# The Locus of Holistic Processing: Relationships between the Composite Effects for Facial Judgments on Identity, Emotional Expression and Gender

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## Abstract

**Abstract of thesis entitled:**

The locus of holistic processing: relationships between the composite effects for facial judgments on identity, emotional expression and gender

Submitted by QU, Zhiyi

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The aim of this study is to examine whether holistic processing, a hallmark of face perception, takes place at an early stage of face processing shared by all facial judgments, or at later stages specific for processing different facial information such as identity, expression and gender. In Study 1, a composite paradigm was used where the two face halves could differ in identity, expression, or both. Participants' performance on recognizing the identity (or expression) from half of the face was influenced by incongruent identity (or expression) from the other half, but unaffected by incongruent expression (or identity) from the other half. This indicates that holistic processing of identity and expression are independent of each other. In Study 2, we found that the magnitude of holistic processing for identity and expression as measured by separate face composite tasks were not correlated across individuals. In Study 3, we also found no correlation between the magnitudes of holistic processing for identity and gender. The dissociation found between holistic processing of different facial information suggests that holistic processing does not originate from

the general visual encoding required for all facial judgments. Instead it emerges later in processes devoted specifically to different facial judgments.

# 摘要

从 Bruce 和 Young（1986）面孔识别的模型出发，面孔的加工要经过最初的结构编码的阶段，然后经过表情分析、面孔识别单元以及负责加工性别、种族等视觉处理单元，所以对于表情、面孔身份和性别的加工通路是并行分离的。本研究旨在探讨对面孔的整体加工发生在知觉加工的早期阶段，例如结构编码阶段，还是发生在具有任务特定性的知觉加工的晚期阶段。

在研究一中，实验采用面孔组合范式，一共有三种不同的面孔组合：上半张脸和下半张脸的身份相同，但表情不同；上半张脸和下半张脸的表情相同，但身分不同；上半张脸和下半张脸的身份和表情皆不相同。研究一的结果发现，当要求被试识别半张脸的身份（或表情）时，识别表现会受到另半张脸的身份（或表情）相同与否的影响，然而不会受到另半张脸的表情（或身份）相同与否的影响。说明对面孔身份和对面孔表情的整体加工是彼此独立的。在研究二和研究三中，从个体差异的角度探讨对面孔身份和表情的整体加工，以及面孔身份和性别的整体加工之间的关系。结果发现，无论对面孔身份和表情的整体加工还是面孔身分和性别的整体加工，它们之间都是彼此独立的。

本研究结果表明，面孔的整体加工并不发生于知觉加工的早期阶段，而是发生在知觉加工的晚期阶段。此外，整体加工具有任务特定性，取决于对面孔信息（比如身份、表情、性别）的判断。

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# Chapter 1

## Literature Review

An old saying states that the face is the mirror of the mind. Starting from birth, most of us are living in a world full of faces. For its uniqueness, face processing is often said to be distinct from other objects in that it is processed holistically (Farah, Wilson, Drain & Tanaka, 1998; Kanwisher, Tong & Nakayama, 1998; Tsao & Livingstone, 2008). The holistic nature of the face essentially reflects the obligatory processing of all information from a face so that it is difficult to attend exclusively to part of it. The current project examines the locus of holistic processing, i.e., when holistic processing takes place in face processing. The central question we will ask here is whether holistic processing takes place during the early perceptual encoding stage or later stages specific for different facial judgments. Answering this question will improve our understanding on: 1) how humans extract the holistic information of face temporally; 2) how models of face perception can be modified. In the literature review below, I will firstly introduce the classic models of face perception historically. Secondly, I will describe the holistic processing as found in facial judgment and discuss the widely-used paradigms in which holistic processing can be measured. Then I will summarize the recent evidence on holistic processing for other facial judgments such as facial expression, gender categorization and facial attractiveness, etc. Finally, I will introduce the hypotheses and logic of the current study.

## 1.1 Stages of Face Processing

Bruce and Young (1986) proposed a functional model of face recognition which described the different pathways and steps involved in face processing (See Figure 1). According to the model, the initial step of face processing is structural encoding, i.e., visual encoding of faces to result in information useful for different facial judgments. Structural encoding includes *view-centered descriptions* as well as *more abstract, expression-independent descriptions* both of the global configuration and of facial features. View-centered descriptions provide information for later analyses of facial speech, expression and directed visual processing. The more abstract, expression-independent descriptions provide information for the face recognition units which contain stored structural codes describing one of the faces familiar to an observer. If there is match between stored representation and the input provided by structural encoding when a face is perceived, the face recognition unit can be activated. Moreover, there may be an early face detection stage proposed by Tsao and Livingstone (2008) recently. They posit that the most basic aspect of face perception is simply detecting the presence of a face, which requires the extraction of features that it has in common with other faces. After a face is detected, it must be measured in a way that allows for accurate, efficient identification which may lead to a more efficient classification process in terms of identity, gender, age, race and expression. The face detection stage here has been supported by finding that a cortical region in the temporal lobe consists entirely of face-selective cells through single unit recording in face processing (Tsao et al., 2006) and then different facial judgment processes take over to an extent depending on task demand. On the other hand, some neural studies show that face processing proceeds through two stages: an initial stage of distinguishing between face and non-face, and a later stage at which the identity of the individual face is extracted (Liu, Harris & Kanwisher, 2002). It should be stressed that structural encoding stage in terms of Bruce and Young's model is not considered as a face detection stage to differentiate face and nonface, but rather as a level of extracting the features of a face essential to distinguish it from other faces (Rossion & Gauthier, 2002).

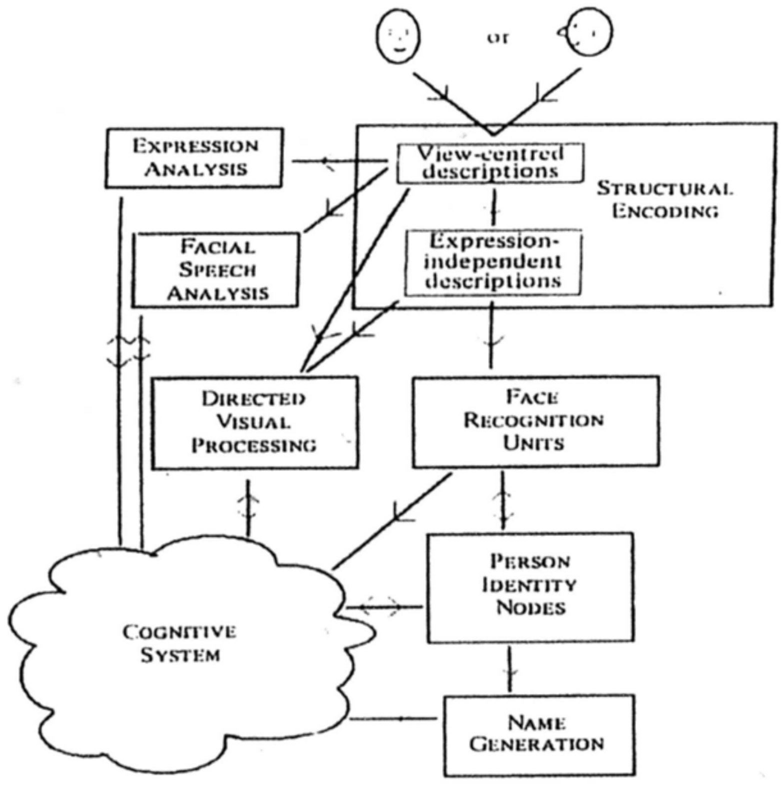



*Figure 1.* Functional model of face recognition by Bruce and Young (1986).

The output of the structural encoding stage then feeds to separate pathways responsible for processing different aspects of facial information, such as identity, expression, and speech-related movements. A possible neural basis for this model has been proposed by Haxby, Hoffman, & Gobbini (2000). Specifically, different neural structures are involved when people process facial information, including dynamic characteristics such as expression, gaze and lipspeech compared with nonchangeable characteristics, such as identity. Processing of changeable facial properties engages the inferior occipital gyri and superior temporal sulcus (STS), whereas processing of invariant facial properties involves the inferior occipital gyri and lateral fusiform gyrus (Calder & Young, 2005). Therefore, according to the well-known Bruce and Young model (1986) and the neurological account of face perception proposed by Haxby and colleagues (2000), the process underlying the judgment of emotional expression is independent of those responsible for judging facial identity. In addition to the abovementioned studies, which were involved with the critical question regarding the visual pathways for recognition of facial identity and facial expression were separate or interconnected at the function level, some researchers began to explore the relationship between facial identity and gender judgment within the framework of Bruce and Young's model (1986). It was also very important, for familiar and unfamiliar faces, that some information referred as visually derived semantic code could be obtained during the structural encoding process in which judgment about age and sex was dependent on perceived faces. As mentioned in this model, sex is a kind of "visually derived semantic information" that can be extracted equally, and is thought to be processed later in parallel to facial identity processing. Some evidence from behavioral studies (Bruce, 1986) and neuroimaging studies (Mouchetant-Rostaing et al., 2000) on human provide the support for the independence of two pathways regarding facial identity and gender. Furthermore, the analysis of facial speech, expression analysis, face recognition units, directed visual processes and person identity nodes provide information to the rest of the cognitive system.

However, as Bruce and Young's model has been influential in the understanding of face recognition, Ellis (1986) proposed another cognitive model of face recognition (See Figure 2). In this model, face perception begins with an initial stage of structural encoding. Following this, two aspects of information including judging facial identity and gender are processed successively. Structural encoding firstly enters into a process of physical analysis in which a face is categorized in terms of a number of dimensions like gender, age and race. At the same time, expression is processed in parallel to face identity. And then the same processing stream continues forward to what Ellis called *face register*, which is similar to the processing of facial identity unit by Bruce and Young (1986). The critical difference between these two models is that facial identity and gender judgment is conducted by separate routes in Bruce and Young's model and a single route in Ellis' model.

This single route has been supported by recent behavioral experiments indicating that processing of identity and gender are integral (Rossion, 2002, Ganel & Goshen-Gottstein, 2002; Clutterbuck & Johnston, 2004; Richards & Ellis, 2008). For instance, Ganel and Goshen-Gottstein (2002) investigated this question using Garner's speeded-classification task in which participants were required to make speeded classifications of familiarity while ignoring the irrelevant changes in sex. The results indicated that participants could not selectively attend to sex without being influenced by irrelevant variations in familiarity, and they could not selectively attend to familiarity without being affected by irrelevant variations in sex. The logic behind these studies is that if the processes underlying the judgment of gender are dependent of those responsible for judging the familiarity of faces, the speed of gender judgment should be affected by the familiarity of the face being judged. Also, this claim was supported by other studies adopting different paradigms (Rossion, 2002). Using morphing faces to generate facial continua of visual similarity to familiar faces, participants were faster at identifying the gender of faces that were perceived as familiar. Richards and Ellis (2008) found that there were similar patterns between the effects of age of acquisition and masculinity in familiarity and gender decision task. Although it is plausible, to some extent, for this claim that identity and gender may be processed throughout the entire range of information processing within a single route, there is another possibility that identity and gender are processed separately, but interact at an initial stage of processing instead of being completely independent of processing.

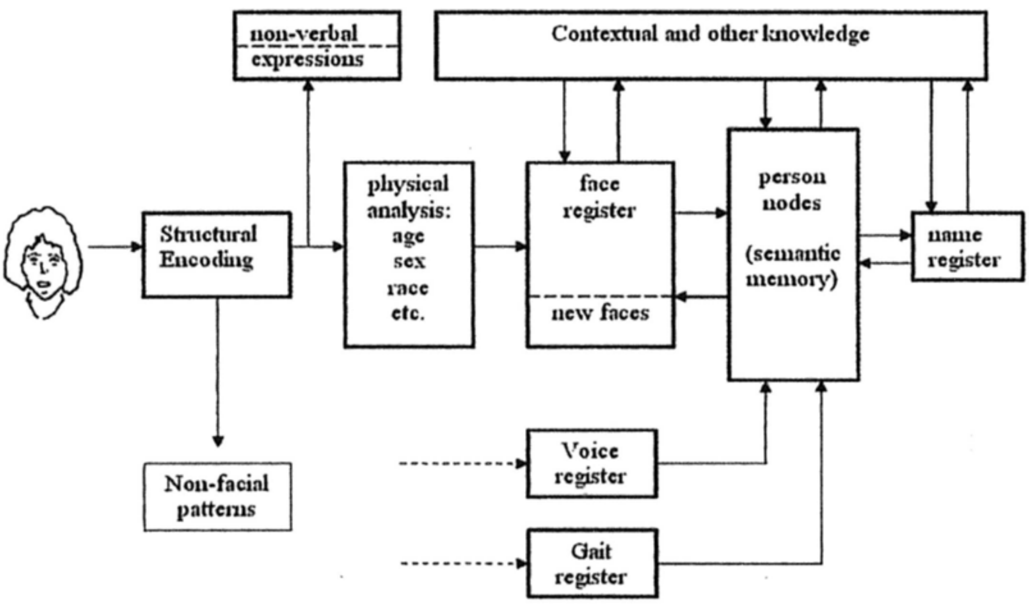


*Figure 2.* An information processing model of face recognition by Ellis (1986).

In short, the models elucidate how faces are processed and how different functional components work in the human face processing system. The core of these two models of face perception is aimed at clarifying the different functional streams involved in face processing and how they interact with each other, as well as what kinds of facial cues are used to perform these functional streams. More importantly, these models provide the theoretical basis for the research question.

## 1.2 Overview of Holistic Face Processing

Face processing has typically been regarded as a special case of object processing. One specific behavioral phenomenon associated with face perception is that faces are processed more holistically than other objects. Face processing has once been assumed to be represented as gestalts (Farah, Wilson, Drain & Tanaka, 1998). Following this, some researchers propose that face perception adopts parallel processing, in that all parts of a face are perceived simultaneously rather than serially, and the processing of different parts influences each other (Bradshaw & Wallace, 1971; Sergent, 1984). Other researchers define holistic processing of faces as a reliance on configural properties, i.e., the spatial relationship among discrete facial features such as the eyes, nose, mouth, etc. (Diamond & Carey, 1986; Rhodes, 1988). On the other hand, holistic processing has arguably been regarded as the most important benchmark of face perception. It has been used as a behavioral marker to distinguish between perception of faces and non-face objects (e.g., McKone, Kanwisher, & Duchaine, 2007; McKone & Robbins, 2007; Richler, Tanaka, Brown &

Gauthier, 2008). Holistic processing has also been used to distinguish between different types of perceptual expertise. For example, in contrast to face expertise, which is marked by an increase in holistic processing, expertise with words and characters come with a decrease in holistic processing (Farah et al., 1998; Hsiao & Cottrell, 2009). Besides, holistic processing has also been used as an indicator that face-like expertise has been acquired with novel, artificial objects in laboratory training studies (Gauthier, Williams, Tarr, & Tanaka, 1998; Wong, Palmeri & Gauthier, 2009).

At the beginning researchers only tried to use indirect ways to measure holistic processing of faces. For example, holistic processing has been measured with inversion of a face. Yin (1969) found that the memory of inverted faces was worse than those shown upright. The interpretation is that when a face is presented upright, perception is based on both featural and configural information, but when it is inverted, perception is based mainly on featural information. Therefore, the performance difference between upright and inverted faces indirectly reflects the magnitude of configural processing.

Later, more direct measures of holistic processing were developed, the most well-known of which is the part-whole paradigm and the composite paradigm. In the part-whole paradigm, holistic processing is indicated by the better recognition of an isolated facial feature (e.g., eyes, nose and mouth) in the context of an entire face than in isolation or when the configural information of the original face is changed (Tanaka & Sengco, 1997). Holistic processing here is indicated by better performance for identifying the facial features within the context of other parts. In this paradigm, participants learn the name-face pairing during a study phase. Then memory of a part of one of the target faces (e.g., Bob's nose) is assessed in a forced-choice recognition test in which the target part appears in isolation, in a new configuration (e.g., with eyes closer together compared with the study face), or in an old configuration (i.e., everything the same as the study face). Results showed that subjects recognized features the best when they were presented in the old configuration, poorer in the new configuration, and the poorest in isolation. One problem with this design is that it can test whether faces are stored holistically in memory, but not necessarily whether faces are perceived holistically. Another problem is that the best performance in the old configuration can be explained by encoding the specificity principle which states that memory is better when the condition during retrieval is more similar to the condition during encoding.

Another popular way to measure holistic processing is the use of the composite paradigm. In this paradigm, a composite face is made by combining the top half of one face with the bottom half of another face and for non-composite face, the top half of one face and the bottom half of another face is misaligned (Young, Hellawell, & Hay, 1987). In the study by Young et al. (1987), the participants were firstly asked to try to remember each face and learn the name of the faces, and then name either the top or bottom segment of composite faces and non-composite face they had remembered before. The result was that it was difficult for the participants to make recognition judgment based on the top or bottom part of the face in the composite face than non-composite face. Later, a sequential matching version of the composite task was first introduced (Hole, 1994). Specifically, participants view two composite faces presented sequentially, and have to judge if the parts (e.g., the tops) of the two composites are the same or not. Holistic processing is regarded as an inability to selectively focus on the task-relevant part and completely ignore the irrelevant part. One version of the composite paradigm adopts a *'partial design'*, in which the irrelevant face parts are always different, while the relevant parts may be the same, or different (McKone & Robins, 2007). In addition, the two face parts are shown in an aligned or a misaligned format. Holistic processing is typically indicated by an alignment effect on same trials, i.e., worse performance when the relevant and irrelevant parts are aligned than misaligned. Then some researchers used another version of the composite paradigm called the *'complete design'* (Gauthier & Bukach, 2007). The main difference from the partial design is that the relevant face parts can be the same or different and the irrelevant parts can also be the same or different, resulting in congruent trials in which both the top and bottom parts can be the same or both of them are different, and incongruent trials in which one of the parts is the same but the other part is different. In such a case, holistic processing is measured by (1) the congruency effect, by comparing the difference between congruent trials and incongruent trials; and, (2) the congruency × alignment interaction, by comparing the congruency effect between aligned and misaligned trials. The complete design includes all the possible conditions such that both same and different trials can be either congruent or incongruent. Critically, both same and different trials are used to measure sensitivity independent of response bias. In other words, the holistic processing effects obtained are not confounded by response bias.

Taken together, so-called holistic processing that was measured by different paradigms makes a difference in understanding the notion of *holistic*. Holistic processing represented in inversion effect concerns the disruption of configural information holding the spatial relationship among facial features. Holistic processing in the part-whole paradigm relies more on the contextual effect in which best performance in identifying the facial feature embedded in old configuration comes from stored representation in memory. Nevertheless, here the focus is on one definition of holistic face processing - the obligatory processing of all information from a face, such that it is difficult to attend exclusively to just one part of it. Therefore, the literature review below emphasizes research on holistic processing defined as obligatory processing of all information, though research on holistic processing, defined as reliance on configural properties, will also be mentioned.

## 1.3 Holistic Processing in Different Facial Judgments

Although the studies discussed so far provide evidence on holistic processing of face identity (Young, et al., 1987; Hole, 1994; Hancock, et al, 2000), the role of holistic processing in facial emotional expression has not come to a conclusion. The earliest study relevant to the issue of whether facial expression is processed holistically or not was held by Ellison and Massaro (1997), who manipulated two facial features, eyebrow deflection and mouth deflection, and asked participants to decide whether each face image signaled a happy or an angry expression. The result showed that participants made their decision on their individual shapes rather than the holistic impression of the face. Recent studies also tried to use different techniques or methods to look into how our brain encodes or decodes facial expressions and which part of the face (upper or lower) could contribute more to facial expression. For instance, Smith et al. (2005) found that human reflected bias to intersection of the lower forehead and eyebrows in the anger expression, the region surrounding the nose in the disgust expression, and mouth in the surprise expression by applying *Bubbles* to estimate how the brain decodes facial signals and classifies the six basic facial expressions. Using morphing faces, Chen and Chen (2010) discovered that the alignment of the upper and lower halves of the face had an effect on classification of facial expressions, and there was also no interaction between the two halves of the face in facial expression classification. This evidence suggests that processing of facial expressions relies much more on facial features. That is, perception and classification of facial expressions is more likely to underlie an analytic process rather than a holistic process.

