects with the same task. Finally, we found that there was a significant positive correlation between the CFE and face identification accuracy. This last result differs from the results obtained in a previous study that used the same tasks and which found no evidence of an association between the CFE and face identification accuracy in younger adults. The current findings are consistent with previous claims that older adults rely more heavily on holistic processing to identify objects in conditions of limited processing resources.

4.1 Introduction

Holistic processing is thought to be a critical component of face recognition in younger adults (e.g., Maurer, Grand, and Mondloch, 2002; Rossion, 2008). One way to index holistic processing is through the composite face effect (CFE), sometimes referred to as the composite face illusion (Hole, 1994; Konar, Bennett, and Sekuler, 2010; Le Grand, Mondloch, Maurer, and Brent, 2004; Young, Hellawell, and Hay, 1987), and the most common way to assess the CFE is to measure performance in a task that requires participants to discriminate faces composed of the top and bottom halves of different faces (Le Grand et al., 2004). Participants typically are shown two successive faces, and are instructed to judge whether the top halves of the two faces are the same or different. The bottom halves of the faces differ on every trial, and therefore provide no useful discrimination information. Performance is measured in an aligned condition, in which the top and bottom halves are aligned and therefore are perceived as a single face, and a misaligned condition, in which the top and bottom halves are shifted horizontally relative to each other. When the faces are upright, performance on "same" trials in the aligned condition typically is worse than in the misaligned condition, presumably because holistic processing produces greater interference when the tops and bottom halves form a single perceptual unit. The CFE is defined as the difference between response accuracy and/or response times (RTs) measured in aligned and misaligned conditions.

A common assumption in the face perception literature is that holistic processing is associated with adults' ability to recognize upright faces (Maurer et al., 2002; Rossion, 2008). In Chapter 2 we tested this assumption by measuring the correlation between the magnitude of the CFE and face identification accuracy in 125 younger adults. Surprisingly, we found that there was no correlation between the two measures, which suggests that, if the CFE is indeed a valid measure of holistic processing, then holistic processing does not constrain accuracy in these face identification tasks. This result was corroborated by findings from Chapter 3 where we showed that neither CFE nor the Whole-Part Effect or the Face Inversion Effect, which are two other indexes of holistic processing, were significantly correlated with face identification accuracy in young adults. The current study examines whether the relationship between holistic processing, as indexed with CFE, and face identification changes across the lifespan.

Many studies have shown that face processing deteriorates during normal aging (e.g., Grady et al., 1995, 2000; Grady, 2002; Habak et al., 2008; Owsley et al., 1981; Resnick et al., 1995; Rousselet et al., 2009, 2010; Searcy et al., 1999). These age-related changes in face perception may be due, in part, to age-related changes in holistic processing (Chaby et al., 2010; Murray et al., 2010), although the evidence on this point is equivocal. For example, using a memory-based version of the CFE similar to one described by Young et al. (1987), which required participants to memorize names of faces and then identify the top halves of composite faces, Boutet and Faubert (2006) found evidence for holistic processing in younger, but not older, adults. On the other hand, Boutet and Faubert found that the Whole-Part Effect, another common index of holistic face processing (Tanaka and Farah, 1993), did not differ between younger and older adults. Furthermore, Dror et al. (2005) found evidence suggesting that older adults are *more* likely than younger adults to use holistic processing of objects in mental rotation tasks.

Given the conflicting accounts of the effects of aging on holistic processing, we used the methods described in Chapter 2 to re-examine the question of whether older observers show evidence of holistic processing using a standard composite face task (Le Grand et al., 2004), and we also addressed the question of whether older observers make use of holistic processing differently than younger observers in the context of face identification.

4.2 Methods

4.2.1 Participants

A group of 49 older adults ($60-82; M = 69$) participated in this experiment. All had normal or corrected-to-normal visual acuity (Snellen decimal acuity: $M = 0.96$; $SEM = 0.23$), and each received \$10/hour for participation. Results from 77 younger adults ($17-25; M = 19$) previously tested in an identical experiment (Chapter 2, Experiment 2) were used for age comparisons.

4.2.2 Procedure

Each participant completed the CFE task first, followed immediately by the face identification task.

Composite Face Effect Task

We used the same composite face task as was described in Chapter 2, in which composite faces were made up of the tops and bottoms of different faces (see Figure 4.1a on page 59). An Apple G3 computer controlled stimulus presentation and response collection using Matlab, the Psychophysics and Video Toolboxes (Brainard, 1997; Pelli, 1997), and a 21-inch Apple Studio Display (75Hz; 1152×870 pixels; 22.6°×17.1°). From the viewing distance of 100 cm, the width and height of the aligned faces subtended visual angles of 5.4 and 8.2 deg, respectively. In the misaligned condition, the faces subtended 8.2×8.2 deg.

As in Chapter 2 (Exp. 2), participants completed three blocks of aligned and misaligned trials, with each block consisting of 48 trials. Sets of aligned and misaligned stimuli alternated during the experiment, and half of the participants started with aligned stimuli. On each trial, participants determined, as quickly and accurately as possible, whether the tops of two stimuli were the same or different. The bottoms differed on every trial, and therefore provided no information about the correct response. Participants were informed that the bottom halves were not informative, and so they should try to ignore the bottom halves and focus attention on the top halves of faces. The dependent measures were response time (RT) and accuracy, the latter indexed by d'. d' in the aligned and misaligned conditions were estimated from correct and incorrect responses using standard formulae for Same-Different designs (MacMillan and Creelman, 1991). To test whether younger and older adults had different response biases, we used the formula $-0.5 \times [z(Hit) + z(FA)]$ to calculate the response criterion, c, a common measure of response bias (MacMillan and Creelman, 1991). Note that $c < 0$ corresponds to a bias to respond "same," whereas $c > 0$ corresponds to a bias to respond "different."

Two measures of the CFE, one based on response time (CFE_{RT}) and another based on d' (CFE_d), were estimated for each participant. CFE_{RT} was calculated, as in most studies (e.g., Hole, 1994; Konar et al., 2010; Le Grand et al., 2004), by subtracting the median RT for correct misaligned trials from that for aligned trials for *same* trials only. CFE_d was calculated by subtracting d' for aligned trials from d' for misaligned trials. We used d' rather than percent correct to reduce the influence of response bias, which may differ between younger and older adults (Searcy et al., 1999). For both CFE measures, positive values indicate poorer performance in the aligned condition and negative values indicate poorer performance in the misaligned condition. The standard view of holistic face processing predicts that both measures should be positive. CFE_d and CFE_{RT} were

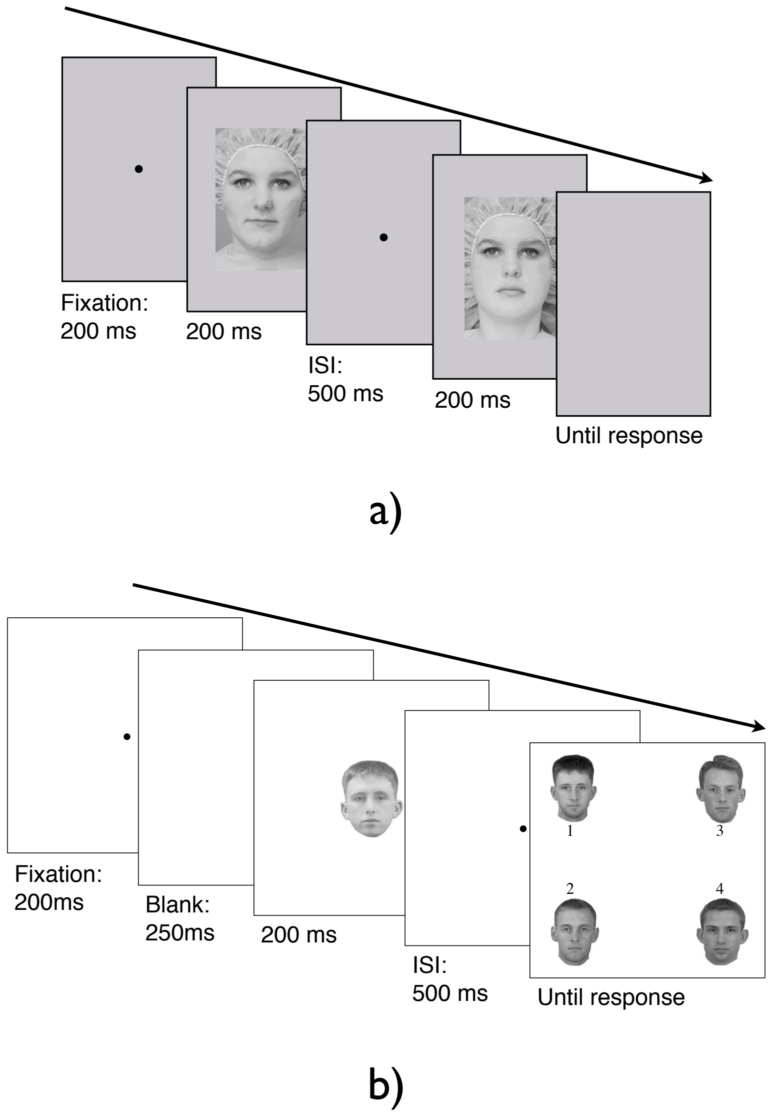


Figure 4.1: **a)** Example of an aligned trial in the composite face task. Stimuli were created by splitting grey-scale frontal-view faces (24 male and 24 female) horizontally across the middle of the nose and recombining top and bottom halves within gender (see Le Grand et al., 2004 for details). The two face halves were spatially aligned or misaligned: aligned and misaligned stimuli were presented in separate blocks of 48 trials. The order of the aligned and misaligned conditions was counterbalanced across participants. **b)** Example of a trial from the 4-AFC identification task used in Experiment 2. A correct match was always present.

calculated separately for each block, and then averaged across blocks.

Face Identification Task

The stimuli and task were the same as those used in Chapter 2 (Experiment 2). The faces were displayed on a Sony Trinitron monitor with a resolution set to 1280×1024 pixels, which subtended 30.9 × 23.6 deg of visual angle at the viewing distance of 70 cm. For each of the 80 target-present stimuli used by Bruce et al. (1999), we constructed 11 images: a target face, a correct match, and nine distractors. On average, target faces subtended 5.8 × 8.2 deg and selection faces subtended 4.5 × 6.7 deg (see Figure 4.1b on page 59). Target stimuli were presented for 200 ms, and were then followed by a display that contained four faces arranged in a 2 × 2 array. The participant's task was to select the face that matched the target. Importantly, the face that matched the target was taken with a different camera under slightly different lighting conditions, and therefore the task was not an image-matching task. Auditory feedback was provided after each trial. Each participant completed three blocks of 80 trials, for a total of 240 trials. Proportion correct was estimated from all 240 responses.

4.3 Results

Data were analyzed with R (R Development Core Team, 2010). The results are summarized in Table 4.1 (page 61). Confidence intervals for CFE_{RT} and CFE_d were calculated using a bootstrap method described in Chapter 2.

In the face identification task, accuracy was significantly lower in older adults than younger adults ($t(124) = 5.74$, $p < 0.001$). In the CFE task, older adults had longer response times than younger adults in both the aligned ($t(124) = 6.72$, $p < 0.001$) and misaligned ($t(124) = 5.44$, $p < 0.001$) conditions. Older adults also had lower d' in both conditions (aligned: $t(124) = -5.52$, $p < 0.001$; misaligned: $t(124) = -4.94$, $p < 0.001$).

The mean CFE_d and CFE_{RT} scores in younger and older participants were significantly different from zero (in both cases, $t \geq 3.8$, $p < 0.001$). Hence, both age groups exhibited significant CFEs. The CFE_d scores in the two age groups did not differ significantly from each other ($t(124) = 0.94$, $p = 0.35$). There was, however, a group difference on CFE_{RT}, with larger values in the older group ($t(124) = -4.22$, $p < 0.001$).

A measure of response bias, c, was calculated for each participant after averaging performance across the three blocks of the CFE task (Figure 4.2 on page 62). On average,

Table 4.1: Summary of results obtained with older and younger adults. The younger adults' data are from Chapter 2 (Exp. 2).

OLDER	Mean	95% CI	Range
FaceID	62.9	(60, 65)	(38, 79)
RT (aligned)	878	(803, 953)	(565, 2006)
RT (misaligned)	785	(698, 818)	(451, 1565)
d' (aligned)	2.18	(2.01, 2.35)	(0.86, 3.53)
d' (misaligned)	2.59	(2.33, 2.86)	(-0.52, 4.49)
CFE_{RT}	120.1	(80, 160)	(-167, 579)
CFE_d	0.42	(0.20, 0.64)	(-2.59, 1.85)

YOUNGER	Mean	95% CI	Range
FaceID	71.9	(70, 74)	(46, 88)
RT (aligned)	652	(627, 677)	(466, 1030)
RT (misaligned)	611	(590, 631)	(385, 912)
d' (aligned)	2.75	(2.63, 2.88)	(1.41, 4.06)
d' (misaligned)	3.28	(3.14, 3.43)	(0.42, 4.59)
CFE_{RT}	41.8	(27, 57)	(-154, 342)
CFE_d	0.53	(0.40, 0.67)	(-2.42, 1.57)

the bias measures were slightly negative, which means that subjects had a slight bias to respond "same". The bias measures were analyzed with a 2 (Age) × 2 (Alignment) mixed-design ANOVA. The main effects of Age ($F(1, 124) = 10.9$, $p = 0.0012$) and Alignment ($F(1, 124) = 21.9$, $p < 0.001$) were significant, as was the Age × Alignment interaction ($F(1, 124) = 50.4$, $p < 0.001$). In younger subjects, the mean value of c differed from zero ($F(1, 76) = 30.06$, $p < 0.001$), but the simple main effect of Alignment was not significant ($F(1, 76) = 0.56$, $p = 0.46$). In older subjects, the mean value of c also differed from zero ($F(1, 48) = 43.6$, $p < 0.001$), but, for this group, the simple main effect of Alignment was significant ($F(1, 48) = 78.7$, $p < 0.001$): c differed from zero for misaligned stimuli ($t(48) = -11.8$, $p < 0.001$), but not for aligned stimuli ($t(48) = -0.353$, $p = 0.76$). In summary, subjects had an overall bias to respond "same", and among older adults, but not younger adults, that bias was significantly greater in the misaligned condition.

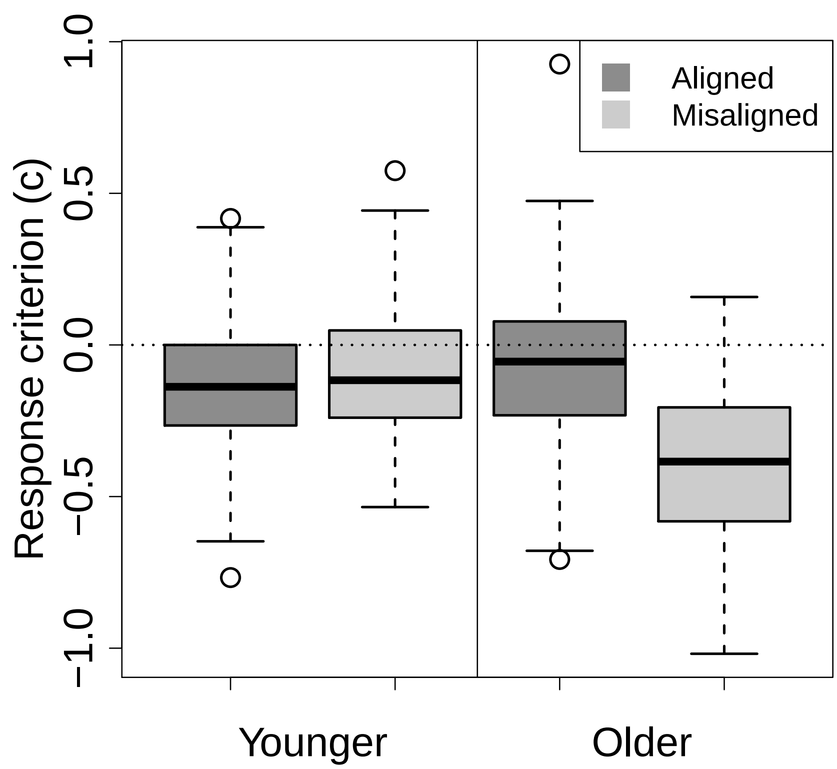


Figure 4.2: Boxplots summarizing response criteria for younger and older adults. Bias to respond 'same' is indicated by negative values. Bias to respond 'different' is indicated by positive values. The median values of c are indicated by the horizontal lines in each boxplot.

Identification accuracy vs. d′

To assess the association between face identification accuracy and d' separately in the aligned and misaligned conditions of the CFE task, we constructed linear models that included identification accuracy as the dependent variable, and age, d', and the age $\times$ d' interaction as predictor variables (Figure 4.3 on page 64). Note that this measure of d' is an index of sensitivity in each of the aligned and misaligned conditions; it is not a measure of holistic processing, CFE_d, which requires a comparison across those conditions. Association strength was expressed as η^2, which is the proportion of the total variation in the dependent variable that is accounted for by a predictor variable. In both conditions, the effect of age was significant ($F(1,122) \geq 37$, $p < 0.001$, $\eta^2 = 0.21$), reflecting the fact that identification accuracy was lower in older adults. In each condition, after controlling for the effect of age, the effect of d' (aligned: $F(1,122) = 19.5$, $p < 0.001$; $\eta^2 = 0.11$; misaligned: $F(1,122) = 36.4$, $p < 0.001$, $\eta^2 = 0.18$) was significant, but the age $\times$ d' interaction was not (aligned: $F(1,122) = 0.01$, $p = 0.92$, $\eta^2 < 0.0001$; misaligned: $F(1,122) = 0.15$, $p = 0.70$, $\eta^2 = 0.0007$). These results indicate that face identification accuracy was linearly associated with sensitivity in face discrimination in the separate components of the CFE task – d' accounted for 11% and 18% of the variation in identification accuracy in the aligned and misaligned conditions – but that the association did not differ between age groups.