However, Calder, Young, Keane and Dean (2000) provided the first evidence of holistic processing in facial expression perception by using composite faces formed by combining face halves with different expressions (e.g., sadness for top and happiness for bottom). It has been found that participants were slower and less accurate at identifying the expression of the target part when it's aligned with an irrelevant part compared with the condition when the target and irrelevant parts were misaligned. Following this study, composite effect for facial expression was also occurred with matching paradigm for which subjects were asked to indicate whether the top halves of two composite faces are the same or different. In line with the finding for facial identity, holistic processing for facial expression was disrupted by inversion rather than photographic negative manipulation. To some extent, it suggests a possibility that both facial identity and facial expression reflect a common perceptual mechanism that was involved with holistic encoding operating within the structural encoding stage referred to in Bruce and Young's model (Calder & Jansen, 2005).

Holistic processing has also been shown in other types of facial judgments, such as recognition of gender and rating of facial attractiveness. Earlier studies have shown that facial features, including eyebrows (Brown & Perrett, 1993; Bruce et al., 1993), face outline (Yamaguchi, et al., 1995) may play an important role in understanding the task of gender classification. The role of holistic processing in gender categorization has been demonstrated with better performance for upright than inverted or scrambled faces (Bruce, et al., 1993; Bruce & Langton, 1994; Bruyer, et al., 1993; Zhao & Hayward, 2009). Some researchers used the naming version of the composite paradigm to investigate holistic effects in gender categorization, showing slower responses and more errors when the two parts of a composite face had a different gender in comparison to the same gender, and such interference was larger when the relevant and irrelevant parts were aligned compared with misaligned parts (Baudouin & Humphreys, 2006; Zhao & Hayward, 2009). Using the composite-face paradigm to look for holistic processing in facial attractiveness, Abbas and Duchaine (2008) demonstrated holistic processing in facial attractiveness judgment using the partial design of the composite paradigm. In this study, participants were instructed to ignore the bottom halves and to make their judgments solely on the basis of the top half of each face presented by making the response for indicating which top face was more attractive. The result showed that the top halves of upright faces are judged to be more attractive when aligned with an attractive bottom half than when aligned with an unattractive bottom half. And such a difference was larger when the top and bottom halves were aligned, compared with when the top and bottom halves were misaligned. In addition, holistic effect has been found for judgment of trustworthiness (Todorov, Loehr and Oosterhof, 2010). Specifically, judgment of the facial halves were more positive when aligned with trustworthy than with untrustworthy halves despite the instructions to ignore the aligned parts. This effect was substantially reduced when the faces were inverted or the facial halves misaligned. Therefore, this line of research on holistic processing of face has extended from the nature of face processing itself to other aspects of face processing such as emotional expression, gender categorization and different social judgments.

Therefore, holistic processing found in different facial judgment suggests a possibility that holistic processing may occur at an early structural encoding stage shared by facial judgments. Alternatively, holistic processing may occur for all facial judgments but at a later stage where separate pathways are devoted for processing different aspects of facial information.

**1.4 Issues in the Debate**

Attempts have been made to understand the mechanisms underlying holistic face processing. Questions have been asked about the time-course of holistic processing (Richler, Mack, Gauthier & Palmeri, 2009), whether holistic processing has a perceptual and/or decisional basis (Cheung & Gauthier, 2010), the neural correlates of holistic processing (Maurer, Le Grand, & Mondloch, 2002), etc. Goffaux and Rossion (2006) firstly attempted to study the holistic face processing by means of composite tasks with faces filtered by spatial frequency. It was found that the holistic effect was larger for faces containing only low spatial frequency compared with those containing only high spatial frequencies or full spectrum faces, suggesting that holistic processing may happen at an early stage of face processing because low spatial frequency information can be extracted at a more rapid representation. The finding is also supported in the study by Richler et al. (2009) in which holistic processing could be observed for exposure as rapid as 50ms, yet the holistic effects were neither especially large when the presentation time is short nor getting larger with the increase of presentation time. And a similar finding was also found in holistic face processing in judging whether the face looked trustworthy or untrustworthy (Todorov, Loehr & Oosterhof, 2010). In other words, the magnitude of the holistic effect would not be influenced by manipulation of perceptual encoding time though it may emerge rapidly, suggesting another possibility that holistic processing may arise at later stages of face processing, in which local information of faces such as facial features are initially represented independently but integrated when decisions are made about them. Therefore, the study by Goffaux and Rossion (2006) only provides the indirect link between perceptual encoding time and holistic processing. Although recent studies (Richler et al., 2009; Todorov et al., 2010) have demonstrated that holistic processing could emerge at short presentation time, the findings from these studies can't exclude another possibility that holistic processing could happen at a later, task-specific stage of face processing. These studies only adopted composite face paradigm by manipulating the perceptual encoding duration of facial identity at the study or test phase. So far there is no conclusive evidence for probing the locus of holistic processing by examining if it takes place during the early perceptual encoding stage or later stages, depending on different facial judgment tasks such as facial identity, emotional expression judgment and gender categorization.

In order to clarify the locus of holistic processing, some researchers regarded face perception process as disentangling perceptual and decisional stages (See also Cheung & Gauthier, 2010). The separation of two processes is based on the point where participants have to form a perceptual representation of a stimulus for a particular task and interpret the percept and select a response in terms of task before producing a response. Most of the studies adopted two methods: One was to examine the magnitudes of the holistic effect induced by manipulation during the perceptual coding stage (or study phase) and decisional judgment stage (or test phase) in different tasks, the other one was to examine the perceptual and decisional effects by assessing sensitivity and response bias that affect judgments in tasks measuring holistic processing (Richler, Gauthier, Wenger & Palmeri, 2008). However, there is still a debate whether the perceptual stage or decisional stage is much more important to face holistic processing even when the two methods have been adopted to examine this question. For instance, some studies found that the inversion effect was larger during the study phase than that during the test phase on face processing (Farah, 1995), implying perceptual coding may be important to holistic processing. In contrast, perceptual coding of whole faces during study phase was not necessary to produce the holistic effect at the test phase. For instance, a larger inversion effect was found for face parts than for whole faces presented during the test phase (Moscovitch & Moscovitch, 2000). So it is possible that decisional components might be crucial in holistic processing.

However, it is difficult to completely separate perceptual encoding stage and decision stage from face perception process. Despite the aim of this project is to probe the locus of holistic processing as well, the current study would not separate the perceptual encoding components and decisional components by experimental manipulation as compared with previous studies. Instead, the current study tries to distinguish early perceptual encoding processing from late task-specific processing on the basis of face models as mentioned above. On the other hand, most interesting for this study, it is the first attempt to probe the locus of holistic processing among the relationship revealed by different facial judgments including facial identity, expression and gender. Unlike previous studies that only examine this question by a single route that is processed by facial identity, this study goes beyond the previous studies. Facial judgment in real life involves more aspects such as emotion, gender and attractiveness, etc. Therefore, the current project asks whether holistic processing is mainly supported by processes engaged in the early face processing stage, or by processes involved in separate analyses of different types of facial information.

One possibility is that holistic processing takes place at an early stage of face perception, which has been supported by early detection gating hypothesis emphasizing that holistic processing can be explained by an obligatory detection stage that uses a coarse template to detect whole faces (Tsao & Livingstone, 2008). Specifically, if holistic face processing occurs during an early perceptual coding stage, then one should expect a correlation between holistic processing of facial identity and expression, as well as a correlation between holistic processing of facial identity and gender categorization because facial identity, emotional expression and gender categorization take parallel routes but are processed initially at the perceptual encoding stage. In other words, the overlapping mechanism for holistic processing may occur at an early stage of face processing regardless of task. It means that holistic processing may be crucial in the early stages of face processing and have been less influenced by task-specific face processing.

Another possibility is that holistic processing does not arise during face detection but rather emerges later, depending on processing of different types of facial information. If this is the case, then holistic processing for identity, expression and gender categorization should occur independently of each other because of parallel routes. Also, the expectation is that there is no correlation between holistic processing for facial identity and emotional expression, as well as for facial identity and gender categorization. Calder, Young, Keane and Dean's (2000) study provides support for this possibility by examining the relationship between holistic processing for facial identity and expression. In their study, three types of composite faces were prepared: (i) the target and irrelevant parts had the same identity posing different facial expressions; (ii) the two parts had different identities posing the same facial expression; and (iii) the two parts had different identities posing different facial expressions. A naming task was used in which the participants were instructed to look at a set of non-composite faces and try to remember their names during the training phase. Afterwards, they were asked to indicate the name or expression of a face part by making a button-press response. The rationale of this study was that if holistic processing in identity and expression are independent, then judgment about expression would not be affected by the incongruent identity between the top and bottom parts, and thus performance should not differ in identifying the expression shown in the bottom half of the same identity and different expressions, or different identities and different expressions. The same would be true for the performance in identity judgment. As was demonstrated, participants were significantly slower to perform the task (the identity or expression) that they were asked to attend to was incongruent across the two face halves. Results showed that even if the unattended attribute (e.g., identity or expression) was incongruent across the two halves, there was no additional significant RT cost. One issue of this study is that although reaction time data suggest independent holistic processing of identity and expression, accuracy data showed signs of evidence for a common mechanism: participants significantly made much more errors when performing the task when the unattended attribute (e.g., identity or expression) was incongruent rather than congruent, implying that judgment about identity is influenced by the incongruent expression between the top and bottom halves, and judgment about expression is influenced by the congruent identity between the top and bottom halves. In addition, a line of studies only focuses on the testing, if the relationship among facial identity, expression and gender categorization are independent or not. However, so far there have been no studies that directly point to the locus of holistic processing from the perspective of the relationship among holistic processing revealed by facial identity, expression and gender categorization. More importantly, although the locus of holistic processing is still an issue now, it provides a perspective for understanding the underlying mechanism of face perception.

**1.5 The Current Study**

In the current study, my aim was to probe the locus of holistic processing by examining the relationship between holistic processing of facial identity and expression information in Study 1 and 2, as well as the relationship between holistic processing of facial identity and gender categorization in Study 3. In the methodology, I adopted the naming version of the composite paradigm. This was because the composite paradigm was the most appropriate tool to measure the construct underlying holistic processing defined in this study in contrast to the inversion and part-whole paradigm.

In Study 1, I followed the study by Calder et al. (2000). Although the aim of their study pointed directly to the question whether facial identity and expression were independent or not, data on reaction time and accuracy was inconsistent. So I made some improvement to the basic procedure in the Calder et al. (2000) study and added more trials to re-examine the question.

In Study 2, I used an individual difference approach (Vogel & Awh, 2008) to demonstrate the associations on holistic processing between facial identity and emotional expression tasks. The logic of Study 2 was that if the holistic processing occurred at an early structural encoding stage, then the holistic processing between identity and expression tasks should be highly correlated across individuals. On the other hand, if holistic processing occurred in later, task-specific processing stage where separate pathways were devoted for processing identity and expression, then there would be little or relatively low correlation between holistic processing of the identity and expression tasks.

In Study 3, I also used an individual difference approach to demonstrate the associations on holistic processing between facial identity and gender categorization tasks. The logic of Study 3 was similar to that of Study 2. If holistic processing took place during the early structural encoding stage, then the holistic processing between identity and gender tasks should be highly correlated across individuals. Otherwise, if holistic processing took place at a later, task-specific stage of face processing, then there would be little or relatively low correlation between holistic processing of the identity and gender categorization tasks.

# Chapter 2

## Holistic Processing for Identity and Expression: Independent Processing or not?

In this chapter, using selected faces based on Pilot Study 1 and 2, the objective of Study 1 was to examine the locus of holistic processing that was revealed by the relationship on holistic processing for both facial identity and emotional expression. It was expected that holistic processing for identity and expression would be independent of each other, suggesting that holistic processing might take place at a later stage of face processing.

### 2.1 Pilot Study 1

The objective of pilot Study 1 was to select the best emotional faces that could meet two standards: 1) Either top or bottom segment of each face was expressive; 2) The whole face was expressive enough to be identified. The main reason was that if the expression posed by face models was not expressive enough, participants' performance on identifying the expression would be affected due to the nature of the face stimuli, so that the accuracy to identify the emotional expression was probably low. In addition, in the formal experiment, composite emotional faces posing same or different expressions were used, which was combined by the top part of one face posing one type of expression with the bottom part of another face posing another type of expression. Participants were asked to identify the expression of either the top or bottom part of composite faces. Thus, it was important to select the faces, either the top or bottom part of the face which was expressive.

2.1.1 Method

*Participants.* Fifteen participants (6 males, 9 females) .at the Department of Psychology in The Chinese University of Hong Kong took part in this pilot experiment for credit. Participants were between 19 and 20 years of age. All had normal or corrected-to-normal vision.

*Materials.* Eighteen models (9 males, 9 females) were recruited to take personal pictures. Each model was asked to pose neutral as well as six types of expressions (angry, disgust, fear, sad, surprise and happy) while their pictures were taken, resulting in 126 (108 expressive + 18 neutral) whole face images in total. Each grayscale face image was processed with Adobe Photoshop CS2 and was masked by an oval shape to eliminate hair, beards, or other salient peripheral details. The size of the oval was 350 pixels in width and 350 pixels in height. Each of the 108 images with facial expressions was divided into top and bottom segments at the bridge of the nose. Each resulting face image was 260 pixels in width × 300 pixels in height. The face images were presented on an LCD monitor with a 1680 (H) × 1050 (V) resolution and a 60-Hz temporal refresh rate.

*Design and procedure.* There were three blocks, the order of which was counterbalanced across subjects. In each block, participants viewed either 108 whole faces, 108 face tops, or 108 face bottoms. They were asked to take a break when they had finished seeing half of the 108 faces in each of the three blocks. In each trial, a fixation cross was shown for 500ms followed by a face image, which remained in view for 5000ms or until the participant responded. The face tops were presented in the location corresponding to the top half of a whole face and face bottoms in the location corresponding to the bottom half of a whole face. Each image subtended a vertical visual angle of approximately $4.6^{\circ}$, and a horizontal visual angle of approximately $5.7^{\circ}$. Participants were asked to identify the expression of each face stimulus and respond as accurately as possible by pressing the keys indicated by six different types of expressions (S-Angry, D-Fear, F-Disgust, J-Sad, K-Surprise, L-Happy). To familiarize the participants with the face images, the actual experiment was preceded by six practice trials selected at random from the 324 experimental trials.

**Table 1. Proportion of Correct Expression Naming in Pilot Study 1.**

| | Male | | | | | |
|---|---|---|---|---|---|---|
| Face format | Whole | | Top | | bottom | |
| Emotion | *M* | *SE* | *M* | *SE* | *M* | *SE* |
| Angry | 0.25 | 0.02 | 0.18 | 0.01 | 0.25 | 0.03 |
| Disgust | 0.58 | 0.02 | 0.30 | 0.02 | 0.29 | 0.01 |
| Fear | 0.16 | 0.01 | 0.10 | 0.01 | 0.08 | 0.01 |
| Sad | 0.70 | 0.02 | 0.61 | 0.03 | 0.59 | 0.02 |
| Surprise | 0.69 | 0.03 | 0.22 | 0.03 | 0.61 | 0.04 |
| Happy | 0.93 | 0.02 | 0.84 | 0.03 | 0.84 | 0.03 |

| | Female | | | | | |
|---|---|---|---|---|---|---|
| Face format | Whole | | Top | | bottom | |
| Emotion | *M* | *SE* | *M* | *SE* | *M* | *SE* |
| Angry | 0.37 | 0.03 | 0.24 | 0.02 | 0.21 | 0.02 |
| Disgust | 0.50 | 0.03 | 0.35 | 0.03 | 0.28 | 0.03 |
| Fear | 0.14 | 0.01 | 0.15 | 0.01 | 0.11 | 0.01 |
| Sad | 0.64 | 0.02 | 0.46 | 0.03 | 0.52 | 0.03 |
| Surprise | 0.67 | 0.03 | 0.39 | 0.03 | 0.43 | 0.03 |
| Happy | 0.98 | 0.00 | 0.95 | 0.01 | 0.94 | 0.01 |

2.1.2 Results and Discussion

Participants' mean correct proportions were involved with repeated measures analysis by each face model. Two factors were investigated: face format (top segment, bottom segment and whole faces; repeated measures) and emotional expression (angry, disgust, fear, sad, surprise and happy; repeated measures).

Firstly, the analysis showed that there was a significant effect of emotional expression, $F$ (5, 85) = 63.95, $p$ <.0001; Post hoc-t tests (Bonferroni) indicated that accuracy for happy was significantly larger than that for angry, disgust, fear, sad and surprise, $p$ < .0001; accuracy for surprise was significantly larger than that for angry ($p$ = .001) and fear ($p$ < .0001); accuracy for sad was significantly larger than that for angry ($p$ < .0001), disgust ($p$ = .047) and fear ($p$ < .0001). Therefore, as can be seen from Table 1, three types of emotional expression, happy, surprise and sad, were more readily identified by participants than other expressions like angry, disgust and fear.

Secondly, there was a significant effect of face format, $F$ (2, 34) = 20.86, $p$ < .0001, indicating that the accuracy for identifying the expression of whole faces was significantly larger than that for identifying the expression of top segment of faces and bottom segment of faces, which did not reliably differ. Also, an interaction effect between face format and expression was significant, $F$ (10, 170) = 3.24, $p$ = .001; Simple effects analysis by each face model showed significant effects of face format for all emotional expressions except angry and fear. It suggested that even though the accuracy for identifying the happy, surprise and sad for whole faces was significantly larger compared with that for identifying the disgust, angry and fear, the accuracy for identifying the happy, surprise and sad expressions seemed not be distributed equally across the face tops, face bottoms and whole faces. As Table 1 shows, accuracy for identifying the top part of face was lower than the bottom parts and whole face especially for surprise face. However, it was expected that, for selected face stimuli, there should not be a large discrepancy among accuracy for face tops, face bottoms and whole faces.

Thirdly, on the basis of preliminary results from repeated measure analysis, the range of face stimuli selection was limited to three types of emotional expressions: happy, surprise and sad. Further analysis was aimed at investigating if there was a difference of gender of face model in happy, surprise and sad regardless of face format. Participants' mean correct proportions were then submitted to a repeated measures analysis, with gender of face model as between-face model factors and expression as within-face model factors. The accuracy for identifying the female face model was larger than that for identifying the male model (60.0% vs. 55.6%) though it didn't reach a significant level.

To summarize, three types of emotion expressions (sad, surprise and happy) were selected because they were most expressive. Also, female face models were more expressive than male face models. But it was difficult to select the face stimuli in which not only whole faces were most expressive, but also either top or bottom segment of faces was most expressive during the first pilot study. The participants' correct proportion was relatively low in surprise and sad.

2.2 Pilot Study 2

Following Pilot Study 1, Pilot Study 2 aimed at selecting the best faces within the range of female faces with sad, surprise and happy expressions.

2.2.1 Method

*Participants.* Fifteen participants (5 males, 10 females) at the Department of Psychology in the Chinese University of Hong Kong took part in the pilot study. Participants were between 18 and 19 years of age. All the subjects had normal or corrected-to-normal vision and received monetary compensation (HK$10).

*Materials.* Images of nine female face models (9 females) with three different types of expressions (sad, surprise and happy) were used (See Figure 3). The nine female face models were the same models as in Pilot Study 1.

*Design and procedure.* The design and procedure were same as the first pilot study except that there were 27 whole faces, 27 top segments of faces and 27 bottom segments of faces in respective three blocks. The order of three blocks was counterbalanced across subjects. Participants were asked to identify the expression of each face stimulus and make a response as accurately as possible by pressing the keys indicated by three different types of expressions (J-Sad, K-Surprise, L-Happy). The entire session lasted approximately for 5 minutes.