To examine if face identification was linked to our measure of holistic processing – CFE_d, which is the difference between d' in the aligned and misaligned conditions – we altered the linear models by replacing the d' and age $\times$ d' predictor variables with CFE_d and the age $\times$ CFE_d interaction. After controlling for the effect of age ($F(1,122) = 34.9$, $p < 0.001$, $\eta^2 = 0.21$), the effect of CFE_d ($F(1,122) = 6.96$, $p = 0.009$, $\eta^2 = 0.04$) and the age $\times$ CFE_d interaction ($F(1,122) = 3.93$, $p = 0.05$, $\eta^2 = 0.023$) were significant (Figure 4.4 on page 65). Separate analyses of the two age groups revealed that the effect of CFE_d was significant in older adults ($F(1,47) = 11.47$, $p = 0.0014$, $\eta^2 = 0.20$), but not younger adults ($F(1,75) = 0.19$, $p = 0.66$, $\eta^2 = 0.003$). Next, we calculated the correlation between identification and CFE_d in each age group. As a measure of association, we prefer Spearman's ρ because it is based on ranks, and therefore is less influenced by outliers. To facilitate comparison with other studies, however, we also include Pearson's r. The correlation between identification accuracy and CFE_d was significant in older adults ($\rho = 0.43$, $S = 11164$, $p = 0.002$; $r = 0.44$, $t(47) = 3.39$, $p = 0.0014$), but not in younger adults ($\rho = 0.13$, $S = 66177$, $p = 0.26$; $r = 0.05$,

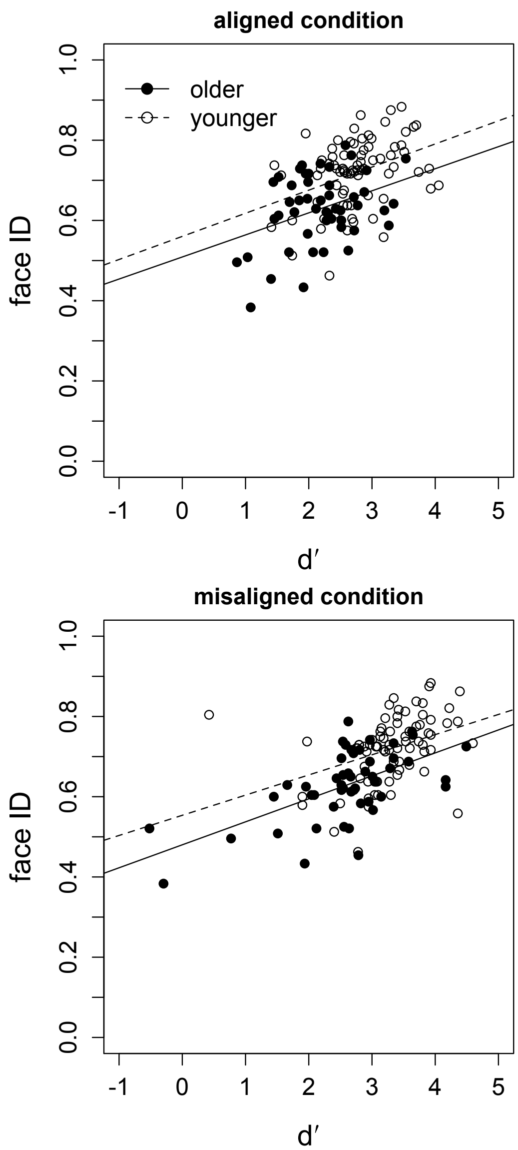


Figure 4.3: Identification accuracy (proportion correct) plotted against d' in the aligned and misaligned conditions. In each plot, the dotted and dashed lines illustrate the fits of a linear model that contained an effect of age, d', and the age $\times$ d' interaction. In each condition, the effects of age and d' were significant, but the interaction was not (i.e., the slopes of the lines did not differ significantly). Data from younger adults are from Chapter 2 (Exp. 2).

$t(75) = 0.45$, $p = 0.66$). Inspection of Figure 4.4 (page 65) shows that two older subjects and one younger subject had very low CFE_d scores that may have had an unusually strong influence on the correlations. However, removing these cases did not alter the main results: the correlation between accuracy and CFE_d remained significant in older adults ($\rho = 0.37$, $S = 10949$, $p = 0.01$; $r = 0.30$, $t(45) = 2.09$, $p = 0.04$) and non-significant in younger adults ($\rho = 0.16$, $S = 61137$, $p = 0.16$; $r = 0.14$, $t(74) = 1.24$, $p = 0.22$) even after the three outliers were removed.

In summary, face identification accuracy in both age groups was associated with d' in the separate aligned and misaligned conditions of the CFE task, but face identification accuracy was associated with the holistic index CFE_d (i.e., the *difference* between d' in the aligned and misaligned conditions) only in older adults.

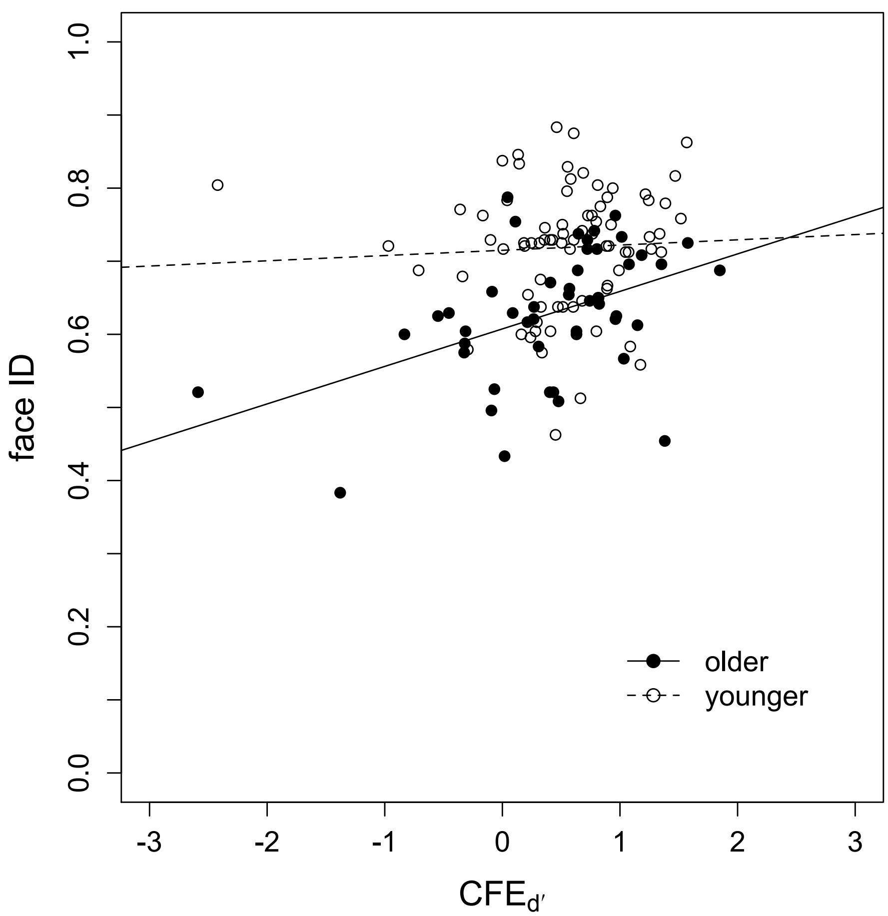


Figure 4.4: Identification accuracy (proportion correct) plotted against CFE_d. The dotted and dashed lines illustrate the fits of a linear model that contained an effect of age, CFE_d, and the age $\times$ CFE_d interaction. The interaction was significant (i.e., The effects of age and d' differed significantly from zero. Data from younger adults are from Chapter 2 (Exp. 2).