**Table 2. Proportion of Correct Expression Naming in Pilot Study 2.**

| | Top | | | Bottom | | | Whole | | |
|---|---|---|---|---|---|---|---|---|---|
| Model | Sad | Surprise | Happy | Sad | Surprise | Happy | Sad | Surprise | Happy |
| 1 | 0.80 | 0.93 | 0.93 | 0.87 | 0.93 | 0.93 | 0.86 | 0.87 | 0.93 |
| 2 | 0.53 | 0.87 | 0.93 | 0.87 | 0.87 | 0.87 | 0.80 | 1.00 | 0.93 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 0.87 | 0.73 | 0.93 | 0.93 | 0.80 | 0.93 | 0.93 | 0.67 | 0.93 |
| 4 | 0.79 | 0.93 | 0.27 | 0.86 | 0.13 | 0.93 | 0.93 | 0.67 | 0.93 |
| 5 | 0.73 | 0.71 | 0.93 | 0.80 | 1.00 | 0.93 | 0.93 | 1.00 | 0.93 |
| 6 | 0.67 | 0.43 | 0.80 | 0.80 | 0.67 | 0.87 | 0.73 | 0.53 | 0.93 |
| 7 | 0.87 | 0.27 | 0.80 | 0.60 | 0.00 | 1.00 | 0.71 | 0.07 | 0.93 |
| 8 | 0.80 | 0.64 | 0.80 | 0.27 | 0.73 | 0.87 | 0.93 | 0.87 | 0.93 |
| 9 | 0.80 | 0.50 | 0.87 | 0.67 | 0.73 | 0.93 | 0.80 | 0.80 | 0.93 |
| Total | 0.76 | 0.67 | 0.81 | 0.74 | 0.65 | 0.92 | 0.85 | 0.72 | 0.93 |

2.2.2 Results and Discussion

As Table 2 shows, the 1st, 2nd 3rd and 5th face models were most expressive regardless of face format since not only accuracy for identifying the whole faces, but also the accuracy for identifying the top or bottom segment of face was above chance level (50%). Finally, I decided to make use of the 2nd, 3rd and 5th face model but not the 1st face model because nose position of the 1st face model was not located at the center of the whole image, so that it was not good enough to be composed with other halves of face stimuli. Composites faces, using either the top or bottom half of the 1st face model and other face models, did not match (i.e. the top part was not aligned with the bottom part), thus the composite face was not like whole face.

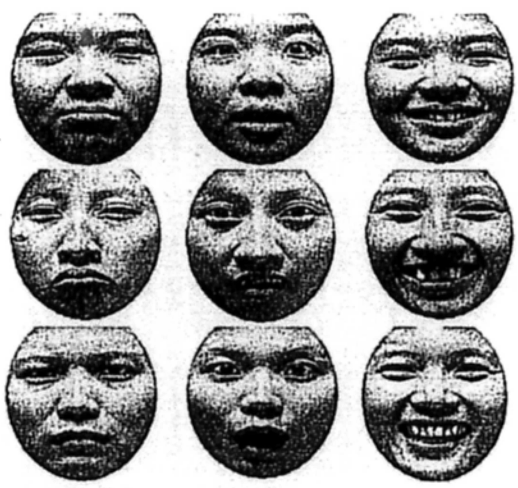


**Figure 3. Stimulus selected for actual experiments based on pilot study results. The rows**

**represent the three models and the columns represent the sad, surprised, and happy expressions respectively.**

## 2.3 Study 1 - The Relationship between Facial Identity and Emotional Expression on Holistic Processing of Faces

In this study, three types of composite faces were used where the two face halves differed in identity, expression, or both: a) same expression posed by different face models (same-expression-different-identity); b) different expressions posed by different face models (different-expression-different-identity); c) different expressions posed by same face model (different-expression-same-identity). The prediction was that if participants' performance on recognizing the identity (or expression) from half of the face was influenced by incongruent identity (or expression) from the other half, but unaffected by incongruent expression (or identity) from the other half, it suggested that holistic processing of identity and expression were independent of each other. On the other hand, if participants' performance on recognizing the identity (or expression) was influenced by incongruent identity (or expression) from the other half, but also their performance on recognizing the identity (or expression) was affected by incongruent expression (or identity) from the other half, suggesting that holistic processing of identity and expression were interdependent.

### 2.3.1 Study 1a

#### 2.3.1.1 Method

*Participants.* Eighteen participants (9 males, 9 females) at the Department of Psychology in the Chinese University of Hong Kong took part in Study 1 for credit.

All subjects had normal or corrected-to-normal vision. Participants were between 19 and 21 years of age. Two participants were discarded from the seventeen participants because the accuracy for at least one of three conditions was less than 33.3% (below chance level).

*Materials.* Four faces (sad, surprise, happy, neutral) from each of the three individuals were chosen based on the results of Pilot Study 2. Each face image was 260 pixels in width × 300 pixels in height. The top and bottom halves of each face were cut along the bridge of the nose and were used to create 12 composite faces. The images of the top halves of faces were 260 pixels in width × 120 pixels in height, and the images of bottom halves of faces were 260 pixels in width × 180 pixels in height. The horizontal line was 2 pixels wide. Three types of composite faces (See Figure 3) were made by combining the top and bottom halves of faces with (a) the same expressions posed by different face models (different-identity-same-expression), (b) different expressions posed by different face models (different-identity-different-expression), (c) different expressions posed by the same face model (different-expression-same-identity). The visual stimuli were presented with E-Prime 1.1 on 15 –in. CRT monitor controlled by a PC computer. The CRT monitor had a 1024 (H) ×768 (V) spatial resolution and a 75 Hz temporal refresh rate.

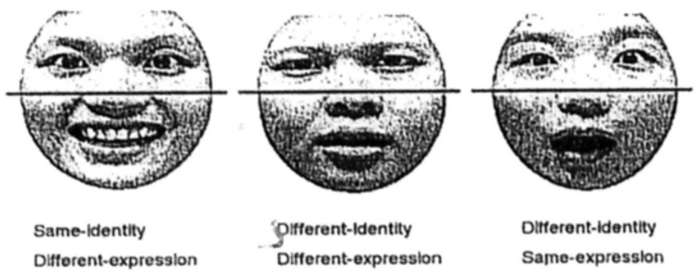



*Figure 4*. Three types of composite faces.

*Design and procedure.* Three within-subject factors were investigated: composite type (different expression-same identity, same expression-different identity and different expression-different identity), type of tasks ("identity judgment" and "expression judgment") and decision for the part ("top segment of composite face" and "bottom segment of composite face").

*Identify-the-person trials*. The section began with a training session. In this training session, the three faces with neutral expression were presented individually and each of them was assigned a name at random (ROSE, MARY, ANNA). The names were presented in uppercase letters below the face. Each face-name pair was presented 5 times for 5 seconds each in random order. The participants were asked to look at the faces and try to remember their names.

Following this, the faces posing the three facial expressions, sad, surprised and happy, were presented individually and without name labels. The participants were asked to identify each face's name by pressing one of three keys marked with names (e.g., J for ROSE, K for MARY, L for ANNA) as quickly and accurately as possible. Each of the nine images (3 faces × 3 expressions) was presented 2 times in random order, resulting in 18 trials in total in this session. In each trial, a fixation cross was shown for 500ms followed by a face image, which remained in view for 3000ms or until the participant responded, with their response initiating the next trial after an interval of approximately 1second. The participants were given feedback after each image was presented so that they could know if the response to each trial was correct or not. If participants made a right response, "correct!" would be shown on the screen. Otherwise if participants made an error, they would be given the hint - "incorrect! And the correct response should be…" The participants were asked to try it again until all the trials reached 100% accuracy.

Next, half of the participants were presented with the top halves of the same faces and half of the participants with the bottom halves of the same faces. Each image was presented individually three times in random order, and the participant's task was to indicate each face name by making a key-press response. The participants were given feedback after each image was presented so that they could know if the response to each trial was correct or not. If participants made a right response, "correct!" would be shown on the screen. Otherwise if participants made an error, they would be given the hint -"incorrect! And the correct response should be…" The participants were invited to try it again until all the trials reached 90% accuracy for both of top and bottom part sessions. Following this, the participants who had seen the top sections were presented with the bottom sections of the same faces and vice versa. Therefore, the order of the top and bottom judgment of faces was counterbalanced across participants.

Lastly, the participants were presented with the three types of composite faces (different-expression-same-identity, different-expression-different-identity, and same-expression-same-identity) in random order; each image was presented three times. For different-expression-different-identity composites, there were 36 composite faces in the stimulus set (compared with 18 only for the other two types of composites). Given the different number of images in the three types of composite faces, the number of composite faces was divided into two stimulus sets at random. Half of the participants were assigned to one stimulus set and half to the other, such that for each participant there were 18 different images for each type of composite faces. Each image subtended a vertical visual angle of approximately 4.6˚ and a horizontal visual angle of approximately 5.7˚ .The participants were asked to identify the name of either the top or bottom half of each composite face by pressing one of the three keys listed above. Half of the participants judged the top half of faces firstly and then the bottom half of faces, and vice versa for the other participants. And each composite face was presented three times in each condition. There were 324 trials in total for both of the top and bottom half of faces. To familiarize the participants with the composite images, the actual experiment was preceded by six practice trials selected at random from the 324 experimental trials.

*Identify-the-expression trials.* The section began with exactly the same training session described above, in which each model was presented five times with a neutral expression and their name labels. Next, the same three faces were presented posing the expressions sad, surprised and happy, and participants were asked to identify their facial expression by pressing one of three keys (1-Sad, 2-Surprise, 3- Happy) as quickly and accurately as possible. Each face was presented two times in random order. The participants were given feedback after each image was presented so that they could know if the response to each trial was correct or not. If participants made a right response, "correct!" would be shown on the screen. Otherwise if participants made an error, they would be given the hint -"incorrect! And the correct response should be..." The participants were asked to try it again until all the trials reached 100% accuracy. In all other aspects, the design of the identify-the-expression trials was the same as the identifying – the – person trials described above. The only difference was in the task instruction in which participants were asked to identify the expression shown in either the top or bottom half of the three types of composite faces.

**2.3.1.2 Results**

*Training session.* Two within-subject factors were investigated with face format (whole faces, top segment of faces and bottom segment of faces; repeated measures) and types of tasks (identity judgment or expression judgment; repeated measures). As Table 3 shows, the repeated measures analysis demonstrated that there was significant effect of types of tasks, $F(1, 15) = 25.61$, $p < .0001$, indicating that participants took significantly more blocks to learn the facial identity than facial expression. Also, there was significant interaction between types of tasks and face format, $F(2, 30) = 4.23$, $p = .024$. Simple effects analysis showed a significant effect of face format for types of tasks: expression judgment, $F(2, 30) = 3.32$, $p = .05$, and identity judgment, $F(2, 30)$

= 3.65, $p$ = .038. Post hoc t tests showed that, for the expression judgment, the blocks that were taken at learning the whole faces was significantly more than learning the bottom segment of faces, $p$ = .043; for identity judgment, there wasn't any difference in times that were taken at learning the whole faces, the top and bottom segment of faces (all $ps > .05$).

**Table 3.** The mean blocks for which participants could reach 100% accuracy on whole faces and 90% accuracy on either top or bottom segment of faces during three types of training session (whole faces, top segment of faces and bottom segment of faces) for Study 1a.

| Types of tasks | Face format | | |
|---|---|---|---|
| | whole face | Top | Bottom |
| Facial identity | 3.38 | 2.06 | 4.19 |
| Facial expression | 1.63 | 1.38 | 1.06 |

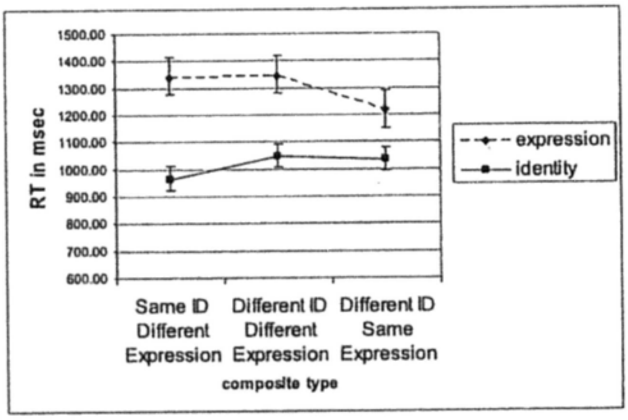
*Formal experiment session.* Data were submitted to repeated-measures ANOVA with three factors: composite type (different expression-same identity, same expression-different identity, and different expression-different identity), types of tasks ("identity judgment" and "expression judgment") and decision for the part ("top segment of composite face" and "bottom segment of composite face"). Data from two participants were excluded from analysis because the accuracy for one of three conditions was lower than 33.3% (chance level). For RTs, correct trials with an RT below 150 msec or more than 3 standard deviations from the mean of all the correct trials in all conditions were not included in the analysis. The removed trials accounted for 1.54% in all the correct trials for decision for the top part and bottom part.

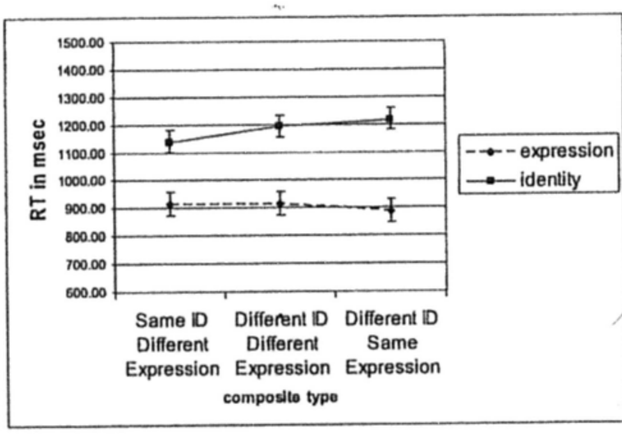
*RTs.* Firstly, there was a significant effect of composite type, $F$ (2, 30) = 4.22, $p$ = .024.

Also, there was a significant effect of decision for the part, $F(1, 15) = 7.00$, $p = .018$, indicating that RTs to the bottom part were significantly faster than those to the top part.

Secondly, there was a significant interaction effect between types of tasks and composite type, $F(2, 30) = 12.42$, $p < .0001$. Simple effects analysis showed a significant effect of composite type for types of tasks: expression judgment, $F(2, 62) = 7.51$, $p = .001$, and identity judgment, $F(2, 62) = 7.60$, $p = .001$. Post hoc t-tests (Bonferroni) showed that during expression judgment, performance was better when the irrelevant part showed the same rather than different expressions, as indicated by the faster responses for the different-identity-same-expression condition than the same-identity-different-expression ($p = .023$) or different-identity-different-expression condition ($p = .002$). The latter two conditions did not differ from each other, suggesting that whether the irrelevant part showed the same identity or not did not matter during expression judgment; during the identity judgment, performance was better when the irrelevant part showed the same rather than different identities, as indicated by the faster response for the same-identity-different-expression condition than the response for the different-identity-same-expression ($p = .010$), or different-identity-different-expression condition ($p = .012$). The latter two conditions did not differ from each other, suggesting that whether the irrelevant part showed the same expression or not did not matter during the identity judgment.

Thirdly, there was a significant interaction effect between types of tasks and decision for the part, $F(1, 15) = 70.30$, $p < .0001$. Simple effects analysis showed a significant effect of types of tasks for both levels of decision conditions: For the top part, $F\ (1,\ 17) = 26.13, p < .0001$, and for the bottom part, $F\ (1,\ 17) = 69.91, p < .0001$. Post hoc t-tests (Bonferroni) showed that for the top part, RTs to the identity judgment was significantly faster than those to the expression judgment, $p < .0001$; for the bottom part, RTs to the expression judgment were significantly faster than those to the identity judgment, $p < .0001$ (See Figure 5 below).

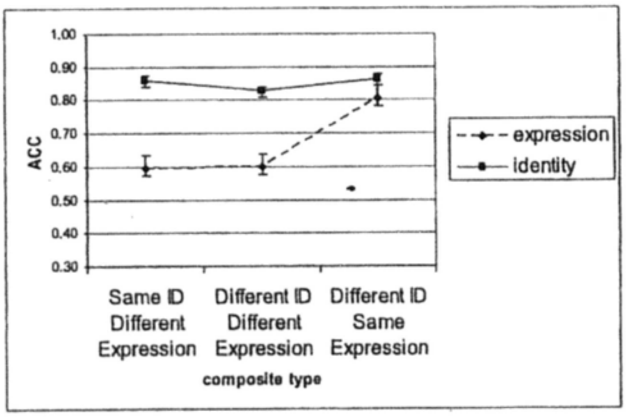


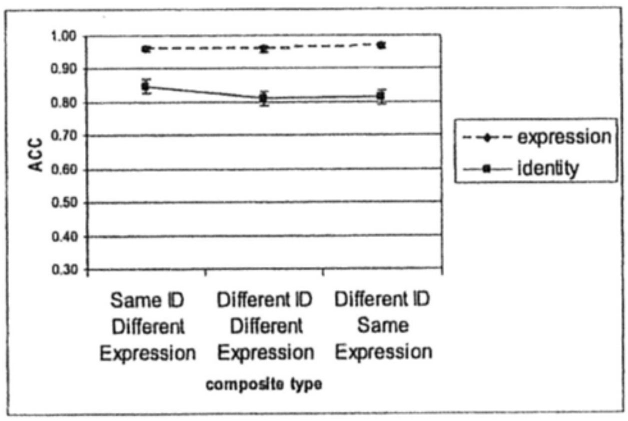

(5a) Decision for the top part (5b) Decision for the bottom part

*Figure 5.* The reaction time to identify the expression or person in the top or bottom segment of three types of composite images in Study 1a.

*Accuracy.* There was three-way interaction among types of tasks, composite type, and decision for the part, $F\ (2,\ 30) = 13.61, p < .0001$. For decision for the top part, the interaction between types of tasks and composite type was significant, $F\ (2,\ 30) = 27.05, p < .0001$. Simple effects analysis showed a significant effect of composite type for expression judgment, $F\ (2,\ 30) = 17.06, p < .0001$. Post hoc t-tests (Bonferroni) showed that for during the expression judgment, performance was better when the irrelevant part showed the same rather than different expressions, as indicated by higher accuracy for the different-identity-same-expression condition than for the same-identity-different-expression ($p < .0001$) or different-identity-different-expression condition ($p < .0001$). The latter two conditions did not differ from each other, suggesting that whether the irrelevant part showed the same identity or not, did not matter during the expression judgment. For decision for the bottom part, the interaction between types of tasks and composite type was not significant (See Figure 6 below).




(6a) Decision for the top part




(6b) Decision for the bottom part

*Figure 6.* Accuracy to identify the expression or person in the top or bottom segment of three types of composite images in Study 1a.

### 2.3.1.3 Discussion

The result of Study 1a showed that different RTs' pattern depended on types of tasks ("expression judgment" or "identity judgment"). Participants' performance on recognizing the identity (or expression) from half of the face was influenced by incongruent identity (or expression) from the other half, but unaffected by incongruent expression (or identity) from the other half. Thus, on one hand, processing of facial identity and expression was holistic because the performance was better when the top and bottom halves of faces are congruent in identity or expression. On the other hand, holistic processing for both facial identity and expression occurred independently of each other because recognizing the identity (or expression) from half the face was unaffected by incongruent expression (or identity).

In contrast to RTs' pattern, pattern in accuracy was different. As Figure 5a shows, the accuracy to identify the different-identity-same-expression was significantly larger than the same-identity-different-expression and different-identity-different-expression, which did not reliably differ, only when the task was to identify the expression that was displayed in the top segment of composite images. However, for two conditions in which top halves of the composite faces contained different expressions (same-identity-different-expression and different-identity-different-expression), the accuracy was approximately at chance level (59% vs. 60%). It was still inconclusive that there was no interference from facial identity when the task was to recognize the expression because the relatively low accuracy implied that RTs under those two conditions are not representative for showing that there was not any difference between same-identity-different-expression and different-identity-different-expression condition. Therefore, it was worth adjusting the accuracy level to re-examine this question in the following experiment.

### 2.3.2 Study 1b

The chance level in accuracy was due to less facial information in the top segment of the face when the task was to identify the expression. For the sake of adjusting the low accuracy for two conditions in which the two halves contained same-identity-different-expression and different-identity-different-expression composites, I made changes to the face stimuli, which was originally divided into the top and bottom half by cutting each face along a horizontal line through the bridge of the nose. In order to provide more facial information displayed in the top segment of the face for the identify-the-expression task, the top and bottom half of each face was made by cutting each face along a horizontal line above the nostril instead. The objective of Study 1b was the same as for Study 1a.

**2.3.2.1 Method**

*Participants.* Seventeen students (8 Males, 9 Females) at the Chinese University of Hong Kong took part in the study. All the subjects had normal or corrected-to-normal vision and received monetary compensation (HK$50/hr). Two participants were discarded from the seventeen participants because accuracy for at least one of the three conditions was less than 33.3% (below chance level).

*Materials.* The materials used were the same as for Study 1a except that the top and bottom half of each face was composed by cutting each face along a horizontal line above the nostril instead of through the bridge of the nose.

*Design and procedure.* All the design and procedure was same as that in Study 1a. The entire session lasted for about 1hr. For RTs, correct trials with an RT below 150 msec or more than 3 standard deviations from the mean of all the correct trials in all the conditions were not included in the analysis. The removed trials accounted for 3.54% in all the trials for the decision for the top and bottom part.

**2.3.2.2 Results**

*Training session.* Two within-subject factors were investigated with face format (whole faces, top segment of faces and bottom segment of faces; repeated measures) and types of tasks (identity judgment or expression judgment; repeated measures). As

Table 4 shows, the repeated measures analysis demonstrated that there was significant effect of types of tasks, $F(1, 14) = 30.40$, $p < .0001$, indicating that participants took significantly more blocks to learn the facial identity than the facial expression. Also, there was significant effect of face format, $F(2, 28) = 5.278$, $p = .021$, indicating that the blocks taken at learning whole faces were significantly more than those that were taken at learning the top ($p = .023$) and bottom segment of faces ($p = .014$). The interaction between face format and types of tasks was significant, $F(2, 28) = 4.48$, $p = .02$. Simple effects analysis showed a significant effect of face format for types of tasks: expression judgment, $F(2, 30) = 14.47$, $p < .0001$, and identity judgment, $F(2, 30) = 3.97$, $p = .045$. Post hoc t-test showed that for expression judgment, the blocks that were taken at learning the whole faces were significantly more than learning the bottom segment of faces, $p = .043$, and the blocks that were taken at learning the top segment of faces were significantly more than learning the bottom segment of faces, $p = .020$; for identity judgment, the blocks that were taken at learning the whole faces were significantly more than learning the top segment of faces, $p = .033$.

**Table 4.**The mean blocks for which participants could reach 100% accuracy on whole faces and 90% accuracy on either the top or bottom segment of faces during three types of training sessions (whole faces, top segment of faces and bottom segment of faces) for Study 1b.

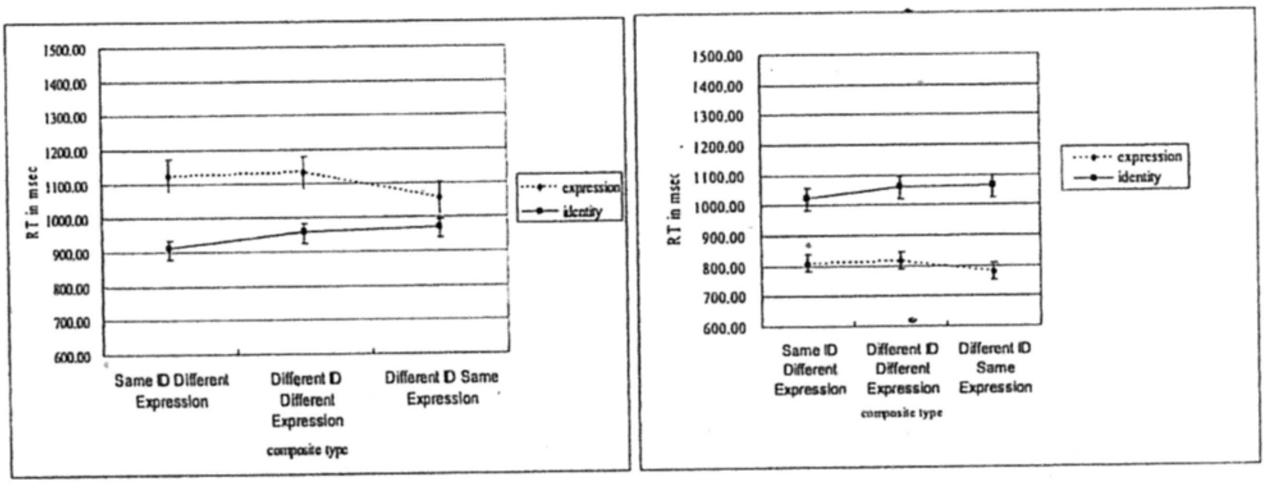
| Types of tasks | Face format | | |
|---|---|---|---|
| | whole face | top | Bottom |
| Facial identity | 5.13 | 2.33 | 2.60 |
| Facial expression | 1.73 | 1.53 | 1.00 |

*Formal experiment session.*

*RTs.* Firstly, there was a significant effect of composite type, $F\ (2, 28) = 4.15, p = .026$. Also, there was a significant effect of decision for the part, $F\ (1, 14) = 20.24, p < .0001$, indicating that the RTs to decision for the top part were significantly slower than those to decision for the bottom part.

Secondly, there was a significant interaction between types of tasks and composite type, $F\ (2, 28) = 15.30, p < .0001$. Simple effects analysis showed a significant effect of composite type for types of tasks: expression judgment, $F\ (2, 58) = 10.84, p < .0001$, and identity judgment, $F\ (2, 58) = 8.35, p = .001$. Post hoc t-tests showed that during expression judgment, performance was better when the irrelevant part showed the same than different expressions, as indicated by the faster responses for the different – identity – same - expression condition than the same – identity – different - expression or different – identity – different - expression condition, $p = .002$. The latter two conditions did not differ from each other, suggesting that whether the irrelevant part showed the same identity or not did not matter during expression judgment; during identity judgment, performance was better when the irrelevant part showed the same than different identities, as indicated by the faster response for the same-identity-different-expression condition than the different-identity-same-expression ($p = .005$) or different-identity-different-expression condition ($p = .015$). The latter two conditions did not differ from each other, suggesting that whether irrelevant part showed the same expression or not did not matter during the identity judgment.

Thirdly, there was a significant interaction between types of tasks and decision for the part, $F(1, 14) = 110.60, p < .0001$. Simple effects analysis showed a significant effect of types of tasks for both levels of decision for the part: For decision for the top part, $F(1, 16) = 8.92, p = .01$; for decision for the bottom part, $F(1, 16) = 45.60, p < .0001$. Post hoc t-test showed that for decision for the top part, RTs to the expression judgment was significantly slower than those to the identity judgment, $p = .01$; for decision for the bottom part, RTs to the identity judgment were significantly slower than those to the expression judgment, $p < .0001$(See Figure 7 below).



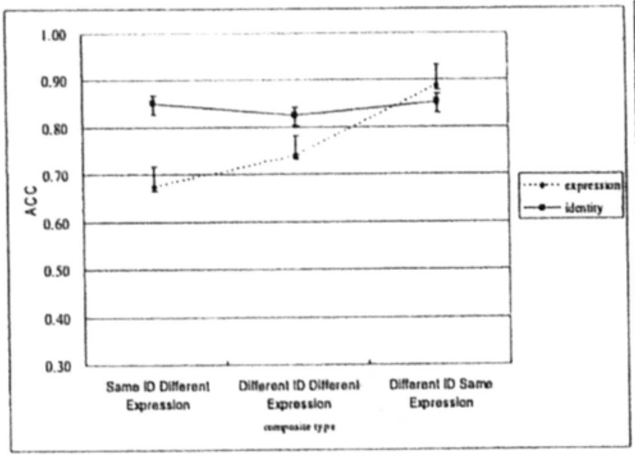

(7a) Decision for the top part (7b) Decision for the bottom part

*Figure 7. The reaction time to identify the expression or person in the top or bottom segment of three types of composite images in Study1b.*

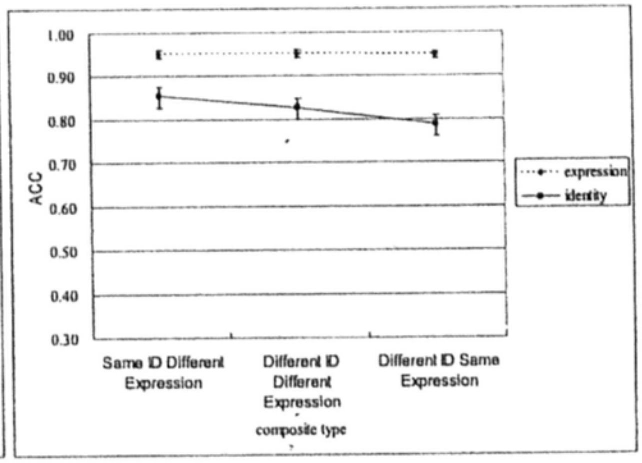
*Accuracy*. There was a significant three-way interaction among composite type, types of tasks and decision for the part, $F(2, 28) = 5.58, p = .009$.

Firstly, for decision for the top part, there was a significant interaction between types of tasks and composite type, $F(2, 28) = 14.60, p < .0001$; Simple effects analysis only showed a significant effect of composite type for the expression judgment, $F(2, 28) = 16.48, p < .0001$. Post hoc t-test (Bonferroni) showed that for the expression judgment, performance was better when the irrelevant part showed the same than different expressions, as indicated by the higher accuracy for the different-identity-same-expression condition than the same- identity- different-expression ($p$ = .001) or different-identity-different-expression condition ($p$ = .015). For the latter two conditions, accuracy to different- identity- different- expression was significantly higher than that to the same-identity-different-expression ($p$ = .006), suggesting that whether irrelevant part showed the same identity or not did not matter during expression judgment. However, there was not any significant effect of composite type for identity judgment.

Secondly, for decision for the bottom part, there was a significant interaction between types of tasks and composite type, $F$ (2, 28) = 5.16, $p$ = .016; Simple effects analysis only showed a significant effect of composite type for identity judgment, $F$ (2, 28) = 7.03, $p$ = .003. Post hoc t-test (Bonferroni) showed that for identity judgment, performance was better when the irrelevant part showed the same than different identities, as indicated by higher accuracy for the same-identity-different-expression condition than the different-identity-same-expression, $p$ = .013, but accuracy to different-identity- same-expression and different-identity-different-expression did not reliably differ, and also accuracy to different-identity-different-expression\ and same-identity-different- expression did not reliably differ. However, there was not any significant effect of composite type for expression judgment (See Figure 8 below).




(8a) Decision for the top part




(8b) Decision for the bottom part

*Figure 8.* Accuracy to identify the expression or person in the top or bottom segment of three types of composite images in Study1b.

### 2.3.2.3 Discussion

The participants' RT pattern in Study 1b fundamentally replicated the RT pattern in Study 1a. In relation to Study 1a, the RT pattern in Study 1b suggests that whether the top and bottom halves of facial identity are the same or different, there is no additional time for identifying the expression, and whether the top and bottom halves of the facial expression are the same or different, there is no additional time for identifying the person. For accuracy in Study 1b, when the task was to decide the top part, effect of composite type was only significant for expression judgment task: accuracy to different-identity-same-expression was significantly higher than that to different-identity-different-expression; accuracy to different-identity-different -expression was significantly higher than that to same-identity-different-expression. However, when the task was to decide the bottom part, effect of composite type was only significant for the identity judgment task: accuracy to same-identity-different-expression was significantly higher than that to different-identity-same-expression, but accuracy to same-identity-different-expression and different-identity-different

-expression did not reliably differ, and also accuracy to different-identity-different-expression and different-identity-same-expression did not reliably differ. It's different from the result of Study 1a showing that there was not any difference between these two conditions for different-identity-different-expression and same-identity -different-expression only when the participants are asked to identify the expression.

Although there is a subtle difference between Study 1a and 1b that has been mainly shown for accuracy pattern, overall results indicate that processing for both identity and expression are encoded holistically, showing that RTs are fastest in same-identity-different-expression condition for identity judgment task, and fastest in different-identity-same-expression condition for expression judgment task. Thus, forming a configuration, in which the top and bottom halves of composites are the same identity or expression, facilitates holistic processing. Similarly, accuracy was highest in same-identity-different-expression condition for identity judgment task when the task was to decide the bottom part. And accuracy was also highest in different –identity –same -expression condition for expression judgment task when the task was to decide the top part. On one hand, holistic processing takes much more effect for decision for the bottom part in identity judgment task and for decision for the top part in expression judgment task. In other words, attending to the bottom part relies much more on the top part because the bottom part was harder to identify than the top part for the identity judgment task, and attending to the top part relies much more on the bottom part because the top part was harder to identify than the bottom part for the expression judgment task. The result during the training session also confirmed this point: during the identity judgment, participants took much more blocks to learn the bottom segment of faces than the top segment of faces. By contrast, participants took more blocks to learn the top segment of faces than the bottom segment of faces during the expression judgment. Apart from the data during the training session, the results from formal experiment also indicated that while the top part (i.e. eye region) was much more important for the determination of people's identity, the bottom part (i.e. mouth region) was more informative for the determination of one's expression. On the other hand, identifying the expression (or identity) was not influenced by whether congruent and incongruent halves of identity (or expression), implying that processing of identity is independent of processing of expression although both of them may be encoded holistically. More importantly, the implication of this study is that holistic processing may take place at the later perceptual stage of face processing rather than the initial stage of structural encoding. The interpretation is that if holistic processing is dominant in the early stage and will not forward to the later stage, processing of facial identity and expression originates from the initial stage of structural encoding though they diverge later, so holistic processing of facial identity and expression will be interdependent with each other. Otherwise, holistic processing, which takes place at the later stage of face processing, will emerge at the separate route of facial identity and expression, thus being specific to different task requirements. This leads to functional independence of holistic processing between facial identity and expression.

# Chapter 3

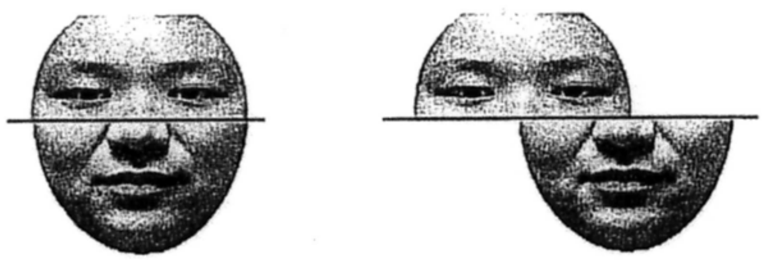
## Study 2 - Correlations on Holistic Processing for both Facial Identity and Emotional Expression

On the basis of Study1, the finding provided the evidence that holistic processing of facial identity and expression were independent of each other, which supports one possibility: holistic processing might mostly took place at the later stage of face processing. The independent relationship on holistic processing between facial identity and expression could be due to the separate paths of face processing that are responsible for identity and expression in terms of the model by Bruce and Young (1986). Study 1 was a standard experimental design, which included three conditions of composite types. They were: same-identity-different-expression, different -identity-different-expression and different-identity-same-expression and the variability across individuals were typically treated as error variance, potentially obscuring differences among levels of composite types. By contrast, Study 2 tested the hypothesis from different perspectives using the individual difference approach (Vogel & Awh, 2008), which attempted to understand how an individual's holistic processing for identity and expression would be instead of trying to understand the holistic processing for identity and expression at the general level. The logic of this approach was that if holistic processing emerged dominantly at an early perceptual stage, one would expect individual differences in holistic processing for facial identity to be associated with individual differences in holistic processing for emotional expression. Otherwise if holistic processing mainly occurred at a later, task-specific stage of face processing, one would expect that individual differences in holistic processing for facial identity to be dissociated from individual differences in holistic processing for emotional expression. The prediction was that holistic processing for identity and expression was dissociated across individuals. In order to provide a lower-bound correlation between these tasks, the color perception task was designed for measuring the individual difference in general tendency or ability to ignore one part of an object and exclusively attend to the other part of the object. It was expected that the correlation on holistic processing between facial identity and color perception as well as the correlation on holistic processing between expression and color perception was not significant because color perception task measured the general response tendency in processing rather than holistic processing.

**3.1 Method**

*Participants.* Forty-six participants (14 Males, 32 Females) at the Department of Psychology in the Chinese University of Hong Kong took part in Study 2. Participants were between 19 and 23 years of age. All the subjects had normal or corrected-to-normal vision. Thirty participants received monetary compensation (HK$50/hr) and sixteen participants obtained course credits.

*Materials.* For the identity task, four female face images with neutral expression were selected from remaining six female face models. They were different from the three face models used in Study 1. Each grayscale face image was processed with Adobe Photoshop CS2 and was masked by an oval shape to eliminate hair, beards, or other salient peripheral details. The size of the oval was 350 pixels in width and 350 pixels in height. Each of the four images with neutral facial expressions was divided into top and bottom segments above the nostril. The face tops was 120 pixels in width × 300 pixels in height, and face bottoms was 180 pixels × 300 pixels in height. Each resulting face image was 260 pixels in width × 300 pixels in height. The separate images of face tops and bottoms were reorganized to create 12 composite faces (See Figure 9a). All of the 12 possible face tops and bottoms used to make the composite stimuli were used again to make noncomposite faces. The noncomposite faces were essentially identical to the composites except that the top and bottom segments were misaligned horizontally (See Figure 9b). Because the noncomposite stimuli occupy a wider horizontal visual angle than do the composites, screens were taken so that the center of each noncomposite stimulus was in the center of the screen; This is done by aligning the middle of the nose in the top segment with the edge of the face in the bottom segment, and the left and right positions of top and bottom segments of the noncomposites were counterbalanced across stimuli.



(9a) composite face (9b) noncomposite face

*Figure 9.* Materials in the facial identity task in Study2.

For the expression task, the same three facial identities with three types of facial expressions (sad, surprise and happy) were used as in Study1; each of the nine images with facial expressions was divided into top and bottom segments above the nostril.

For each of the three models, all six possible combinations of top and bottom segments were prepared; these combinations were as follows: sad-surprise, sad-happy, surprise-sad, surprise-happy, happy-sad, happy-surprise. This resulted in a total of 18 composite facial expressions. The size of whole face images, face tops and bottoms was the same as the facial identity task. The noncomposite facial expressions were essentially identical to the composites except that the top and bottom segments were misaligned horizontally (See Figure 10b). All of the 18 possible top and bottom halves used to make the composite stimuli were used again to make noncomposite faces. Composite facial expressions were prepared by aligning the top half of a top expression with the bottom half of a bottom expression by the same identity (See Figure 10a). Note that when the noncomposites were presented in the center of the computer screen, neither the top nor bottom half of the image was centralized on the screen. To allow for this fact, half of the composite stimuli were presented in the same position as the left section of the noncomposites and half in the same location as their right section; positioning was counterbalanced across stimuli.

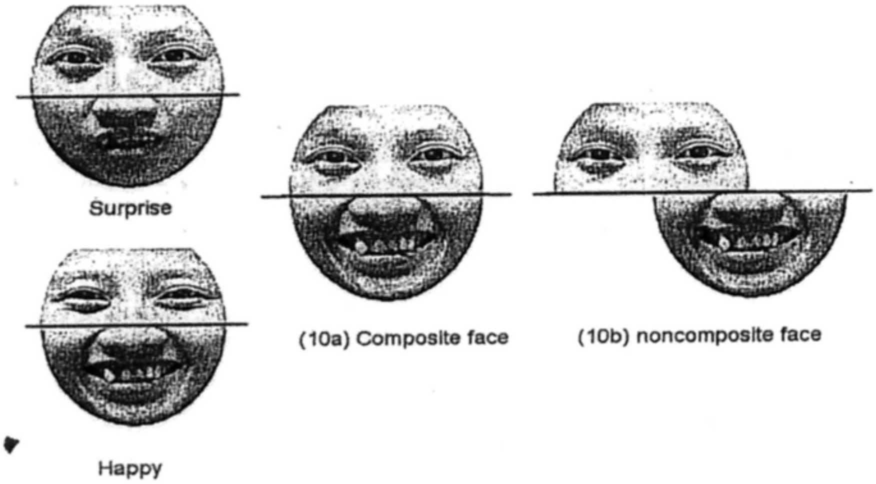


Figure 10. Materials in the facial expression task in Study 2. (10a) an example of composite face which is combined by the top part of surprised face with bottom part of happy face. (10b) an example of noncomposite face in which the top part of surprised face and the bottom part of happy faces are misaligned.

The face images were displayed on 15-in. CRT monitors using PC with a 1680 (H) × 1050 (V) resolution and a 75-Hz temporal refresh rate. The composite images subtended a horizontal visual angle of approximately 4.6˚ , and a horizontal visual angle of approximately 5.7˚ . And for the noncomposites, a horizontal visual angle was approximately 4.6˚ , the vertical visual angle was approximately 7.2˚ .

For the color perception task, four face-like ovals filled with colors were prepared and each shape was assigned to each color (four types of colors in total: RED, BLUE, GREEN, And YELLOW). The top and bottom halves of each oval shape, by cutting along the midline, were saved as separate images and reorganized to create 12 composites (See Figure 11a). The noncomposites were essentially identical to the composites except that the top and bottom segments are misaligned horizontally (See Figure 11b).