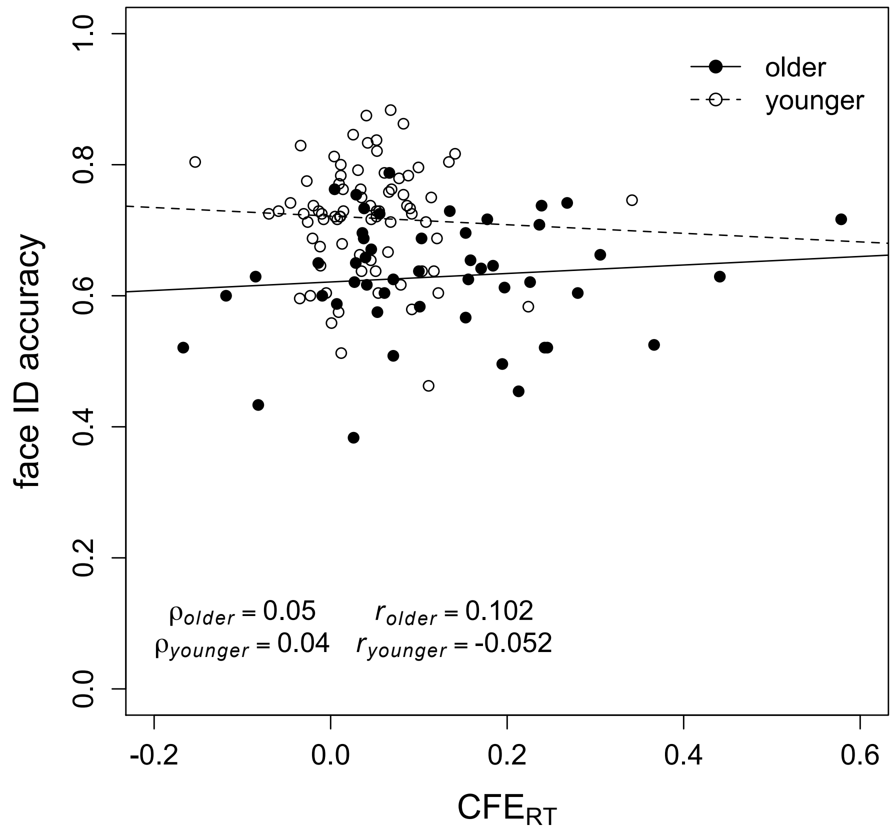


Figure 4.5: Identification accuracy (proportion correct) plotted against CFE_{RT}. The dotted and dashed lines illustrate the fits of a linear model that contained an effect of age, CFE_{RT}, and the age $\times$ CFE_{RT} interaction. Only the effect of age was significant: The slopes of the two lines did not differ significantly from zero or from each other. Data from younger adults are from Chapter 2 (Exp. 2).

Identification Accuracy vs. Response Times

Analyses similar to the ones described in the previous section were used to assess the association between face identification accuracy and response time (RT) in the aligned and misaligned conditions of the CFE task. In each condition, after controlling for the effect of age ($F(1, 122) \approx 32$, $p < 0.001$, $\eta^2 = 0.21$), the effects of RT (aligned: $F(1, 122) = 0.01$, $p = 0.92$, $\eta^2 < 0.0001$; misaligned: $F(1, 122) = 0.02$, $p = 0.89$, $\eta^2 = 0.0001$) and the age $\times$ RT interaction (aligned: $F(1, 122) = 0.005$, $p = 0.94$,

$\eta^2 < 0.0001$; misaligned: $F(1, 122) = 0.18$, $p = 0.67$, $\eta^2 = 0.001$) were not significant. Hence, we found no evidence that identification accuracy was associated with response times in the aligned or misaligned conditions.

The association between face identification and CFE_{RT} was assessed with a linear model that included age, CFE_{RT}, and age $\times$ CFE_{RT} as predictor variables. The effect of CFE_{RT} ($F(1, 122) = 0.15$, $p = 0.69$, $\eta^2 = 0.001$) and the age $\times$ CFE_{RT} ($F(1, 122) = 0.56$, $p = 0.45$, $\eta^2 = 0.004$) interaction were not significant. Finally, in older adults the correlation between identification accuracy and CFE_{RT} was not significant ($\rho = 0.054$, $S = 18526.2$, $p = 0.71$; $r = 0.10$, $t(47) = 0.70$, $p = 0.48$), a result that is similar to the one reported in Chapter 2 (Experiment 2) for 77 younger participants ($\rho = 0.04$, $S = 73034$, $p = 0.73$; $r = -0.052$, $t(75) = -0.45$, $p = 0.65$).

In summary, we found no evidence of an association between face identification accuracy and CFE_{RT}.

Identification accuracy vs. response criterion (c)

Analyses similar to the ones described in the previous two sections were used to assess the association between identification accuracy and response criterion (c). Figure 4.6 (page 68) shows the data and best-fitting linear models for the aligned and misaligned conditions of the CFE task. In each condition, the effects of age ($F(1, 122) > 33$, $p < 0.001$, $\eta^2 = 0.21$) and c (aligned: $F(1, 122) = 9.32$, $p = 0.003$, $\eta^2 = 0.056$; misaligned: $F(1, 122) = 5.18$, $p = 0.025$, $\eta^2 = 0.032$) were significant, but the age $\times$ c interaction was not (aligned: $F(1, 122) = 0.08$, $p = 0.94$, $\eta^2 < 0.001$; misaligned: $F(1, 122) = 1.15$, $p = 0.29$, $\eta^2 = 0.007$). Thus, c was associated with face identification accuracy – accounting for 5.6% and 3.2% of the variation in identification accuracy in the aligned and misaligned conditions – but the association did not differ between age groups.

Figure 4.7 (page 69) shows identification accuracy plotted against the difference between c in the aligned and misaligned conditions (Δc). After controlling for the effect of age ($F(1, 122) = 32.2$, $p < 0.001$, $\eta^2 = 0.21$), the effect of Δc ($F(1, 122) = 0.43$, $p = 0.51$, $\eta^2 = 0.003$) and the age $\times$ Δc interaction ($F(1, 122) = 0.005$, $p = 0.94$, $\eta^2 < 0.001$) were not significant. The correlation between identification accuracy and Δc was not significant in older adults ($\rho = 0.057$, $S = 18478.74$, $p = 0.69$; $r = 0.047$, $t(47) = 0.32$, $p = 0.75$) or younger adults ($\rho = 0.056$, $S = 71817$, $p = 0.63$; $r = 0.067$, $t(75) = 0.58$, $p = 0.56$).

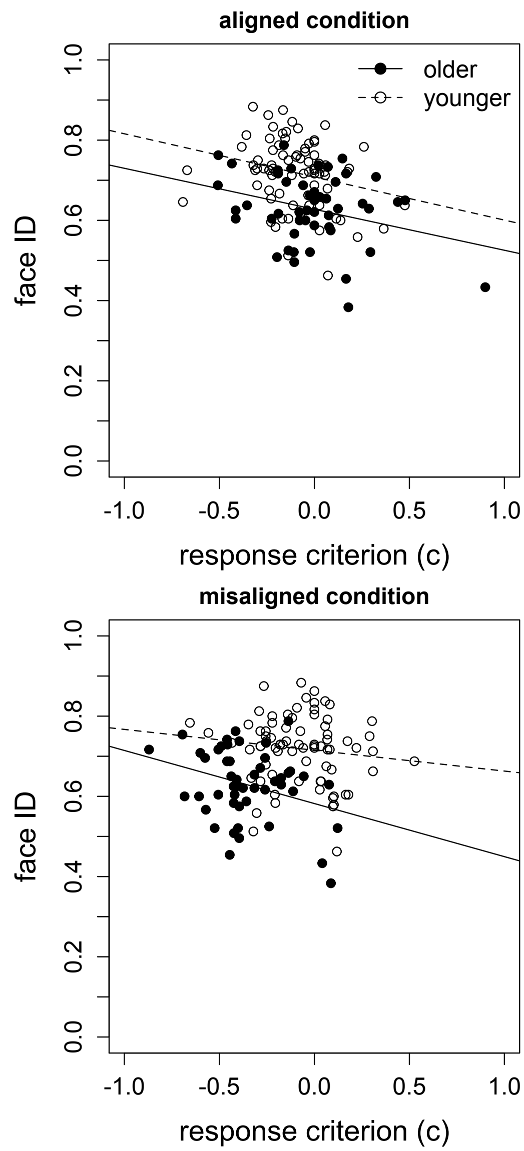


Figure 4.6: Identification accuracy (proportion correct) plotted against c in the aligned and misaligned conditions. In each plot, the dotted and dashed lines illustrate the fits of a linear model that contained an effect of age, c, and the age $\times$ c interaction. In each condition, the effects of age and c were significant, but the interaction was not (i.e., the slopes of the lines did not differ significantly). Data from younger adults are from Chapter 2 (Exp. 2).

In summary, these analyses show that face identification accuracy in both age groups was related to c in both the aligned and misaligned conditions of the CFE task, but not to the difference between c in the two conditions (i.e., Δc).

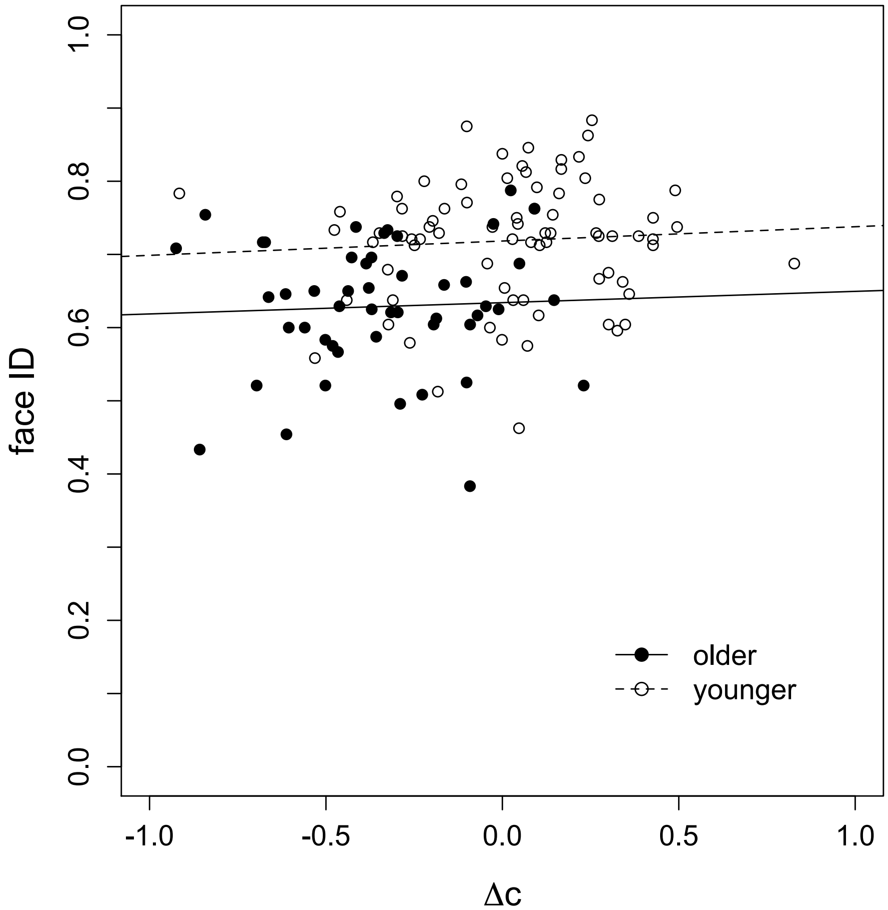


Figure 4.7: Identification accuracy (proportion correct) plotted against Δc (i.e., the difference between c in the aligned and misaligned conditions of the CFE task). The dotted and dashed lines illustrate the fits of a linear model that contained an effect of age, Δc, and the age $\times$ Δc interaction. Only the effect of age was significant: the slopes of the two lines did not differ significantly from zero or each other. Data from younger adults are from Chapter 2 (Exp. 2).

4.3.1 CFE vs. response criterion (c)

Some researchers have suggested that the values of CFE_d estimated from the methods used in this study are susceptible to response bias (Richler et al., 2011a), despite the fact that CFE_d is derived from measures of d' which should reduce the effects of bias. To test this prediction, we correlated CFE_d with Δc for each group separately. Neither group of participants had a significant correlation between CFE_d and Δc (Younger adults:

$\rho = 0.007$, $p = 0.95$; Older adults: $\rho = -0.27$, $p = 0.06$). As mentioned above, two older participants have very low CFE_d scores and may be influencing the correlation analysis. After removing the two outliers, the correlation between CFE_d and Δc remained non-significant ($\rho = -0.19$, $p = 0.20$).

In summary, the correlation between CFE_d and Δc was not significant for either group, indicating that the CFE_d measure was not associated significantly with response bias in our tasks.

Confidence intervals for CFE correlations

We found that CFE_d is correlated with face identification accuracy in older subjects, but not younger subjects. To what extent might this age difference simply be the result of higher variance in the younger subjects' results? To address this issue, we used the bootstrap method described in Chapter 2 to calculate 95% confidence intervals for the correlations between face identification accuracy and CFE_d, CFE_{RT}, and Δc. The results are shown in Table 4.2 (page 70). Three results are noteworthy. First, the confidence interval for the CFE_d-based correlation was slightly wider in older adults than younger adults. Therefore, the failure to find a significant correlation in the younger group cannot be due to our measures being less precise in those subjects. Second, the extent to which confidence intervals were wider for older adults compared to younger adults (23%) was nearly identical to the 25% difference predicted by the difference in sample size – suggesting that the precision of our measures was approximately the same in the two age groups. Third, in both age groups the widths of the three confidence intervals were nearly the same. This last result suggests that the failure to find significant correlations between identification and CFE_{RT} and Δc was not caused by higher error with the RT and c measures.

Table 4.2: 95% confidence intervals for correlations (ρ) between face identification (ID) accuracy and CFE_d, CFE_{RT}, and Δc.

ρ	Older	Younger
ID & CFE_d	(0.18, 0.48)	(-0.09, 0.17)
ID & CFE_{RT}	(-0.09, 0.24)	(-0.16, 0.09)
ID & Δc	(-0.13, 0.20)	(-0.09, 0.18)

4.4 General Discussion

Face identification accuracy was significantly lower in older adults than younger adults, a result that is consistent with previous studies (see Searcy et al., 1999, for a review). In the CFE task, older adults had lower d' scores and longer response times in both the aligned and misaligned conditions. Nonetheless, unlike Boutet and Faubert (2006) who did not find a significant CFE_d in older participants, we found that both CFE_d and CFE_{RT} were significantly greater than zero in older adults, and that CFE_d scores in older adults did not differ from young adults' scores. Note, however, that the CFE tasks used in the current study and by Boutet and Faubert differed considerably. Most critically, Boutet and Faubert required subjects to first memorize the names of faces and then recall the names corresponding to the top or bottom halves of composite faces, whereas the current study relied on perceptual comparisons that presumably minimized the memory load. Therefore, the different results obtained in the two studies may reflect the differential role of memory in the two types of CFE tasks.

The current study examined not just face identification accuracy and the CFE, but also the relationship between performance in a CFE task and face identification accuracy. We found that d' in both aligned and misaligned conditions of the CFE task had a significant linear relationship with identification accuracy for both age groups, and there was no difference in the strength of the relationship between the groups. Note that significant relationships between aligned and misaligned d's for both age groups suggests that similar strategies are used on the CFE task. [1]

In contrast, the difference in d's – which corresponds to CFE_d and is interpreted as an index of holistic face processing – was significantly related to identification accuracy in older adults only. Response times in aligned and misaligned conditions did not relate linearly to identification accuracy for either age group, and CFE_{RT} also did not relate significantly to identification accuracy in either age group. Thus, although previous studies have reported CFEs sometimes in terms of accuracy (d' or proportion correct) and sometimes in terms of RT, our analyses suggest that quantifying CFE with d's may be a more sensitive measure of the way in which holistic processing relates to face identification.

[1] Correlation analyses between aligned and misaligned d's for older and young adults revealed that for both age groups d's between the two alignment conditions are significantly correlated: $\rho = 0.48$, S $= 10127.8$, $p < 0.001$ for older adults, and $\rho = 0.55$, S $= 34238.1$, $p < 0.001$ for young adults.

Analyses of the linear relationship between response criteria and identification accuracy revealed that c in each condition was correlated significantly with identification accuracy, but that there was no difference in the correlations between younger and older adults. This result suggests that response bias in the CFE task cannot explain the differential age-related link between CFE and face identification.

Several investigators have differentiated CFEs that are measured in experiments using partial and complete experimental designs (Cheung et al., 2008; Richler et al., 2011a,b). In a so-called partial design, like the one used in the current experiment, the irrelevant half of the face (e.g., the bottom) changes across intervals on every trial, and holistic processing is indexed by the difference in performance measured in aligned and misaligned conditions. In a complete design, the irrelevant half of the face changes on only 50% of the trials: on congruent trials, both the top and bottom halves are the same or different, whereas on incongruent trials one part of the face is the same and the other is different. In a complete design, holistic processing is indexed by the congruency effect (i.e., the performance difference on congruent and incongruent trials), which typically is larger for aligned faces than misaligned faces.

In comparing the partial and complete designs, Richler et al. (2011a) suggested that a CFE measured with partial designs may not be an accurate index of holistic processing because the results of partial designs may be affected by response bias. Cheung et al. (2008), for example, demonstrated that response bias differed significantly in aligned and misaligned conditions, and therefore suggested that changes in percent-correct were not an accurate measure of the underlying CFE. However, it is not clear why CFE_d calculated in a partial design, which is based on differences in d' in the aligned and misaligned conditions, should be affected strongly by response bias. Compared to a measure of accuracy like percent correct, d' ought to be relatively stable despite changes in response criterion. Consistent with this idea, we found that the correlation between CFE_d and Δc was not significant in either age group. Moreover, the effects of stimulus alignment on response criterion have been inconsistent across several experiments. Cheung et al. (2008) measured congruency effects in younger subjects with low spatial frequency (LSF), high spatial frequency (HSF), and full-spectrum upright faces, and found a significant bias to respond "different", but only for aligned LSF and full-spectrum faces. Richler et al. (2011b), on the other hand, found a greater tendency to respond "same" for aligned full-spectrum faces at short (50 ms) and medium (183 ms) stimulus durations. At a long (800 ms) stimulus duration, which was similar to the 600 ms stimulus duration used by Cheung et al., Richler et al. reported a small bias to respond "same" (i.e., $c \approx -0.1$) that did not vary significantly with alignment. This lack of an alignment effect is similar to the one we obtained with younger subjects. However, the current experiment also found that older adults had a neutral response criterion when shown aligned stimuli and a significant bias to respond "same" for *misaligned* stimuli, a pattern of results that differs from those reported by Cheung et al. and Richler et al. In summary, although stimulus alignment sometimes affects response bias, the direction of those effects has varied across conditions, age groups, and experiments, and the current experiment found no evidence that changes in response bias were correlated with CFE_d or face identification accuracy. Thus, any effects of the partial design on response bias cannot account for our results.