(11a) composite face (11b) noncomposite face

*Figure 11*. Materials in the color perception task in Study 2.

*Procedure.*

*Facial identity task.* The section began with a training session. In this training session, the four faces with neutral expressions were presented individually and each of them was assigned a name at random (D for ROSE, F for MANDY, J for GRACE, K for FIONA). These names were printed in uppercase letters and positioned below the face. Each face-name pair was presented 5 times for 5seconds each in random order. The participants were asked to look at such faces and try to remember the names of faces. Following this, 4 face images were presented individually and without name labels. The participant was asked to identify each face's name by pressing one of four keys (D for ROSE, F for MANDY, J for GRACE, K for FIONA) as accurately and quickly as possible. Each of the four images was presented 3 times in random order. In each trial, a fixation cross was shown for 500ms followed by a face image, which remained in view for 3000ms or until the participants responded, with their response initiating the next trial after an interval of approximately 1 second. Participants were given feedback after each face image was presented. If participants made the right response, they were given the hint – "correct!" If participants made the wrong response, they were given the hint – "incorrect! The correct response should be…". The participants were asked to try it again until all the trials reached 100% accuracy. The researcher would ensure that participants have learned all the face-name pairs.

Next, half of the participants were presented with the top halves of the same faces and half of the participants with the bottom halves of the same faces. Again, each image was presented individually, three times in random order, and the participant's task was to indicate each face's name by making a key-press response. The participants were given feedback after each image was presented so that they could know if the response to each trial was correct or not. If participants made the right response, "correct!" would be shown on the screen. Otherwise if participants made an error, they would be given the hint -"incorrect! And the correct response should be…" The participants were asked to try it again until all the trials reached 90% accuracy for both of the top and bottom part sessions. Following this, the participants who had seen the top sections were presented with the bottom sections of the same faces and vice versa. Therefore, the order of the top and bottom judgment of faces was counterbalanced across participants. There were 24 trials in total.

Lastly, the participants were presented with one composite or noncomposite face at a time in random order and then asked to name the top or bottom segment of each face as accurately and quickly as possible. Again, the presentation times were identical to the whole-face presentations described earlier. And each image was presented individually, three times in random order. Half of the participants judged the top half of face first and then the bottom half of face, and vice versa for the other participants. The order of presentation of these two blocks was counterbalanced across participants. There were 288 trials in total for both of the top and bottom half of faces. To familiarize the participants with composite and noncomposite faces, the actual experiment was preceded by 8 practice trials selected at random from the 288 experimental trials.

*Facial expression task.* The section began with a training session, in which nine faces with emotional expressions (three faces, each face posing three facial expressions, sad, surprised and happy) were presented two times individually in random order. The participant's task was to identify the emotion displayed in each face by pressing one of the corresponding keys labeled with sad, surprise and happy. Again, the presentation times were identical to the facial identity task described above. Participants were given feedback after each face image was presented. If participants made the right response, they were given the hint – "correct!" If participants made the wrong response, they were given the hint – "incorrect! The correct response should be…". The participants were asked to try it again until all the trials reached 100% accuracy.

Next, participants then completed two blocks of experimental trials. In one block, they were asked to identify the expression displayed in the top half of the composite and noncomposite images and in a second block the expression shown in the bottom half of these face images. Half of the participants were presented with the top halves of the same face images and half of the participants with the bottom halves of the same face images. Again, each image was presented individually, two times in random order, and the participant's task was to indicate each face's name by making a key-press response. The participants were given feedback after each image was presented so that they could know if the response to each trial was correct or not. If participants made a right response, "correct!" would be shown on the screen. Otherwise if participants made an error, they would be given the hint -"incorrect! And the correct response should be…" The participants were asked to try it again until all the trials reached 90% accuracy for both of the top and bottom part sessions. Following this, the participants who had seen the top sections were presented with the bottom sections of the same faces and vice versa. Therefore, the order of the top and bottom judgment of faces was counterbalanced across participants. There were 36 trials in total.

Following this, the actual experiment began. This included one presentation of each of the 18 composites and 18 noncomposite stimuli described above. The left and right positions of the top and bottom segments of the composites or noncomposites were counterbalanced across stimuli. Participants were asked to identify the expression displayed in the top or bottom half of the images by pressing one of three keys (1-Sad, 2-Surprise, 3- Happy) as accurately and quickly as possible. The two blocks including the top and bottom judgment were also counterbalanced across participants. Again, the presentation times were identical to the whole-face presentations described earlier. Each image was presented individually, two times in random order. Half of the participants judged the top half of the faces first and then the bottom half of the faces, and vice versa for the other participants. To familiarize the participants with composite and noncomposite faces, the actual experiment was preceded by 8 practice trials selected at random from the 288 experimental trials.

*Color perception task.* Given the individual difference in general tendency or ability to ignore one part of an object and exclusively attend to the other part of the object, a baseline condition will be designed. The section began with a training session in which four oval shapes with four types of colors (Red, Blue, Green and Yellow) were presented individually three times in random order. The participants were asked to identify the color in the top or bottom segment of oval shapes by pressing one of four keys (D for Red, F for Blue, J for Green, K for Yellow) as accurately and as quickly as possible in the composites or noncomposites. Again, the presentation times were identical to the facial identity task and facial expression task described above. Participants were given feedback after each oval shape was presented. Next, participants completed two counterbalanced blocks of experimental trials. In one block, they were asked to identify the color displayed in the top half of the composite and noncomposite oval shapes. In the second block, they were asked to identify the color displayed in the bottom half of the composite and noncomposite oval shapes. To familiarize the participants with composite and noncomposite faces, the actual experiment was preceded by 8 practice trials selected at random from the 288 experimental trials.

All the participants firstly completed the facial identity task. After 2 - 3 min break, they were asked to fulfill the emotional expression task. Finally they completed the color perception task.

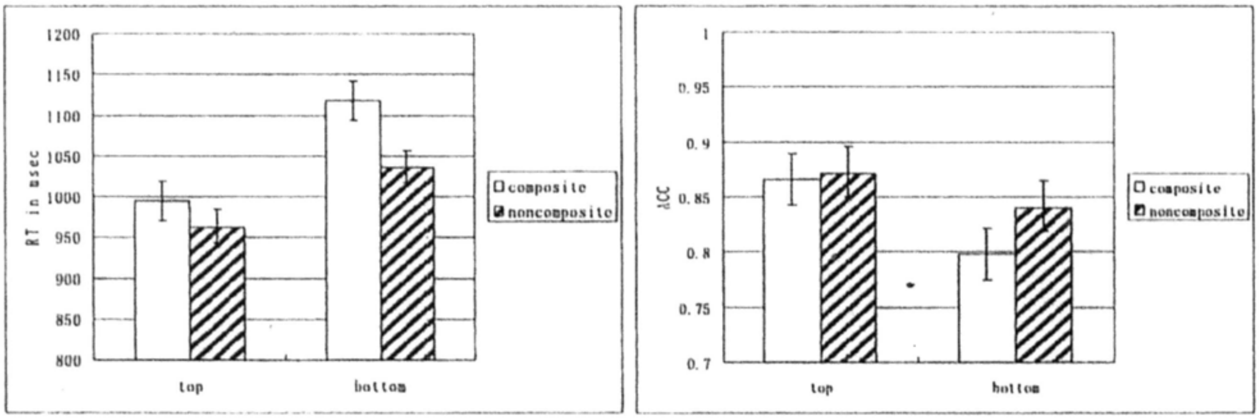
### 3.2 Results

Firstly, in order to examine if there was a holistic effect, repeated measures analysis was used for facial identity, expression and color perception task respectively. Seven subjects were excluded from the analysis since one subject hadn't finished the decision for the top segment of stimuli in the facial expression task and six subjects' performance on accuracy was less than 25% under at least one of four conditions in the facial identity task.

*Facial identity task.* Data were submitted to repeated measures ANOVA with two factors: composite type (composite or noncomposite) and decision for the part ("identify the top-half face" or "identify the bottom-half face").

*RTs.* Correct responses of less than 150 msec and more than 3 standard deviations from the mean in each condition were not included. The removed trials accounted for 2.12% in all the trials. Firstly, there was a significant effect of decision for the part, $F(1, 38) = 22.80, p < .0001$. Also, there was a significant composite effect, $F(1, 38) = 47.84, p < .0001$. Secondly, the interaction between decision for the part and stimulus type was also significant, $F(1, 38) = 7.19, p = .011$. Simple effect analysis showed that there was a significant effect of decision for the part on stimulus type: Decision for the top segment, $F(1, 38) = 7.68, p = .009$; Decision for the bottom segment, $F(1, 38) = 37.97, p < .0001$. Post hoc t-tests showed that RTs to composite stimuli was significantly slower than those to noncomposite stimuli for the decision for both the top ($p = .009$) and bottom segment of stimuli ($p < .0001$), but the composite effect was greater when participants were asked to make a decision for the bottom segment of faces (See Figure 12a).

*Accuracy.* There was a significant composite effect, $F(1, 38) = 11.77, p = .001$. Also, the interaction effect between composite type and decision for part was significant, $F(1, 38) = 18.43, p < .0001$. Simple effect analyses only showed that there was significant composite effect for decision for the bottom segment of composite or noncomposite faces, $F(1, 38) = 24.79, p < .0001$. Post hoc t-test (Bonferroni) showed that for decision for the bottom segment, the accuracy of identifying composite stimuli was significantly lower than that of identifying noncomposite stimuli, $p < .0001$. However, there was not significant difference between composite and noncomposite stimuli for decision for the top segment (See Figure 12b).




(12a) RTs in the facial identity task (12b) Accuracy in the facial identity task

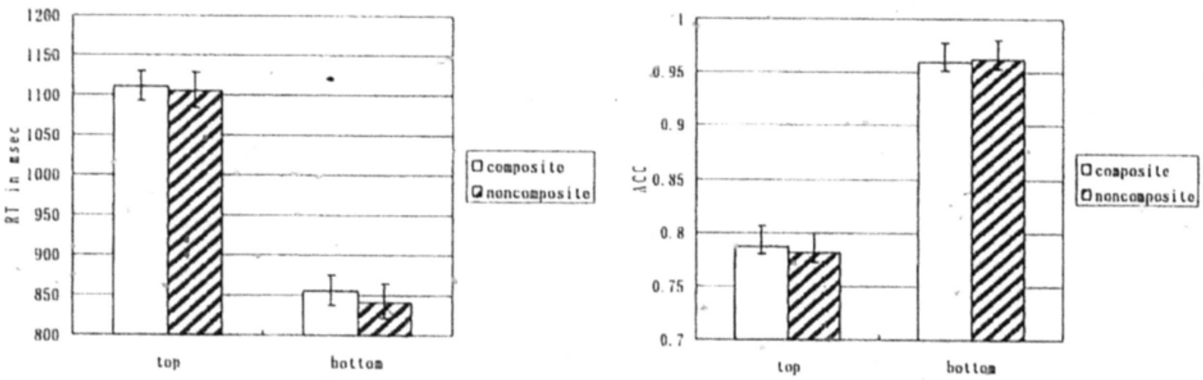
*Figure 12.* RTs and accuracy in the facial identity task in Study 2.

*Facial expression task.* Data were submitted to repeated measures ANOVA with two factors: composite type (composite or noncomposite) and decision for the part ("identify the top-half expression" or "identify the bottom-half expression").

*RTs.* Correct responses to less than 150 msec and more than 3 standard deviations from the mean in each condition were not included. The removed trials accounted for 2.15% in all the trials. There was significant effect of decision for the part, $F(1, 38) = 237.68$, $p < .0001$. Post hoc t-test (Bonferroni) showed that RTs to decision for the top segment was significantly slower than those to decision for the bottom segment, $p < .0001$. However, composite effect was not significant (See Figure 13a).

*Accuracy.* There was a significant effect of decision for the part, $F(1, 38) = 117.25$, $p < .0001$. Post hoc t-test (Bonferroni) showed that accuracy of identifying the top segment was significantly lower than that of identifying the bottom segment, $p$

< .0001. However, composite effect was not significant (See Figure 13b).




(13a) RTs in the facial expression task (13b) Accuracy in the facial expression task

*Figure 13.* RTs and accuracy in the facial expression task in Study 2.

*Color perception task.* Repeated measures ANOVA with two factors: composite type (composite or noncomposite) and decision for the part ("identify the top-half color" or "identify the bottom-half color"). However, any significant effect had not been found for the color perception task.

Secondly, holistic processing of each task was measured by the difference between composite and noncomposite stimuli in RTs and accuracy. One subject was excluded as an outlier because accuracy in holistic processing of facial expression task for this subject was more than 3 standard deviations from the mean of all the subjects.

**Table 5**. Results of holistic effect in facial identity task, facial expression task and color perception task.

| Task and measure | Mean | 95%CI | Range |
|---|---|---|---|
| HP in identity:RTs | 113.4923 | [76.21,147.78] | -56.77 to 394.44 |
| HP in identity:ACC | -0.0417 | [-0.07,-0.02] | -0.21 to 0.13 |
| HP in expression:RTs | 17.5501 | [-8.23,43.33] | -169.14 to 207.6 |
| HP in expression:ACC | -0.0022 | [-0.02,0.02] | -0.11 to 0.15 |
| HP in color:RTs | -7.7415 | [-25.26,9.77] | -124.99 to 145.54 |
| HP in color:ACC | -0.004 | [-0.02,0.01] | -0.08 to 0.08 |

*Note:* Holistic processing (HP) based on reaction time (RTs) was calculated by subtracting the mean RTs (in milliseconds) for correct trials in composite stimuli from those in noncomposite stimuli. Holistic processing (HP) based on accuracy (ACC) was calculated by subtracting the mean accuracy for correct trials in composite stimuli from that in noncomposite stimuli.

*Correlations.* As Table 5 shows above, holistic processing measure for facial identity in RTs was significantly greater than zero, $t$ (37) = 6.707, $p < .0001$, and that in accuracy was significantly lower than zero, $t$ (37) = -3.207, $p = .003$, indicating more interference for composite stimuli. Holistic processing measures for facial expression and color perception in either RTs or accuracy were not significantly above or below zero.

As Tables 6 and 7 show below, for facial identity and expression, the correlations on holistic processing between these two tasks were not significant. For facial identity and color perception, the correlations on holistic processing between these two tasks were also not significant. For facial expression and color perception, the correlations on holistic processing between these two tasks in RTs were marginally significant, ID-C $_{RT}$ $r$ =. 316, $p$ = .053, but the correlations on holistic processing between these two tasks in accuracy were not significant. The scatter plots were shown in Appendix A1.

**Table 6.** Correlation matrix on holistic processing for facial identity, facial expression and color perception in RTs.

| Task | Identity (RTs) | Expression (RTs) | Color (RTs) |
|---|---|---|---|
| Identity (RTs) | 1 | | |
| Expression (RTs) | .034 | 1 | |
| Color (RTs) | .084 | .316 | 1 |

**Table 7.** Correlation matrix on holistic processing for facial identity, facial expression

and color perception in accuracy.

| Task | Identity (ACC) | Expression (ACC) | Color (ACC) |
|---|---|---|---|
| Identity (ACC) | 1 | | |
| Expression (ACC) | -.236 | 1 | |
| Color (ACC) | -.076 | .095 | 1 |

Thirdly, in order to look into the relationship between facial identity, facial expression and color perception, the correlations were analyzed by decision for the top and bottom segment separately. The reasons for separate correlation analysis of the top and bottom segment of faces are that holistic processing in facial identity task was to a greater extent demonstrated for decision for the bottom segment than that for the top segment. Moreover, performance was significantly better for decision for the top segment than that for the bottom segment in facial identity task. On the other hand, although holistic effect in facial expression task was not significant, performance was significantly better for decision for the bottom segment than that for the top segment, suggesting that there may be a difference with regard to processing for the top and bottom segment of faces in facial identity and expression tasks.

As Table 8 and Table 9 show below, for facial identity and emotional expression, the correlations on holistic processing between these two tasks were not significant for the decision for either the top or bottom part.

For facial identity and color perception, the correlations on holistic processing between facial identity and color perception were not significant in accuracy when the task was to identify the top part. However, there was significant correlation in RTs on holistic processing between these two tasks when the task was to identify the top part, ID-C $_{RT}$ $r = .338$, $p = .038$ (See Figure 14). When the task was to identify the bottom part, the correlations on holistic processing between these two tasks were not significant.

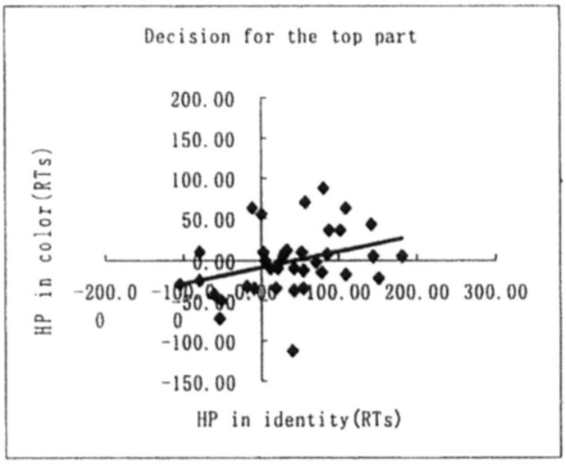



*Figure 14.* Holistic effect for facial identity as a function of holistic effect for color perception across individual participants in RTs for the decision for the top part.

For facial expression and color perception, the correlations on holistic processing between these two tasks were not significant in RTs when the task was to identify the top part. However, there was significant correlation on holistic processing between these two tasks in RTs when the task was to identify the bottom part, E-C $_{RT}$ $r = .423$, $p = .008$ (See Figure 15a). When the task was to identify the bottom part, the correlations on holistic processing between these two tasks were not significant in accuracy. However, there was significant correlation on holistic processing in accuracy when the task was to identify the top part, E-C $_{ACC}$ $r = 0.381$, $p = .018$ (See Figure 15b). Other scatter plots were shown in Appendix A2.

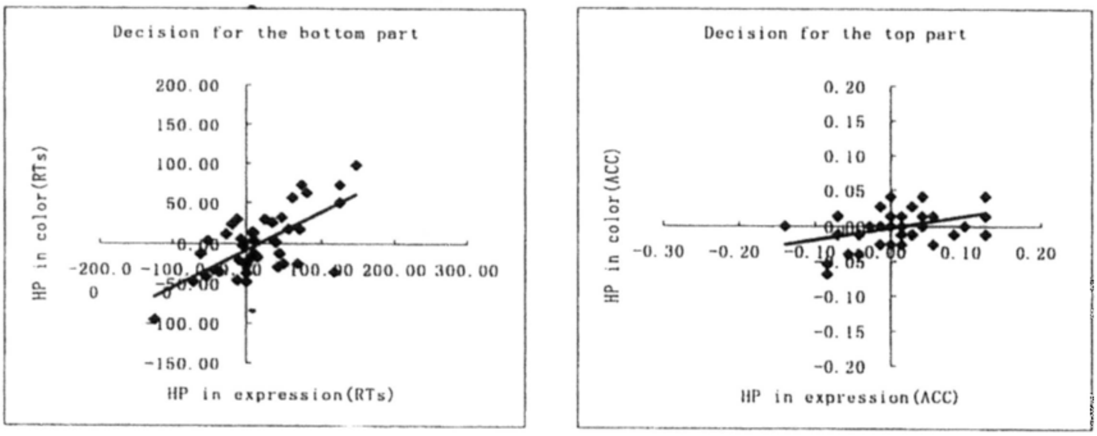



*Figure 15.* (15a) Holistic effect for facial expression as a function of holistic effect for color perception across individual participants in RTs for the decision for the bottom part; (15b) Holistic effect for facial expression as a function of holistic effect for color perception across individual participants in accuracy for the decision for the top part.

**Table 8.** Correlation matrix on holistic processing for facial identity, facial expression and color perception in RTs for either top or bottom part.

(a) Correlation matrix on holistic processing for facial identity, facial expression and color perception in RTs for top part.

| Decision for top part | Identity(RTs) | Expression(RTs) | Color(RTs) |
|---|---|---|---|
| Identity(RTs) | 1 | | |
| Expression(RTs) | .158 | 1 | |
| Color(RTs) | .338* | -.105 | 1 |

(b) Correlation matrix on holistic processing for facial identity, facial expression and color perception in RTs for bottom part.

| Decision for bottom part | Identity(RTs) | Expression(RTs) | Color(RTs) |
|---|---|---|---|
| Identity(RTs) | 1 | | |
| Expression(RTs) | -.060 | 1 | |
| Color(RTs) | .098 | .423* | 1 |

*Note:* * Correlation is significant at the .05 level (2-tailed).