In Chpater 2, where we also used the partial design, we found that neither CFE_d nor CFE_{RT} were correlated with face identification accuracy in younger adults. This finding was replicated by Richler et al. (2011a) in an experiment that used a complete CFE design: analyzing a subset of trials that corresponded to those that would have been included in a partial design, Richler et al. found no evidence of a correlation between face identification and CFE_d or CFE_{RT}. Using all of the trials in the complete design, Richler et al. again found no evidence of a correlation between face identification accuracy and the congruency × alignment interaction that was measured with d' (although the correlation *was* significant when the congruency measure was based on response time). Hence, the evidence so far suggests that, in younger subjects, there is no significant correlation between face identification and CFE_d or a related congruency measure based on d', although Richler et al. did find a correlation between CFE_d and performance on a face memory task.

In contrast to these previous results obtained with younger subjects, the current experiment found that CFE_d was correlated significantly with face identification in older adults, which suggests that older adults may have a greater reliance on holistic processing of faces. Why would older adults rely more on holistic processing? Dror et al. (2005) suggested that using holistic representations and processes could, in some circumstances, reduce the perceptual and cognitive load associated with recognizing objects presented at different viewpoints (at the cost of reducing response accuracy). Furthermore, they argued that age-related reductions in cognitive resources would force older adults to rely on this less-taxing type of processing in a wider range of conditions than younger adults. According to this hypothesis, older adults relied more on holistic processing because identification of upright faces placed a greater demand on their cognitive resources. If this idea is correct, then younger subjects ought to rely more on holistic processing in an upright face identification task that was made more difficult, perhaps by reducing stimulus duration or by including a secondary task, and in such conditions younger adults may exhibit a significant correlation between identification accuracy and the CFE. Indeed, such a prediction could explain why Richler et al. found a relationship between CFE_d and face memory, because, as they suggest, the face memory task may simply be more difficult and therefore force subjects to rely more on holistic processing.

In summary, we found evidence that holistic processing is related to face identification in older adults, but not in younger adults. The current results are consistent with the idea that the extent to which holistic processing influences upright face identification may depend on the relative difficulty of the task: people may rely more on holistic processing under conditions that decrease recognition, and rely less on holistic processing under conditions in which we recognize faces easily and well.

Bibliography

Boutet, I., Faubert, J., 2006. Recognition of faces and complex objects in younger and older adults. Memory & Cognition 34 (4), 854–864.

Brainard, D. H., 1997. The psychophysics toolbox. Spatial Vision 10 (4), 433–436.

Bruce, V., Henderson, Z., Greenwood, K., Hancock, P. J. B., Burton, A. M., Miller, P., 1999. Verification of face identities from images captured on video. Journal of Experimental Psychology: Applied 5 (4), 339–360.

Chaby, L., Narme, P., George, N., 2010. Older adults' configural processing of faces: Role of second-order information. Psychology and Aging.

Cheung, O. S., Richler, J. J., Palmeri, T. J., Gauthier, I., 2008. Revisiting the role of spatial frequencies in the holistic processing of faces. Journal of Experimental Psychology. Human Perception and Performance 34 (6), 1327–36.

Dror, I. E., Schmitz-Williams, I. C., Smith, W., 2005. Older adults use mental representations that reduce cognitive load: mental rotation utilizes holistic representations and processing. Experimental Aging Research 31 (4), 409–420.

Grady, C. L., 2002. Age-related differences in face processing: a meta-analysis of three functional neuroimaging experiments. Canadian Journal of Experimental Psychology 56 (3), 208–220.

Grady, C. L., McIntosh, A. R., Horwitz, B., Maisog, J. M., Ungerleider, L. G., Mentis, M. J., Pietrini, P., Schapiro, M. B., Haxby, J. V., 1995. Age-related reductions in human recognition memory due to impaired encoding. Science 269 (5221), 218–21.

Grady, C. L., McIntosh, A. R., Horwitz, B., Rapoport, S. I., 2000. Age-related changes in the neural correlates of degraded and nondegraded face processing. Cognitive Neuropsychology 17 (1), 165 – 186.

Habak, C., Wilkinson, F., Wilson, H. R., 2008. Aging disrupts the neural transformations that link facial identity across views. Vision Research 48 (1), 9–15.

Hole, G. J., 1994. Configurational factors in the perception of unfamiliar faces. Perception 23 (1), 65–74.

Konar, Y., Bennett, P. J., Sekuler, A. B., 2010. Holistic Processing Is Not Correlated With Face-Identification Accuracy. Psychological Science 21 (1), 38–43.

Le Grand, R., Mondloch, C. J., Maurer, D., Brent, H. P., 2004. Impairment in holistic face processing following early visual deprivation. Psychological Science 15 (11), 762–768.

MacMillan, N. A., Creelman, C. D., 1991. Detection Theory: A User's Guide (2nd edition). Cambridge University Press, Mahwah, NJ.

Maurer, D., Grand, R., Mondloch, C., 2002. The many faces of configural processing. Trends In Cognitive Sciences 6 (6), 255–260.

Murray, J. E., Halberstadt, J., Ruffman, T., 2010. The face of aging: sensitivity to facial feature relations changes with age. Psychology and Aging 25 (4), 846–50.

Owsley, C., Sekuler, R., Boldt, C., 1981. Aging and low-contrast vision: face perception. Investigative Ophthalmology & Visual Science 21 (2), 362–365.

Pelli, D. G., 1997. The videotoolbox software for visual psychophysics: transforming numbers into movies. Spatial Vision 10 (4), 437–442.

R Development Core Team, 2010. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Resnick, S. M., Trotman, K. M., Kawas, C., Zonderman, A. B., 1995. Age-associated changes in specific errors on the benton visual retention test. The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences 50 (3), P171–8.

Richler, J. J., Cheung, O. S., Gauthier, I., 2011a. Holistic processing predicts face recognition. Psychological Science 22 (4), 464–71.

Richler, J. J., Mack, M. L., Palmeri, T. J., Gauthier, I., 2011b. Inverted faces are (eventually) processed holistically. Vision Research 51 (3), 333–42.

Rossion, B., 2008. Picture-plane inversion leads to qualitative changes of face perception. Acta Psychologica 128 (2), 274–89.

Rousselet, G. A., Gaspar, C. M., Pernet, C. R., Husk, J. S., Bennett, P. J., Sekuler, A. B., 2010. Healthy aging delays scalp EEG sensitivity to noise in a face discrimination task. Frontiers in Perception Science 1 (Article 19), 1–14.

Rousselet, G. A., Husk, J. S., Pernet, C. R., Gaspar, C. M., Bennett, P. J., Sekuler, A. B., 2009. Age-related delay in information accrual for faces: evidence from a parametric, single-trial eeg approach. BMC Neuroscience 10, 114.

Searcy, J. H., Bartlett, J. C., Memon, A., 1999. Age differences in accuracy and choosing in eyewitness identification and face recognition. Memory & Cognition 27 (3), 538–552.

Tanaka, J. W., Farah, M. J., 1993. Parts and wholes in face recognition. The Quarterly Journal of Experimental Psychology. A, Human Experimental Psychology 46 (2), 225–245.

Young, A. W., Hellawell, D., Hay, D. C., 1987. Configurational information in face perception. Perception 16 (6), 747–759.

Chapter 5

General discussion

5.1 Summary

In this dissertation we evaluated two key assumptions in the face perception literature:

1. indexes of holistic processing are related to one another; and
2. holistic processing is related to face identification.

To evaluate the first assumption, we used three popular tasks which are thought to measure holistic face processing: the Face Inversion Effect (Yin, 1969), the Composite Face Effect (Young et al., 1987), and the Whole-Part Effect (Tanaka and Farah, 1993).