**Table 9.** Correlation matrix on holistic processing for facial identity, facial expression and color perception in accuracy for either top or bottom part.

(a) Correlation matrix on holistic processing for facial identity, facial expression and color perception in accuracy for top part.

| Decision for top part | Identity(ACC) | Expression(ACC) | Color(ACC) |
|---|---|---|---|
| Identity(ACC) | 1 | | |
| Expression(ACC) | -.162 | 1 | |
| Color(ACC) | -.068 | .381* | 1 |

(b) Correlation matrix on holistic processing for facial identity, facial expression and color perception in accuracy for bottom part

| Decision for bottom part | Identity(ACC) | Expression(ACC) | Color(ACC) |
|---|---|---|---|
| Identity(ACC) | 1 | | |
| Expression(ACC) | -.162 | 1 | |
| Color(ACC) | -.047 | -.232 | 1 |

*Note:* * correlation is significant at the .05 percent level (2-tailed)

Task reliability. The aim of measuring the task reliability was to obtain the upper bound of correlation, which could set criteria to ensure if the correlation coefficient was high or not. Theoretically, the task reliability was assumed to be relatively high because the task reliability of each task is measured by splitting all the trials into halves in terms of odd and even numbers of trials. Task reliability is calculated by measuring the correlation between holistic effects for one half of trials and another half of trials. As Table 10 shows, reliability for each task was low because the trial numbers equally assigned to each condition were reduced by splitting half.

**Table 10. The reliability of facial identity, facial expression and color perception task.**

| Reliability | Identity (*p*) | Expression (*p*) | Color (*p*) |
|---|---|---|---|
| RT | -.005 (.977) | .086 (.576) | -.184 (.221) |
| Accuracy | .152 (.349) | -.183 (.230) | -.119 (.431) |

### 3.3 Discussion

The results suggested that there was a holistic effect of facial identity which interfered in the processing of decision for the part. Participants were slower to process the identity of either the top or bottom segment of the composite when it was aligned with the part of another facial identity, than when it was misaligned with the part of another facial identity. This effect was mainly demonstrated by the greater extent to which decision for the bottom segment was significantly slower to composites than noncomposites in RTs, and lower to composites than noncomposites in accuracy. The holistic effect on facial identity was consistent with that by Young et al (1987). However, the holistic effect for facial expression was not significant as that in facial identity. Holistic effect has not been found in color perception task. The color perception task was relevant to a control condition in which this task provided a way for measuring the general tendency or ability to ignore one part of an object and exclusively attend to the other part of the object. In other words, the processing indexed by RTs and accuracy in composite faces subtracting from noncomposite faces could be interpreted as simply response interference or Stroop-like effects rather than holistic effect.

To investigate the relationship between facial identity and expression, I also measured the correlation on the holistic effect between facial identity and expression across individuals whether the participants were asked to make a response for either the top or bottom part of composite or noncomposite faces. As was hypothesized, if holistic processing took place at an early stage of face perception, processing for both identity and expression might rely on an early structural encoding stage as referred to by Bruce and Young's model (1986). In my study, however, the correlation between holistic effect of facial identity and expression was not significant, implying that holistic processing might occur at the later stage of face perception. It results in a separate processing for facial identity and expression given the separate routes that are derived from perceptual structural encoding stage.

An interesting finding was that the overall correlations on holistic processing between facial identity and color perception were not significant, but the correlations on holistic processing between facial identity and color perception were significant for decision for the top part in RTs only, implying that holistic processing between facial identity task and color perception task for the decision for the top part shared the similar construct. In other words, processing for the top part of facial identity, to some extent, resembled processing for the top part of color composites, but it was not the case for the bottom part of facial identity. This was because the holistic effect of facial identity mainly processes when the task was to identify the bottom part, implying that it was much more difficult for the participants to ignore the top part of composites when they were asked to identify the person displayed in the bottom segment. By contrast, given that it was much easier to identify the top part than the bottom part of facial identity, identification of the top part relied less on information from the bottom part, which resulted in a less holistic processing.

In addition, an important point was that the overall correlations on holistic processing between facial expression and color perception were marginally significant.

Furthermore, the positive correlations on holistic processing between facial expression and color perception were significant for decision for the top part in accuracy and the bottom part in RTs. Although holistic processing in facial expression task was not significant, it implied that participants might tend to attend to the bottom part of composites readily without being influenced by the top part of composites or vise versa. Therefore, expression identification does not necessarily mean to be processed holistically. Instead, the information from face halves can contribute to identify the expression of the whole face. However, it is important to note that holistic processing of facial expression was not found in Study 2, which was inconsistent with the results found in Study 1. The failure to find holistic processing in Study 2 could be due to the following reasons: Firstly, there were fewer trials in Study 2 (288 trials) than Study 1 (324 trials) thus the power was lower. Secondly, Studies 1 and 2 used different paradigms. Holistic processing of facial expression in Study 2 was indicated by the difference between composite trials (when face top and bottom were aligned) and noncomposite trials (when face top and bottom were misaligned). The composite task used in Study 1 involved only aligned composites, and holistic processing was indicated by the difference between the trials with a different-identity-same-expression composite and those with a different-identity-different-expression or same-identity-different-expression composite. Finding from Study 1 revealed that, for expression judgment, responses to different-identity-same-expression composites were significantly faster than same-identity-different-expression composite and different-identity-different-expression composite. However, it could be argued that such an RT difference could simply reflect response interference due to the lack of misaligned trials as the baseline. There was also no color perception task that is relevant to baseline condition of measuring response interference as that in Study 2. Therefore, results from Studies 1 and 2 did not provide strong support for holistic processing of facial expressions.

# Chapter 4

## Study 3 - Correlation on Holistic Processing for both Facial Identity and Gender

Study 2 found that holistic processing for facial identity and emotional expression was dissociated across individuals, indicating that holistic processing might emerge during a later, task-specific stage of face processing due to the parallel route for processing of identity and expression. In addition, processing for emotional expression was not holistic, which was inconsistent with the observation by Calder et al (2000) and Calder and Jansen (2005). Consequently, there was another possibility that expression identification relied much more on local information of faces especially when salient facial features could tell the participants which types of expression the image was transmitting (e.g., open mouth with teeth in happy, empty open mouth in surprise). Study 3 followed Study 2's logic to investigate the relationship on holistic processing for both identity and gender across individuals. It was hypothesized that if holistic processing emerged at an early stage of face processing, holistic processing of identity would be associated with that of gender across individuals. On the contrary, if holistic processing emerged at a later, task-specific stage, holistic processing of identity was expected to be dissociated with that of gender across individuals. The prediction was that holistic processing of identity was associated with that of gender across individuals. In addition, color perception task was also designed as a baseline condition as in Study 2.

### 4.1 Method

*Participants.* Forty-two participants (13 males, 29 females) at the Department of

Psychology in the Chinese University of Hong Kong took part in Study 3. All the subjects had normal or corrected-to-normal vision. Twenty-two participants received monetary compensation (HK$50/hr) and twenty participants obtained course credits. Participants were between 18 and 24 years of age.

*Materials.* For the facial identity and color perception task, same materials were used as in Study 2. For the gender categorization task, grayscale images of six men and six women were used. Six male images and six female images were selected from a pilot study. Five out of six female images were the same as those used in Study 1 and Study 2. Each grayscale face image was processed with Adobe Photoshop CS2 and was masked by an oval shape to eliminate hair, beards, or other salient peripheral details. Each of the twelve images with facial expressions was divided into top and bottom segments above the nostril. The size of the oval, face images and face tops and bottoms was the same as those used in the pilot study. The separate images of face tops and bottoms were reorganized to create 12 composite faces, which were composed by the top segment of one gender and bottom segment of the other gender (See Figure 16a). All of the 12 possible top and bottom halves were used again to make noncomposite faces in which the top and bottom segments were misaligned horizontally (See Figure 16b). Composites occupied counterbalanced positions slightly to the left or to the right of the center of the screen, with the left and right positions being those in which parts of the noncomposites could occur.

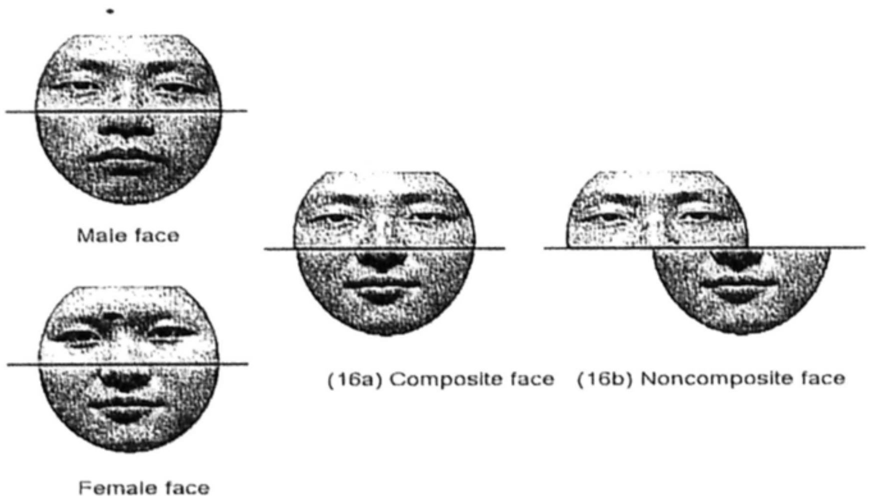



*Figure 16.* Materials in the gender categorization task in Study 3. (16a) an example of composite face is combined by the top part of a male image and the bottom part of a female image. (16b) an example of noncomposite face in which the top part of a male image and bottom part of a female image are misaligned.

*Procedure.* Facial identity task and color perception task. The tasks were identical to those used in Study 2.

*Gender categorization task.* The section began with a training session in which twelve neutral faces were presented individually and each face was presented 2 times in random order. In each trial, a fixation cross was shown for 500ms followed by a face image, which remained in view for 3000ms or until the participant responded, with their response initiating the next trial after an interval of approximately 1 second. The participants' task was to identify the gender when each image was presented. Participants were given feedback after each face image was presented. If participants made the right response, they were given the hint – "correct!" If participants made the wrong response, they were given the hint – "incorrect! The correct response should be…". The participants were asked to try again until all the trials reached 100% accuracy.

In the next training session, participants were presented with the top or bottom halves and were asked to respond as accurately and as quickly as possible. Half of the participants judged the top half of the faces firstly and then the bottom half of the faces, and vice versa for the other participants. The blocks of decision for the top part and bottom part were counterbalanced across participants. Again, each image was presented individually, three times in random order. The participants were given feedback after each image was presented so that they could know if the response to each trial was correct or not. The criterion to test whether participants could identify the gender correctly was that they had to reach 90% accuracy, which was identical to facial identity and expression tasks used in Study 2.

Following this, the actual experiment included one presentation of each of the 12 composites and 12 noncomposite stimuli described above. The left and right positions of the top and bottom segments of the composites or noncomposites were counterbalanced across stimuli. Participants were asked to identify the gender in the top or bottom half of the images by pressing one of two keys (F for male, J for female) as accurately and as quickly as possible. The two blocks including decision for the top and bottom segment were counterbalanced across participants. Again, the presentation times were identical to the whole-face presentation described in the first training session. Each image was presented individually, three times in random order. To familiarize the participants with the composite and noncomposite faces, the actual experiment was preceded by 8 practice trials selected at random from the 288 experimental trials.

First of all, participants were asked to complete the facial identity task. After 1-2 min break, they were required to finish the gender categorization task, and finally finish the color perception task. The whole process lasted for about 1hr.

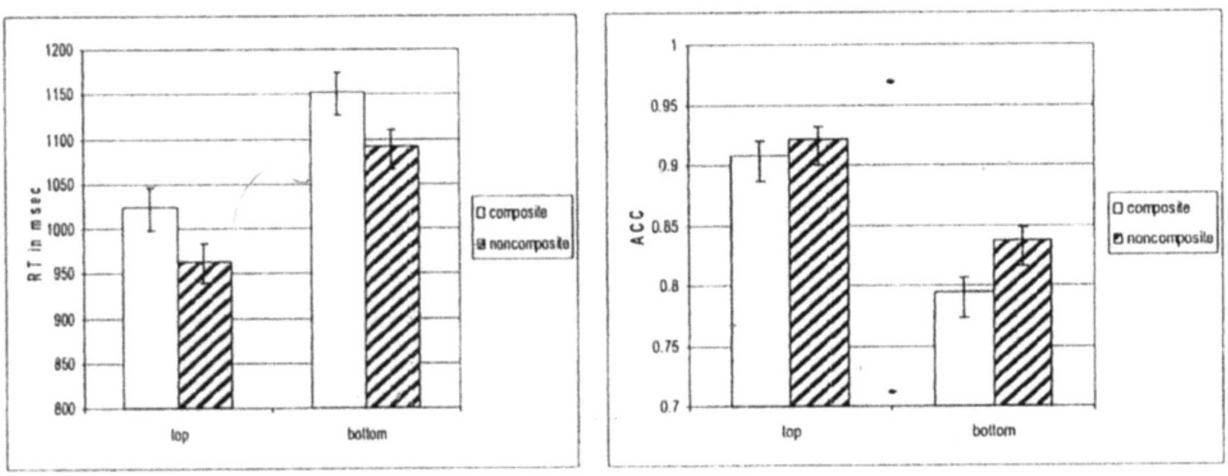
**4.2 Results**

Firstly, in order to examine if there was a holistic effect, repeated measures analysis was investigated for facial identity, gender categorization and color perception task respectively. Two subjects were excluded from the analysis due to less than 25% accuracy for at least one of two conditions in the facial identity task. Three subjects were excluded from the analysis in gender categorization task because one subject's performance was less than 50% accuracy for at least one of four conditions and two subjects hadn't finished the task. One subject was excluded from the analysis in color perception task because the performance was less than 25% accuracy for at least one of four conditions. In total six subjects were excluded from repeated measures analysis for each task and correlation analysis among these three tasks.

*Facial identity task.* Data were submitted to repeated measures ANOVA with two factors: composite type (composite or noncomposite) and decision for the part ("identify the top-half face" or "identify the bottom-half face").

*RTs.* Incorrect trials or trials with an RT below 150 msec or more than 3 standard deviations from the mean of all the trials in all conditions were not included in the analysis. The removed trials accounted for 2.10% in all the trials. There was a significant composite effect, $F(1, 35) = 42.94$, $p < .0001$. Post hoc t-tests (Bonferroni) showed that RTs to composite stimuli were significantly slower than noncomposite stimuli, $p < .0001$. Also, there was a significant effect of decision for the part, $F(1, 35) = 48.31$, $p < .0001$. Post hoc t-tests showed that RTs to the top part were significantly faster than those to the bottom part, $p < .0001$(See Figure 17a).

*Accuracy.* Firstly, there was a significant composite effect, $F(1, 35) = 15.38$, $p < .0001$. Also, there was significant effect of decision for the part, $F(1, 35) = 27.08$, $p < .0001$. Secondly, the interaction effect between composite type and decision for the part was significant, $F(1, 35) = 6.19$, $p = .018$. Simple effect analyses only showed that there was a significant composite effect for decision for the bottom segment, $F(1, 35) = 15.50$, $p < .0001$. Post hoc t-test (Bonferroni) showed that for the decision for the bottom segment, the accuracy of identifying composite stimuli was significantly lower than that of identifying noncomposite stimuli, $p < .0001$. However, there was not a significant difference between composite and noncomposite stimuli for decision for the top segment (See Figure 17b).



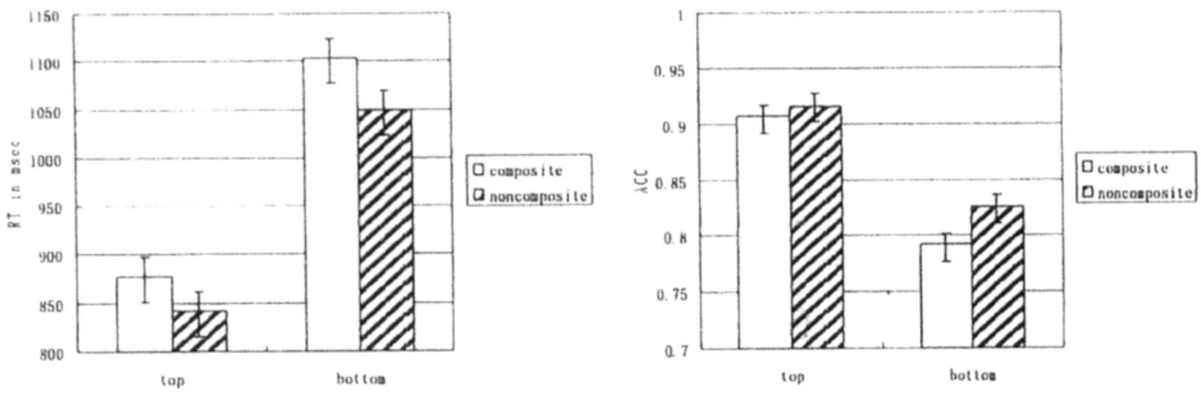

(17a) RTs in the facial identity task (17b) Accuracy in the facial identity task

*Figure 17.* RTs and accuracy in the facial identity task in Study3.

*Gender categorization task.* Data were submitted to repeated measures ANOVA with two factors: composite type (composite or noncomposite) and decision for the part ("identify the top-half face" or "identify the bottom-half face").

*RTs*. Incorrect trials or trials with an RT below 150 msec or more than 3 standard deviations from the mean of all the conditions were not included in the analysis. The removed trials accounted for 2.34% in all the trials. There was a significant composite effect, $F(1, 35) = 31.10$, $p < .0001$. Post hoc t-test (Bonferroni) showed that RTs to composite stimuli were significantly slower than noncomposite stimuli, $p < .0001$. Also, there was a significant effect of decision for the part, $F(1, 35) = 89.63$, $p < .0001$. Post hoc t-test (Bonferroni) showed that RTs to the top part were significantly faster than those to the bottom part, $P < .0001$(See Figure 18a).

*Accuracy*. Firstly, there was a significant composite effect, $F(1, 35) = 13.16$, $p = .001$. Also, there was a significant effect of decision for the part, $F(1, 35) = 47.76$, $p < .0001$. Secondly, there was an interaction effect between composite type and decision for the part, $F(1, 35) = 5.85$, $p = .021$. Simple effect analysis only showed that there was significant composite effect for decision for the bottom segment, $F(1, 35) = 17.26$, $p < .0001$. Post hoc t-tests (Bonferroni) showed that for decision for the bottom segment, the accuracy of identifying composite stimuli was significantly lower than that of identifying noncomposite stimuli, $p < .0001$. However, there was not significant difference between composite and noncomposite stimuli for decision for the top segment (See Figure 18b).




(18a) RTs in the gender categorization task (18b) Accuracy in the gender categorization task

*Figure 18.* RTs and accuracy in the gender categorization task in Study 3.

*Color perception task.*

*RTs.* There was not any significant difference in RTs for the color perception task.

*Accuracy.* There was a significant effect of composite type, $F$ (1, 35) = 9.83, $p$ = .003. Also, there was a significant interaction effect between composite type and decision for the part, $F$ (1, 35) = 13.86, $p$ = .001. Simple effect analysis only showed that composite effect for decision for the bottom segment was significant, $F$ (1, 35) = 18.75, $p$ < .0001. Post hoc t-tests (Bonferroni) showed that for decision for the bottom segment, the accuracy of identifying composite stimuli was significantly higher than that of identifying noncomposite stimuli, $p$ < .0001. The mean accuracy of composite and noncomposite stimuli for decision for the bottom segment was 97% and 95%. The difference between composite and noncomposite stimuli conditions on magnitude of holistic processing is 2%. Therefore, it's negligible difference of magnitude of holistic processing as compared with that in facial identity and expression tasks. Instead, it can be interpreted as a fluke in the experiment.

Secondly, holistic processing of facial identity, gender categorization and color perception tasks was measured by the difference between composite and noncomposite stimuli in RTs and accuracy.

**Table 11.** Results of holistic effect in facial identity task, gender categorization task and color perception task.

| Task and measure | Mean | 95%CI | Range |
|---|---|---|---|
| HP in identity:RTs | 41.18 | [24.67,57.69] | -66 to 128 |
| HP in identity:ACC | -0.022 | [-0.03,-0.01] | -0.10 to 0.04 |
| HP in gender:RTs | 58.1911 | [38.61,77.78] | -33.09 to 187.34 |
| HP in gender:ACC | -0.0274 | [-0.04,-0.01] | -0.13 to 0.05 |
| HP in color:RTs | -6.2672 | [-16.13,3.60] | -69.08 to 60.51 |
| HP in identity:ACC | 0.0098 | [0.00,0.02] | -0.02 to 0.05 |

Note: Holistic processing (HP) based on reaction time (RTs) was calculated by subtracting the mean RTs (in milliseconds) for correct trials in composite stimuli from those in noncomposite stimuli. Holistic processing (HP) based on accuracy (ACC) was calculated by subtracting the mean accuracy for correct trials in composite stimuli from that in noncomposite stimuli.

*Correlations.* As Table 11 shows above, holistic processing measure for facial identity in RTs was significantly greater than zero, $t$ (35) = 6.038, $p < .0001$, and in accuracy was significantly lower than zero, $t$ (35) = -3.727, $p = .001$; Holistic processing measure for gender categorization in RTs was significantly greater than zero, $t$ (35) = 5.070, $p < .0001$, and in accuracy was significantly lower than zero, $t$ (35) = -3.694, $p = .001$, indicating more interference for composite stimuli. Holistic processing measure for color perception in accuracy was significantly larger than zero, $t$ (35) = 2.976, $p = .005$, indicating more interference for noncomposite stimuli. In addition, one subject was excluded as an outlier because accuracy in holistic processing of color perception task for this subject was more than 3 standard deviations from the mean of all the subjects.

As Tables 12 and 13 show, for facial identity and gender categorization, the correlations on holistic processing between these two tasks were not significant. For facial identity and color perception, the correlations on holistic processing between these two tasks were also not significant. For gender categorization and color perception, the correlations on holistic processing between these two tasks in RTs were not significant, but the correlations on holistic processing between these two tasks in accuracy were significant, G-C $_{ACC}$ $r = .380$, $p = .024$. The scatter plots were shown in Appendix B1.

**Table 12.** Correlation matrix on holistic processing for facial identity, gender categorization and color perception in RTs.

| Task | Identity (RTs) | Gender (RTs) | Color (RTs) |
|---|---|---|---|
| Identity (RTs) | 1 | | |
| Gender (RTs) | .050 | 1 | |
| Color (RTs) | -.069 | .116 | 1 |

**Table 13.** Correlation matrix on holistic processing for facial identity, gender categorization and color perception in accuracy.

| Task | Identity (ACC) | Gender (ACC) | Color (ACC) |
|---|---|---|---|
| Identity (ACC) | 1 | | |
| Gender (ACC) | -.094 | 1 | |
| Color (ACC) | -.058 | .380* | 1 |

*Note:* * correlation is significant at the .05 percent level (2-tailed)

Thirdly, in order to look into the relationship among facial identity, gender categorization and color perception, the correlations were analyzed by decision for either the top or bottom segment separately. The reason for separate correlation analysis of top and bottom segment of faces is that performance in RTs was significantly faster for decision for the top segment than that for the bottom segment in both facial identity and gender categorization tasks. On the other hand, holistic effect in accuracy was only shown for the bottom segment in both facial identity and gender categorization tasks.

As Table 14 and Table 15 show below, for facial identity and gender categorization, the correlations on holistic processing between these two tasks were not significant for decision for either the top or bottom part.

For facial identity and color perception, the correlations on holistic processing between these two tasks were not significant for decision for either the top or bottom part.

For gender categorization and color perception, the correlations on holistic processing between these two tasks were not significant either in RTs or accuracy when the task was to identify the top part. However, when the task was to identify the bottom part, the correlations on holistic processing between these two tasks were not significant in RTs, but there was marginally significant correlation on holistic processing in accuracy, G-C $_{ACC}$ $r = 0.326$, $p = .056$. The scatter plots for either top or bottom part were shown in Appendix B2.

**Table 14.** Correlation matrix on holistic processing for facial identity, gender categorization and color perception in RTs for top or either bottom part.

(a) Correlation matrix on holistic processing for facial identity, gender categorization and color perception in RTs for top part.

| Decision for top part | Identity(RTs) | Gender(RTs) | Color(RTs) |
|---|---|---|---|
| Identity(RTs) | 1 | | |
| Gender(RTs) | .096 | 1 | |
| Color(RTs) | -.170 | .191 | 1 |

(b) Correlation matrix on holistic processing for facial identity, gender categorization and color perception in RTs for bottom part

| Decision for bottom part | Identity(RTs) | Gender(RTs) | Color(RTs) |
|---|---|---|---|
| Identity(RTs) | 1 | | |
| Gender(RTs) | .180 | 1 | |
| Color(RTs) | .137 | -.080 | 1 |

**Table 15.** Correlation matrix on holistic processing for facial identity, gender categorization and color perception in accuracy for top or either bottom part.

(a) Correlation matrix on holistic processing for facial identity, gender categorization and color perception in accuracy for top part.

| Decision for top part | Identity(ACC) | Gender(ACC) | Color(ACC) |
|---|---|---|---|
| Identity(ACC) | 1 | | |
| Gender(ACC) | .050 | 1 | |
| Color(ACC) | -.239 | -.044 | 1 |

(b) Correlation matrix on holistic processing for facial identity, gender categorization and color perception in accuracy for bottom part.

| Decision for bottom part | Identity(ACC) | Gender(ACC) | Color(ACC) |
|---|---|---|---|
| Identity(ACC) | 1 | | |
| Gender(ACC) | -.006 | 1 | |
| Color(ACC) | .152 | .326 | 1 |

Task reliability. The reliability was measured in the same way as in Study 2. As Table 16 shows, reliability for each task was low because the trial numbers equally assigned to each condition were reduced by splitting half.

**Table 16. The reliability of facial identity, gender categorization and color perception task.**

| Reliability | Identity (*p*) | Gender (*p*) | Color (*p*) |
|---|---|---|---|
| RT | .019 (.909) | -.080 (.627) | .010 (.950) |
| Accuracy | .380 (.015) | -.362 (.024) | .110 (.506) |

**4.3 Discussion**

The study found the holistic processing for both facial identity and gender categorization task. Overall speaking, participants were slower to process the identity (or gender) of either the top or bottom segment of the composite when it was aligned with the part of another facial identity (or gender), than when it was misaligned with the part of another facial identity (or gender). It was consistent with the previous finding on holistic effect in facial identity (Young et al., 1987; Hole, 1994) and gender categorization (Baudouin & Humphreys, 2006; Zhao & Hayward, 2009). For both identity and gender categorization task, the holistic processing interfered with the decision for the part, which was mainly demonstrated by the greater extent to which decision for the bottom segment was significantly lower to composites than noncomposites in accuracy. Holistic processing here was measured by RTs or accuracy in holistic processing subtracting composite stimuli from those in noncomposite stimuli.

Given the task reliability, the result of facial identity task in Study 3 almost replicated the findings in Study 2 because holistic processing has been found for the facial identity task in both of Studies 2 and 3. Specifically, to a greater extent, it was demonstrated for the decision for the bottom part.

To test the central question with regard to the locus of holistic processing revealed by the relationship between facial identity and gender categorization, it was not only found that the overall correlation between holistic processing for both identity and gender was not significant, but also correlation between holistic processing for identity and gender was not significant either for the top or bottom part across individuals. It implies that holistic processing may emerge during a later stage of face perception that is required for a specific task. In addition, as was hypothesized, the color perception task was designed to act as a control condition. There was no significant correlation between holistic processing for the identity task and that for the color perception task in either RTs and accuracy, and neither for gender and color perception tasks in RTs, suggesting that although facial identity and gender were processed holistically, they were different from processing of color perception. It can be concluded that holistic processing in facial identity and gender categorization task could not attribute to simply response interference or Stroop-like effects as can be seen in a color composite task. Additionally, although the correlation on holistic processing between gender categorization and color perception was significant in accuracy, it doesn't mean that holistic processing of gender categorization can be totally interpreted as response interference or stroop-like effect. This is because the variance on holistic processing for gender, which could be explained by response interference, accounts for a very small proportion. In other words, only part of HP for gender categorization can be explained by response interference. Therefore, processing for gender categorization is holistic unlike processing for emotional expression.

# Chapter 5

# General Discussion

## 4.1 The Three Studies

In Study 1, it was found that recognizing the identity (or expression) from half of the face is influenced by incongruent identity (or expression) from the other half, but unaffected by incongruent expression (or identity) from the other half. These results indicate that holistic processing for identity and expression are independent of each other. In subsequent studies, it was found that the magnitudes of holistic processing for identity and expression (Study 2) as well as those for identity and gender (Study 3) were not correlated across individuals. Together these three studies demonstrate that holistic processing of identity, expression and gender are independent of each other, indicating that holistic processing may take place at the later stages of face processing, being specific to different facial judgments. It is important to note the different paradigms used in Study 1 as compared with Studies 2 and 3. While Study 1 probed the relationship between the holistic processing for different facial judgments by examining the effect of incongruent, task-irrelevant (e.g., expression) information on task-relevant (e.g., identity) judgment, Studies 2 and 3 used an individual difference approach instead. Yet the three studies converged to the same conclusion that holistic processing of identity, expression and gender are largely independent of each other.

While Study 1 used a paradigm similar to that in Calder et al. (2000), Studies 2 and 3 adopted a new, individual difference approach (Vogel & Awh, 2008) to measure whether two similar constructs can be dissociated across individuals in performance or not. Specifically, if an individual's performance on one task can predict his or her performance on another task, then performance variations of the two given tasks can be attributed to the same underlying constructs. Following this rationale, Studies 2 and 3 were aimed at probing the locus of holistic processing revealed by facial identity, expression and gender. If the holistic effect for facial identity and expression tasks (or for facial identity and gender tasks) shares a single resource, then there would be a strong correlation between these two measures. It would then suggest that holistic processing occurs during an early perceptual structural encoding stage obligatory for all facial judgments. Otherwise, if the holistic effect is specific for each task, then there would be no significant correlation between these two measures. It would suggest that holistic processing may take place at a later stage specific with separate routes devoted to the processing of facial identity, expression and gender.

The individual difference approach used in Study 2 and Study 3, which emphasizes the importance of individual performance in holistic processing, is a better way to examine the relationship on holistic processing revealed by identity, expression and gender for a key reason: The paradigm used in Study 1 (examining the relationship between holistic processing of identity and expression) cannot be applied to Study 3 (examining the relationship between holistic processing of identity and gender). This is because, while a same-identity-diffrerent-expression condition is possible as in Study 1, there cannot be a same-identity-different-gender condition. Identity and gender are nested properties of a face, and it is just logically impossible to from a composite from two faces of the same identity but different gender.

## 4.2 Holistic Processing in Identity, Expression and Gender Judgment

Robust holistic processing of facial identity was found for all three studies, consistent with the abundant findings in the literature. Holistic processing of gender was also found in Study 3. Nevertheless, holistic processing of facial expression was less reliable, as it was found in Study 1 but not Study 2. Indeed, some studies do suggest that expression judgment may be an analytic process. Calvo and Nummenmaa (2008) showed essentially the same result patterns in visual search for emotional expressions whether the faces were upright or inverted, suggesting that emotional identification involves featural rather than configural information. Similarly, Chen and Chen (2010) found that the alignment of the upper and lower halves of the face had no effect on happy/sad classification. While the lower face was more informative in identifying the happy expression, the upper face was more important for recognizing the sad expression. A likely reason is that different parts of a face contribute differently to processing of various emotional expressions. For instance, the mouth region may provide salient information for certain expressions, e.g., the empty open mouth in surprise and the open mouth with teeth in happy (Smith, Cottrell, Gosselin & Schyns, 2005). Consistent with this idea, Calvo and Nummenmaa (2008) also showed the mouth region made a strong contribution to the visual search for most expressions especially happy, whereas the eye regions played a minor role. Furthermore, we found a significant correlation between the holistic effects for emotional expression and color in certain conditions in Study 2, suggesting that the holistic processing found in some of the previous studies could be attributed to simply response interference or Stroop-like effects as can be seen in a color composite task.

**4.3 The Locus of Holistic Processing**

In theory, Bruce and Young's (1986) classic model of face perception states that face processing starts with an early perceptual encoding stage, but the model didn't clearly point out if holistic processing took place at an early encoding stage. So far holistic processing has been found in a variety of tasks involving identity (Young et al., 1987; Hole, 1994), emotions (Calder et al., 2000), gender (Baudouin & Humphreys, 2006), attractiveness (Abbas & Duchaine, 2008) and trustworthiness (Todorov, Loehr & Oosterhof, 2010). These findings bring about the idea of a common representational system that allows for extraction of multiple judgments and categorization. It also infers that in relation to Bruce and Young's (1986) functional model of face perception, a suitable level for the holistic effect is at an early stage of processing referred to as structural encoding, that is common to different tasks on facial judgments (Calder & Jansen, 2005). If this is correct, correlations on holistic processing for different facial judgment tasks will be expected to be found when holistic processing takes place at an early perceptual coding stage shared by all the facial judgments. However, this study reveals that correlations on holistic processing among facial identity, expression and gender are not significant, suggesting that holistic processing may emerge at a later stage of face perception process devoted specifically to different facial judgments.

This finding can be explained by the claim that featural and holistic information was processed separately at different moments in time (Bartlett & Searcy, 1993; Diamond & Carey, 1986). In other words, featural information of faces such as eyes, nose and mouth can be perceived as coming first, preceding holistic information that combines facial parts into an integral whole. This account puts more emphasis on a temporal precedence of early featural information over holistic information such that it may take a little bit more time to be processed holistically for faces after face parts are processed. Carbon and Leder (2005) also confirmed this point by using inverted thatcherised faces and inverted normal faces so as to dissociate the featural and holistic information at an early stage of face processing. They found that participants could recognize the inverted thatcherised face better than the inverted normal face during a very brief presentation time (26ms) because the eyes and mouth region in inverted thatcherised faces are correctly oriented with reference to the viewer's position. The featural information leads to the recognition of the whole face stimuli. However, performance with inverted normal faces was improved with the increase of presentation time (200ms) in that holistic information has been gradually formed at longer timings. It suggests that processing of the local facial feature could precede the holistic face processing.

To get a better understanding of the locus of holistic processing, a few recent studies have directly pointed to the time-course of holistic processing and provided supporting evidence that holistic processing has an early perceptual locus. For instance, Richler et al. (2009) recently showed that the holistic effect in the composite face paradigm could arise with the first 50 ms of processing and then resides at equal strength over the whole temporal continuum. Meinhartdt-Injac, Persike and Meinhardt (2010) also found that holistic processing was dominant at the early stage for both external and internal facial features when both feature types were inverted. The holistic effect was larger for low-pass filtered faces as compared to full-spectrum faces and high-pass filtered faces and indeed holistic face representation was built upon low-resolution level (Goffaux & Rossion, 2006). This is because face holistic processing would mainly depend on low spatial frequency, which conveys coarse information. By contrast, processing for face parts would depend on high spatial frequency which was recruited for detailed information such as portraying the contours of facial features. Furthermore, some ERP observations with the N170 component indicated that the face was encoded in the right hemisphere as early as 160ms over the occipito-temporal cortex, and the initial face representation was holistic rather than based on independent features (Jacques, d'Arripe & Rossion, 2007; Jacques & Rossin, 2009). These studies are in agreement with the assumption of a "microgenetic" development of holistic face representations in the course of time proposed by Sergent (1986), in which different face parts interacted from the beginning at both brief and longer viewing times, but evolved from a global coarse representation to a representation being progressively refined with finer resolution information.

Here it is important to discuss their relationship with our results. Richler et al. (2009) found that presenting a face for 50 ms was enough to observe holistic processing and the effect did not increase with a longer presentation time. On the surface this suggests that holistic processing happens early, contrary to our conclusion. However, there was no response deadline in their study, and even with 50-ms presentation participants on average used about 900ms to make a response. It is likely that a brief presentation time only degraded the face stimuli, and sufficient time was available to process this degraded stimuli with early and late perceptual analyses. Hence their findings did not preclude the possibility of holistic processing happening at later, task-specific stages of processing.

In Goffaux and Rossion (2006)'s study, since processing of low spatial frequency information is supposed to occur at the very first stage of object processing before the processing of high spatial frequency information, their results seem to suggest that holistic processing occurs during early perceptual processing, likely around the time of task-general, structural encoding. Nevertheless, it should be noted that their study used the partial design of matching paradigm, whereas Cheung et al. (2008) used the complete design of matching paradigm and found no difference between the holistic processing for faces containing low and high spatial frequency information. The inconsistent results may be relevant to different paradigms used. There are a number of issues with the partial design in which holistic processing is typically indicated by congruency effect: Firstly, given all the "different" trials are always congruent (i.e., both parts are "different") and all the "same" trials are always incongruent (i.e., relevant part is same and irrelevant part is different) in the partial design, there is a confound between same/different response and congruence. Secondly, it has been demonstrated that participants have important response bias demonstrating that they are more likely to respond "same" for aligned than misaligned trials (Gauthier & Bukach, 2007). Therefore, response bias leads to the mistake for a true holistic processing because only "same" trials are analyzed in the partial composite paradigm. Instead, much reliable result can be obtained from complete composite paradigm.

ERP studies mentioned above have found the initial holistic representation of faces is reflected by the larger amplitude in N170 component. For N170 component, it has been argued that the N170 amplitude is not only a manifestation of an early visual mechanism dedicated to analyzing physiognomic information and providing sensory representations of faces but also not influenced by the face recognition and identification process on the basis of some evidences regarding the absence of the N170 amplitude reduction for inverted faces (Bentin et al., 1996) as well as the absence of N170 modulation by face familiarity (Bentin & Deouell, 2000). Nevertheless, it does not mean that the N170 component is reflected by the initial perceptual representation for face holistic processing because initial stage for detecting face and non-face occurs at only 100ms before face identity at the individual level is extracted at a latency of 160ms in an MEG study (Liu et al., 2002), which means that facial identity appeared to be categorized at the individual level at the same latency as 170ms. For instance, N170 amplitude is reduced for repeated facial identity (Campanella et al., 2000). Thus, the N170 component may not play an important role in implicating a very early perceptual stage. Rather, the N170 component may be reflected by a later perceptual stage specific to different facial judgment tasks such as identity.

While Richler et al. (2008) emphasized the decisional locus of face holistic processing, it is important to note that a later, task-specific stage that our results suggest does not correspond to the decisional locus. Moreover, a recent ERP study observed a robust composite face effect at the N170 face-sensitive component but no response bias at the later decisional component such as P3b and Lateralized readiness potential (Kuefner et al., 2010), reflecting that holistic processing measured by the composite face effect primarily has a perceptual locus rather than perceptual locus. Therefore, the importance of decisional locus of holistic processing and how the face holistic processing might be decisional are needed to testify and expand further.

**4.4 Implications and Future Direction**

The study on the locus of holistic processing is important for evaluating existing theories on face processing. As discussed above, there are two different approaches regarding the temporal aspects of holistic processing. It is common to identify two types of face processing: featural and holistic. Based on these two kinds of information some researchers assume that facial features are not encoded or represented independently from each other, but instead form a "Gestalt", a holistic representation (Tanaka & Farah, 1993). Accordingly there is a whole-face representation at the very beginning, with more detailed part information processed afterwards. On the contrary, others stress that featural information is processed first and later integrated into a whole (Bartlett & Searcy, 1993; Diamond & Carey, 1986). Evidently, results of the current study provide support for the latter position. In addition, more complicated scenarios are possible in which featural and holistic processing co-exist but have are prevalent at different points during face processing. Future investigation can focus on how featural and holistic processing interact with each other in face processing.