Over the years, the Face Inversion Effect has become a diagnostic tool for holistic processing (e.g., Avidan et al., 2011; Busigny et al., 2010; Joseph and Tanaka, 2003; Ramon et al., 2010). Researchers use face inversion to determine whether participants from special populations, such as acquired or developmental prosopagnosia, retain normal face processing, which supposedly relies on holistic processing. This approach is misguided given that a number of studies have challenged the idea that the Face Inversion Effect is indicative of a qualitatively different way of processing faces (Gaspar et al., 2008; Pichler et al., 2011; Riesenhuber et al., 2004; Sekuler et al., 2004). For example, using response classification to test strategies during upright and inverted face processing, Sekuler et al. (2004) discovered that the eye and eyebrow regions were the dominant features during face discrimination trials in both orientations. Gaspar et al. (2008) and Willenbockel et al. (2010), using different methods, found that participants relied on a similar band of spatial frequencies to identify faces in upright and inverted orientations, a result that contradicted Goffaux and Rossion's (2006) finding that processing upright faces is reliant on low spatial frequencies and processing inverted faces is reliant on high spatial frequencies. Riesenhuber et al. (2004) found that the Face Inversion Effect could be produced by manipulating faces configurally, a manipulation that failed to produce a FIE in earlier studies (e.g., Freire et al., 2000; Le Grand et al., 2001; Mondloch et al., 2002). Earlier studies that failed to find a FIE presented featural and configural face manipulations in a blocked procedure. On the other hand, Riesenhuber et al. (2004) demonstrated that one can obtain a FIE with both featurally and configurally modified stimuli by intermixing the stimuli instead of blocking them. More recently, Pichler et al. (2011) tested participants on an adaptation task where the adapting stimuli were either intact faces or faces whose configurations were disrupted or scrambled. They found that intact faces were better at inducing adaptation in both upright and inverted orientations compared to the other two manipulations, indicating that inverted faces are sensitive to the same face configurations as are upright faces. Although these studies show that inverted faces are not processed in a qualitatively different way compared to upright, many research groups continue using FIE as a diagnostic tool to test for healthy holistic face processing. Hence, it is important for us to determine whether this effect relates to other less controversial indexes of holistic processing, namely the Composite Face Effect (CFE) and the Whole-Part Effect (WPE). Why should we expect that these three indexes of holistic processing are related? There is some preliminary evidence that FIE and CFE may be triggering the same brain areas. In a review, Kanwisher and Yovel (2006) report on findings that the fusiform face area (FFA) has correlates with both behavioural FIE and CFE, a finding that supports the assumption that behavioural FIE and CFE ought to be significantly correlated.

CFE and WPE are also used frequently in face research on individuals from special populations such as developmental or acquired prosopagnosics (Le Grand et al., 2006; Ramon et al., 2010), children with cataracts (Le Grand et al., 2004), and individuals with autism spectrum disorders (e.g., Joseph and Tanaka, 2003; Nishimura et al., 2008). Many of these studies use more than one of the holistic indexes to test their hypotheses. Although FIE, CFE and WPE are used frequently in face research, no one has conducted a thorough analysis of whether these effects are indexes of a single process or whether they underly unique cognitive processes. In Chapter 3 we analyzed the relations between commonly used versions of each of the effects to test this assumption.

Aside from figuring out whether different indexes of holistic processing are related, it is necessary to find out whether holistic processing is used by healthy adults during face identification and recognition. In most of the papers cited above that make use of holistic indexes there is an underlying assumption that healthy young adults rely on holistic processing during face identification and recognition tasks, an ability that is lost or never acquired by individuals from special populations. Every chapter in this dissertation tested the second assumption that holistic indexes, FIE, CFE and WPE, are correlated with face identification accuracy in healthy adults.

5.1.1 Assumption that holistic indexes are related

As was mentioned above, there is some fMRI evidence that the FIE and CFE are related. It is possible that these two effects are tapping the same underlying process associated with face identification. Yovel and Kanwisher (2005) tested participants on an adaptation task where they measured neural and behavioural Face Inversion Effects. They found a neural FIE, measured as a percent signal change between BOLD responses to upright versus inverted faces, in the Fusiform Face Area (FFA) and the Superior Temporal Sulcus (STS) but not in a third face-selective region, the Occipital Face-selective Area (OFA). Further, they found that the neural FIE was significantly correlated with the behavioural FIE in the FFA only, implicating the FFA as a primary source of the behavioural FIE. Schiltz and Rossion (2006) used an adaptation task to test neural CFEs and found that both the FFA and the OFA demonstrated the effect. Unfortunately, correlations between neural and behavioural CFEs could not be conducted as the behavioural performance was at ceiling. These findings demonstrate that the behavioural FIE and CFE may be produced by the same underlying cortical areas, namely FFA and OFA, with the OFA being implicated for CFE as well. To date, it is unclear what the neural correlates of the behavioural Whole-Part Effect are, but our results indicate that the behavioural WPE may be triggered by a different combination of the face- and/or object-selective areas. In the WPE, parts of faces are an integral part of the calculation of the effect. In a review, Pitcher et al. (2011) concluded that the OFA plays a critical role in processing parts of faces, hence it may be activated during processing of part faces on a WPE task.

Chapter 3 tested the assumption that holistic indexes are related (Maurer et al., 2002). Although fMRI results suggest that the effects ought to be positively correlated, at least to some degree, we found that the correlations between the three effects were not significant in either Experiment 1 or 2. Two of the three correlations in Experiment 1 were negative and in Experiment 2 all correlations were ~ 0.01, or essentially zero. One possible explanation for the failure to find significant correlations is that the tasks have low reliability, which attenuates the true correlations between effects. Alternatively, these results may suggest that FIE, CFE and WPE may be indexes of different types of processes, or different aspects of a single type of holistic process, and therefore that the way we think about holistic processing needs to be revised. In this regard, it would be useful to correlate neurological and behavioural responses in the same group of participants, similar to the approach used by Yovel and Kanwisher (2005), and to determine what aspects of the three indexes are correlated.

An important finding from Chapter 3 was that WPE is not easily reproducible and that WPE is dependent on stimulus set. In an attempt to replicate the WPE (Boutet and Faubert, 2006) in Experiment 1 of Chapter 3 we discovered that using faces that lack an external shape was not sufficient to induce a strong WPE in our participants even though other researchers were successful in obtaining a group WPE using faces that lack hair, ears, and necks (Goffaux and Rossion, 2006). A lack of significant correlations between the three effects may have been masked by a lack of a group WPE, which prompted us to retest a new group of participants on modified stimuli. In Experiment 2 of Chapter 3 we found a significant group WPE with faces that contained external features: ears, necks, and hair. However, the correlations between FIE, CFE, and WPE were again not significant.

5.1.2 Assumption that holistic indexes are related to face identification

In Chapter 2, we tested the relationship between the Composite Face Effect and accuracy on a perceptual face identification task. There were large individual differences on the CFE as well as variable performance on the face identification task. We did not find the predicted significant positive relationship between this common measure of holistic processing and accuracy on a realistic face identification task. Participants in Chapter 3 (Exp. 2) showed significant CFE, WPE, and FIE and their performance on two face identification tasks was typical. However, none of the holistic indexes correlated significantly with face identification. Our findings suggest that if FIE, CFE, and WPE are unique indexes of holistic processing or if they are indexes of unique subprocesses, then they do not predict face identification accuracy. This last point undermines the logic that is used by face researchers who assume that in healthy young adults holistic processing is necessary for face identification.

As was discussed at the end of Chapter 4, one research group has attempted to salvage the idea that holistic processing is related to face identification accuracy (Richler et al., 2011). These researchers claim that the traditional CFE is a byproduct of decisional factors while their measure, referred to as the "congruency effect", is immune from this effect of bias. They found that the congruency effect is not correlated with accuracy on a perceptual face identification task, thus confirming our results that holistic processing is not related to face identification accuracy. However, they found that the congruency effect was correlated with the Cambridge Face Memory Test, a task that is cognitively more demanding than the perceptual face identification task that we used. Trying to find alternative tasks that under restricted conditions predict face identification is not a step in the right direction since we still have not accounted for the tasks that are used ubiquitously. Our results should make face researchers more cautions about the interpretation of their findings that rely on the use of the holistic indexes and should motivate others to determine what real world tasks these indexes are related to. Identification is only one type of information that is coded in a face. Gender, ethnicity or background, emotional state, intentions and thoughts, among other types of information can be extracted from an individual's face. It is possible that holistic indexes are related to some or all of these types of information in a face.

The question of whether holistic processing is preserved with age has only been tested by one research group (Boutet and Faubert, 2006), who found no difference between older adults and young adults on Face Inversion and Whole-Part Effects. In that study, researchers failed to find a significant Composite Face Effect in a group of older adults. In Chapter 4 we found evidence that holistic processing, as indexed by CFE, was preserved with age and that CFE did not differ between young and older adults. Unlike our results from Chapters 2 and 3, where we failed to find significant correlations between holistic indexes and face identification accuracy in young adults, we found evidence to support the second assumption that holistic processing correlates with face identification in older participants (see Chapter 4). Aging leads to various changes in object processing strategies (Dror et al., 2005) and the brain undergoes substantial neuro-functional rearrangements (e.g., Bennett et al., 2001). Evidence also suggests that face processing declines with age (Grady et al., 1995, 1996, 2000; Grady, 2002; Searcy et al., 1999), which may be due to changes in face processing strategies or a general increase in difficulty of performing familiar tasks. The positive correlation between the Composite Face Effect and accuracy on the perceptual face identification task in older adults suggests that unlike young adults, older participants rely more on a strategy that is indexed using the CFE. Proponents of holistic processing as a dominant strategy for face identification would assume that a reliance on holistic processing ought to lead to better face identification. However, that is not the case given that older adults in our study performed significantly worse than young adults, who did not have a significant correlation between the measures.

5.2 Future directions

The findings presented in this dissertation should encourage face researchers who rely on holistic indexes to take pause and reevaluate what it is they are testing. Before we use these tasks as diagnostic tools, it would be prudent to establish validity and reliability of all the effects. An approach for the development and improvement of tasks should be modelled after Duchaine and Nakayama (2006) who created the Cambridge Face Memory Test (CFMT) (also see Wilmer et al. (2010) for more analyses of the CFMT). The researchers established that their task is highly reliable through the use of alternate versions of the test and through short term and long term test-retest reliabilities, among other analysis, to establish reliability. Validity was established by comparing developmental prosopagnosics, who are known to have poor face recognition abilities, against two other diagnostic face recognition tests: the Benton Facial Recognition Test (BFRT) (Benton et al., 1983) and the Recognition Memory test for Faces (RMF) (Warrington, 1984). Unlike the latter two tests, CFMT was able to dissociate healthy young adults from developmental prosopagnosics, thus indicating that CFMT is tapping a process that is impaired in the prosopagnosic group but is intact in the healthy group.

One way to improve the indexes of holistic processing is to first establish whether all of the versions of the effects are reliable. For example, most labs use their own stimuli and there are many variations on the original incarnations of the methods, some that are memory-based and some that are perceptual. A direct analysis of reliability would be to test each method using different stimuli on the same groups of participants. Validity of the indexes can be gleaned from correlational studies between behavioural and neurological responses, similar to the approach used in Kanwisher and Yovel (2006). Once we establish that these effects have good validity and reliability, we can then use these tasks as diagnostic tools.

Bibliography

Avidan, G., Tanzer, M., Behrmann, M., 2011. Impaired holistic processing in congenital prosopagnosia. Neuropsychologia 49 (9), 2541–52.

Bennett, P. J., Sekuler, A. B., McIntosh, A. R., Della-Maggiore, V., 2001. The effects of aging on visual memory: evidence for functional reorganization of cortical networks. Acta Psychologica 107 (1-3), 249–273.

Benton, A. L., Sivan, A. B., Hamsher, K. D. S., Varney, N. R., Spreen, O., 1983. Contribution to Neuropsychological Assessment. New York: Oxford University Press.

Boutet, I., Faubert, J., 2006. Recognition of faces and complex objects in younger and older adults. Memory & Cognition 34 (4), 854–864.

Busigny, T., Joubert, S., Felician, O., Ceccaldi, M., Rossion, B., 2010. Holistic perception of the individual face is specific and necessary: evidence from an extensive case study of acquired prosopagnosia. Neuropsychologia 48 (14), 4057–92.

Dror, I. E., Schmitz-Williams, I. C., Smith, W., 2005. Older adults use mental representations that reduce cognitive load: mental rotation utilizes holistic representations and processing. Experimental Aging Research 31 (4), 409–420.

Duchaine, B., Nakayama, K., 2006. The cambridge face memory test: results for neurologically intact individuals and an investigation of its validity using inverted face stimuli and prosopagnosic participants. Neuropsychologia 44 (4), 576–85.

Freire, A., Lee, K., Symons, L. A., 2000. The face-inversion effect as a deficit in the encoding of configural information: direct evidence. Perception 29 (2), 159–70.

Gaspar, C., Sekuler, A. B., Bennett, P. J., 2008. Spatial frequency tuning of upright and inverted face identification. Vision Research 48 (28), 2817–26.

Goffaux, V., Rossion, B., 2006. Faces are "spatial"–holistic face perception is supported by low spatial frequencies. Journal of Experimental Psychology. Human Perception and Performance 32 (4), 1023–1039.

Grady, C., Horwitz, B., Pietrini, P., Mentis, M., Ungerleider, L., Rapoport, S., Haxby, J., 1996. Effect of task difficulty on cerebral blood flow during perceptual matching of faces. Human Brain Mapping 4 (4), 227–239.

Grady, C. L., 2002. Age-related differences in face processing: a meta-analysis of three functional neuroimaging experiments. Canadian Journal of Experimental Psychology 56 (3), 208–220.

Grady, C. L., McIntosh, A. R., Horwitz, B., Maisog, J. M., Ungerleider, L. G., Mentis, M. J., Pietrini, P., Schapiro, M. B., Haxby, J. V., 1995. Age-related reductions in human recognition memory due to impaired encoding. Science 269 (5221), 218–21.

Grady, C. L., McIntosh, A. R., Horwitz, B., Rapoport, S. I., 2000. Age-related changes in the neural correlates of degraded and nondegraded face processing. Cognitive Neuropsychology 17 (1), 165 – 186.

Joseph, R. M., Tanaka, J., 2003. Holistic and part-based face recognition in children with autism. Journal of Child Psychology and Psychiatry 44 (4), 529–42.

Kanwisher, N., Yovel, G., 2006. The fusiform face area: a cortical region specialized for the perception of faces. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences 361 (1476), 2109–28.

Le Grand, R., Cooper, P. A., Mondloch, C. J., Lewis, T. L., Sagiv, N., de Gelder, B., Maurer, D., 2006. What aspects of face processing are impaired in developmental prosopagnosia? Brain and Cognition 61 (2), 139–58.

Le Grand, R., Mondloch, C. J., Maurer, D., Brent, H. P., 2001. Neuroperception. early visual experience and face processing. Nature 410 (6831), 890.

Le Grand, R., Mondloch, C. J., Maurer, D., Brent, H. P., 2004. Impairment in holistic face processing following early visual deprivation. Psychological Science 15 (11), 762–768.

Maurer, D., Grand, R., Mondloch, C., 2002. The many faces of configural processing. Trends In Cognitive Sciences 6 (6), 255–260.

Mondloch, C. J., Le Grand, R., Maurer, D., 2002. Configural face processing develops more slowly than featural face processing. Perception 31 (5), 553–66.

Nishimura, M., Rutherford, M. D., Maurer, D., 2008. Converging evidence of configural processing of faces in high-functioning adults with autism spectrum disorders. Visual Cognition 16 (7), 859–891.

Pichler, P., Dosani, M., Oruç, I., Barton, J. J., 2011. The nature of upright and inverted face representations: An adaptation-transfer study of configuration. Cortex (0), –.

Pitcher, D., Walsh, V., Duchaine, B., 2011. The role of the occipital face area in the cortical face perception network. Experimental Brain Research 209 (4), 481–93.

Ramon, M., Busigny, T., Rossion, B., 2010. Impaired holistic processing of unfamiliar individual faces in acquired prosopagnosia. Neuropsychologia 48 (4), 933–44.

Richler, J. J., Cheung, O. S., Gauthier, I., 2011. Holistic processing predicts face recognition. Psychological Science 22 (4), 464–71.

Riesenhuber, M., Jarudi, I., Gilad, S., Sinha, P., 2004. Face processing in humans is compatible with a simple shape-based model of vision. Proceedings. Biological Sciences 271 Suppl 6, S448–50.

Schiltz, C., Rossion, B., 2006. Faces are represented holistically in the human occipito-temporal cortex. Neuroimage 32 (3), 1385–1394.

Searcy, J. H., Bartlett, J. C., Memon, A., 1999. Age differences in accuracy and choosing in eyewitness identification and face recognition. Memory & Cognition 27 (3), 538–552.

Sekuler, A. B., Gaspar, C. M., Gold, J. M., Bennett, P. J., 2004. Inversion leads to quantitative, not qualitative, changes in face processing. Current Biology 14 (5), 391–396.

Tanaka, J. W., Farah, M. J., 1993. Parts and wholes in face recognition. The Quarterly Journal of Experimental Psychology. A, Human Experimental Psychology 46 (2), 225–245.

Warrington, E. K., 1984. Recognition Memory Test. Windsor, England: NFER-Nelson.

Willenbockel, V., Fiset, D., Chauvin, A., Blais, C., Arguin, M., Tanaka, J. W., Bub, D. N., Gosselin, F., 2010. Does face inversion change spatial frequency tuning? Journal of Experimental Psychology. Human Perception and Performance 36 (1), 122–35.

Wilmer, J. B., Germine, L., Chabris, C. F., Chatterjee, G., Williams, M., Loken, E., Nakayama, K., Duchaine, B., 2010. Human face recognition ability is specific and highly heritable. Proceedings of the National Academy of Sciences of the United States of America 107 (11), 5238–41.

Yin, R., 1969. Looking at upside-down faces. Experimental Psychology 81, 141–145.

Young, A. W., Hellawell, D., Hay, D. C., 1987. Configurational information in face perception. Perception 16 (6), 747–759.

Yovel, G., Kanwisher, N., 2005. The neural basis of the behavioral face-inversion effect. Current Biology 15 (24), 2256 – 2262.