Moreover, the study on the locus of holistic processing deepens the understanding of the underlying mechanism of face processing. The initial face processing could serve as a "header" to prepare for distinguishing a large number of individual faces. It has been supported by a single neuron recording study (Sugase, et al., 1999) showing that information representing the stimulus group monkey faces, human faces and shape was conveyed in the early part of the response set, peaking at 117ms, and information about identity or expression of human or monkey began on average at 51ms after the global information. The initial part of the neuronal response transmits information on face and non-face objects earlier than information on identity or expression. With regard to stages of face processing, the initial stage was to detect faces as compared to non-face objects, preceding the early structural encoding stage in charge of distinguishing the face from other faces within category discrimination. And further face recognition unit may be associated with the semantic activity involved in the identification of familiar faces (Bentin & Deouell, 2000; Liu, Harris & Kanwisher, 2002). The finding from the current study indicates that the magnitude of face holistic effect may play a dominant role in the later stage of face processing that is related to different facial judgment tasks, which corresponds to separate routes to processing of identity, expression and gender information respectively. It means that holistic processing might exert greater influence on the later stage of face processing depending on different facial judgments which may require semantic process of identifying the person, expression or gender in the naming tasks. Thus, a promising direction would aim at updating the models of face perception, and looking into the changes of magnitude of holistic effect at different stages of face processing with neuroimaging techniques.

The current study suggests that holistic processing is not a general mechanism for different aspects of face processing at a very early perceptual stage. Instead, it may take place at a later perceptual stage of face processing flexibly depending on different facial judgments. It is in tune with the view that facial features are extracted before they would be later combined to form the whole representation. However, currently there aren't any physiopsychological studies supporting this view. Thus, it would be interesting to explore how featural information leads to the formation of holistic processing in further studies. In addition, given the insignificant holistic effect in Study 2, it remains unclear whether processing for expression is holistic or not. So far, an fMRI study found configural similarity exists along different dimensions such as gender, ethnicity and identity, which doesn't necessarily involve separate processing regions (Ng, Ciaramitaro, Anstis, Boynton & Fine, 2006), whereas emotion information is mostly recruited for the anterior portion of the superior temporal sulcus and identity information is mostly recruited for the fusiform cortex and posterior temporal sulcus (Winston et al., 2004). It suggests that processing mode for expression is different with processing for identity and gender because more dynamic information is conveyed by emotional expression. Therefore, further studies can investigate how the pattern of time course on holistic processing of emotional expression as compared to other facial information such as identity, gender and ethnicity.

In addition, a number of modifications of the current study could be implemented. Firstly, the trial numbers in facial identity, expression and gender categorization tasks of Study 2 and Study 3 was relatively small so that the task reliability was low when splitting the data into halves. Future studies should consider adding the trial numbers to increase the task reliability. Secondly, in spite of low task reliability, to some extent, holistic processing of facial identity found in both Study 2 and 3 implied the fixed results. Further studies may re-run the facial expression and gender tasks to see if holistic processing can be obtained within these tasks. Thirdly, Apart from increasing the trial numbers, one way to increase the task reliability is to emphasize accuracy and try to restrict all effects on RTs, or vise versa. For instance, in order to emphasize RT, participants would be given a short response deadline in the response window. By contrast, in order to emphasize accuracy, participants could be instructed to make response as accurately as possible, and give a long and annoying negative feedback screen (e.g., 4 sec), such that they would try their best to avoid errors. In addition, the result revealed that processing for identity, expression and gender was not significantly correlated across individuals. However, the findings don't answer how three tasks are not correlated with each other. Therefore, it would be better for the present study to find the upper bound of correlation on the basis of increasing the task reliability.

Secondly, the insignificant holistic effect in facial expression task of Study 2 might be caused by only three types of expression (sad, surprise and happy) used in facial expression task. It would be a better way to use six basic types of expressions such as sad, surprise, fear, disgust, angry and happy. Also, the image selection is limited by the pilot study in which nine males and nine females were invited to be face models. As a result, only three female models with three types of emotional expressions were selected in that these images ideally meet the two standards: Either top or bottom segment of each face is not only expressive but also the whole face is expressive enough to be identified. Thus, the study should recruit more face models so that there are more images that can be selected.

# Chapter 6

# Conclusion

Holistic processing for different facial judgments was dissociated in two experimental ways. First, recognizing the identity (or expression) from half of the face was influenced by the incongruent identity (or expression) from the other half, but unaffected by the incongruent expression (or identity) from the other half. Second, using an individual difference approach, I demonstrated that the magnitude of holistic processing of identity, expression or gender was not correlated across individuals. These findings suggest that holistic processing takes place at a later, task-specific stage of face processing rather than at the early structural encoding stage.

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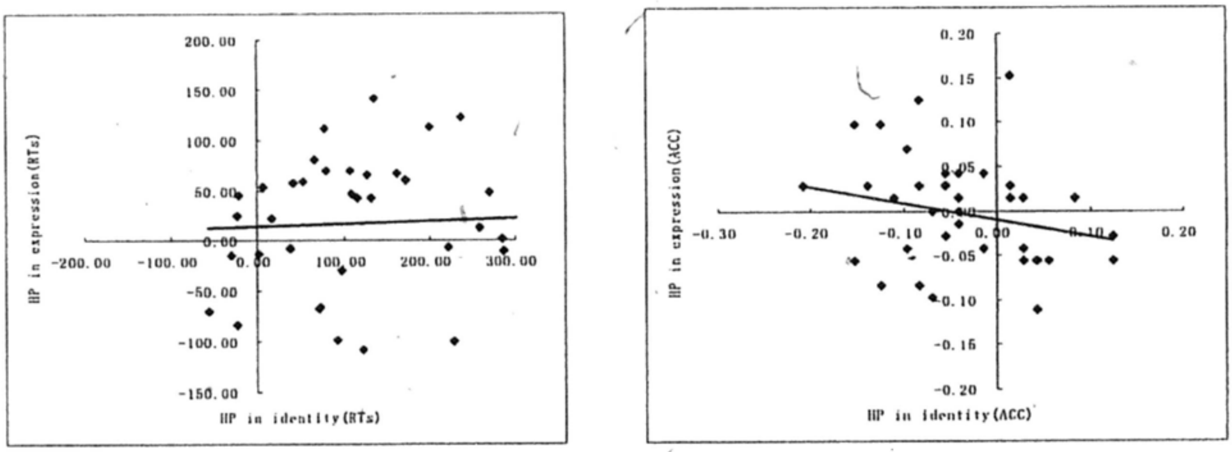
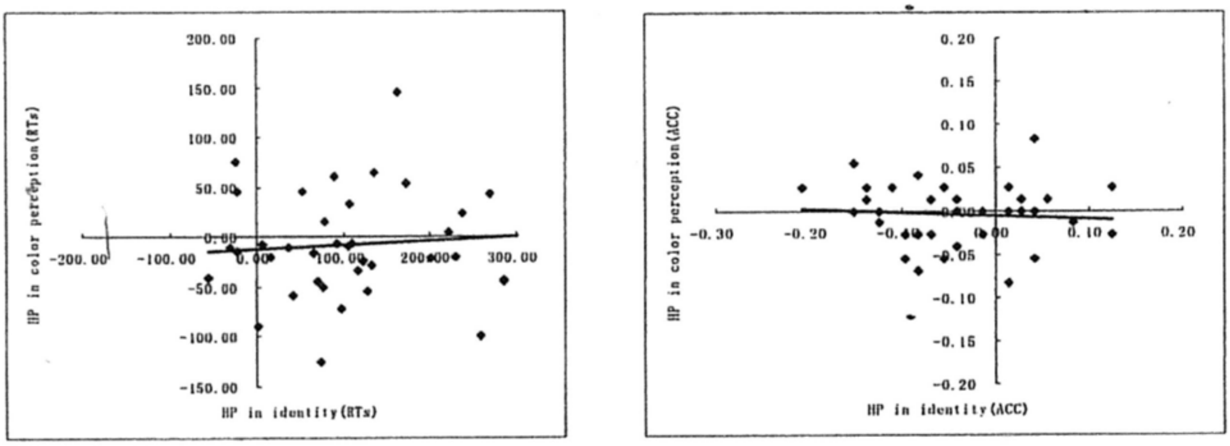
**Appendix A1:** Scatter plots for correlations among facial identity, expression and gender in Study 2

(a)




(b)




(c)

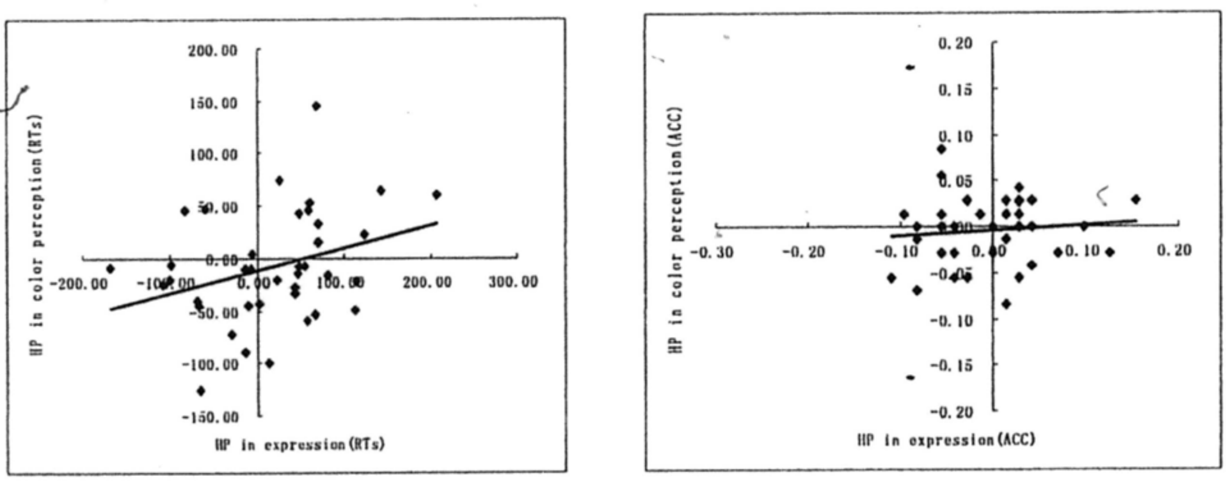
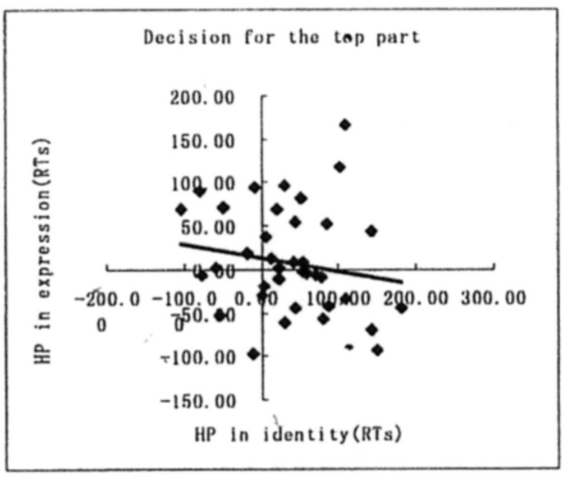


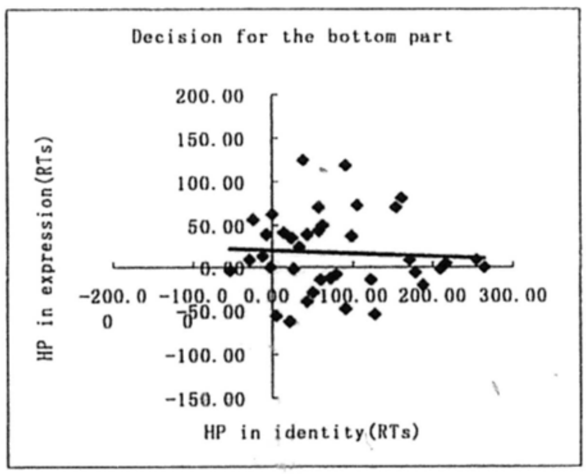
Figure A1. Correlations on holistic processing among facial identity, expression and color perception in Study 2. From top to bottom row: (a) Holistic effect for facial identity in RTs (accuracy) for individual participants as a function of holistic effect for facial expression in RTs (accuracy); (b) Holistic effect for facial identity in RTs (accuracy) for individual participants as a function of holistic effect for color perception in RTs (accuracy); (c) Holistic effect for facial expression in RTs (accuracy) for individual participants as a function of holistic effect for color perception in RTs (accuracy).

**Appendix A2:** Scatter plots for correlations among facial identity, expression and color for either top or bottom part in Study 2.

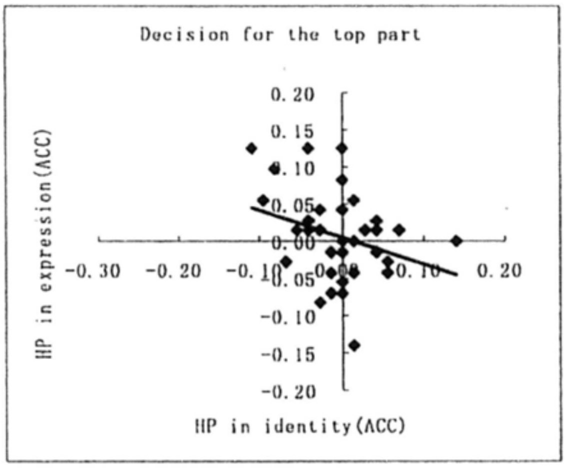
(a1)



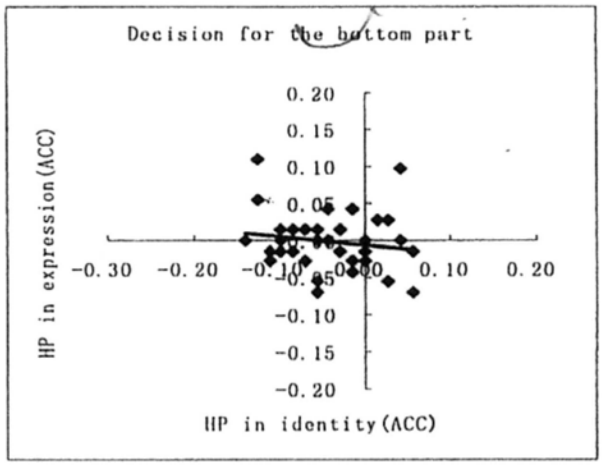

(a2)



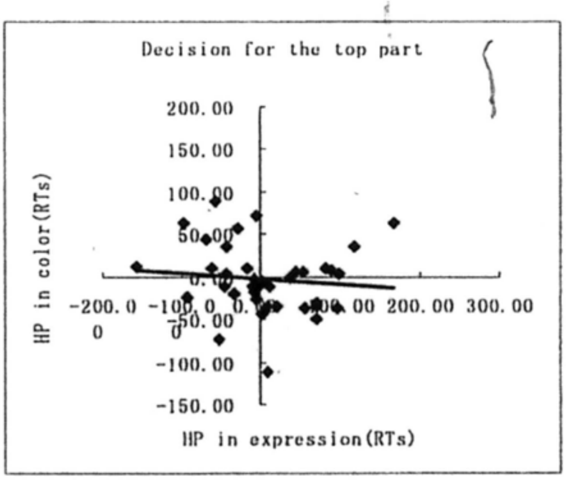
(a3)



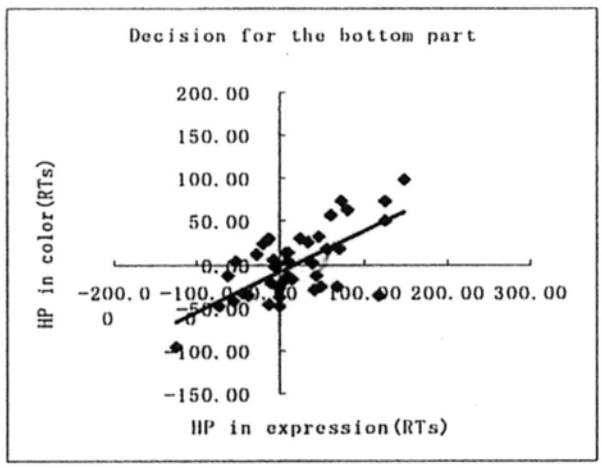

(a4)



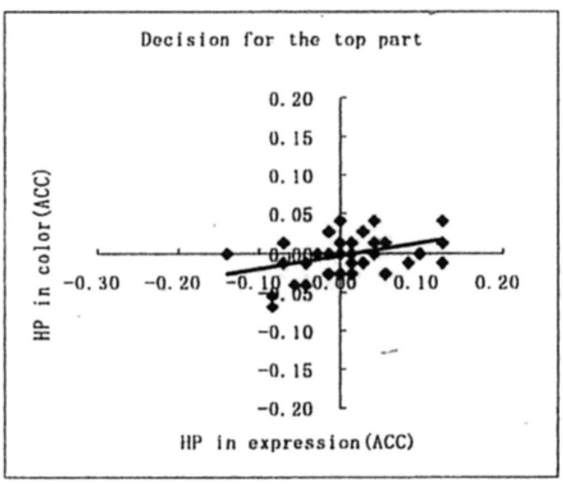

(b1)



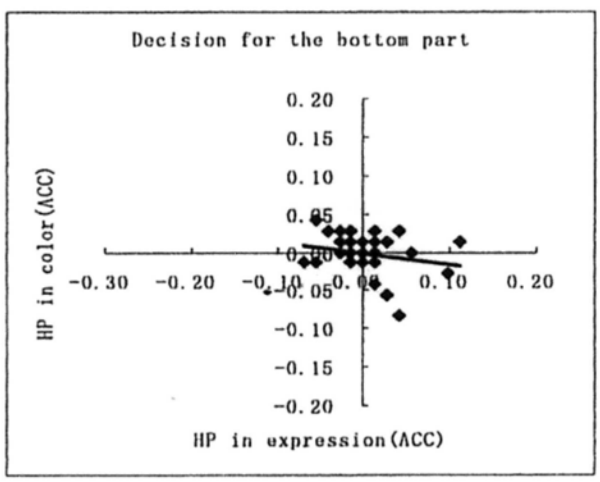

(b2)



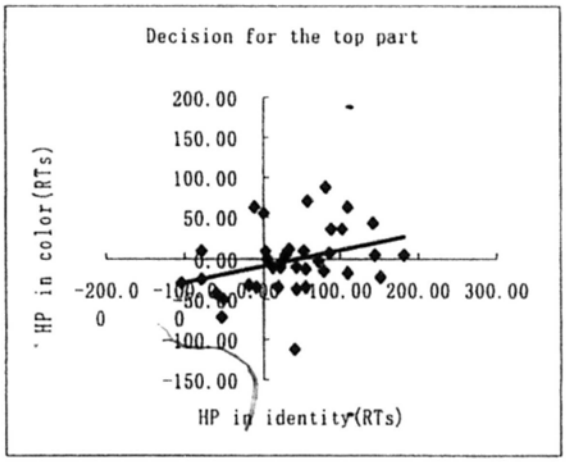

(b3)



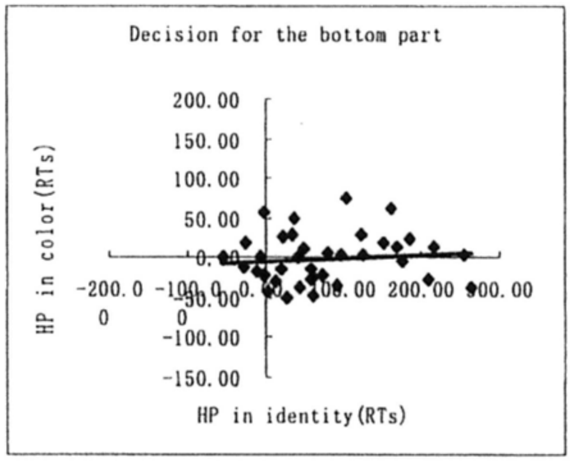

(b4)



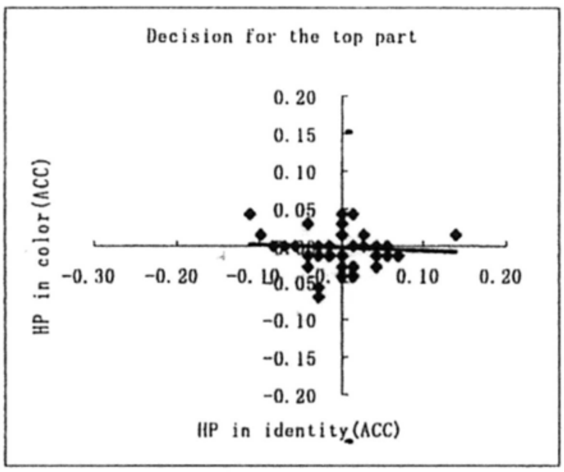
(c1)




(c2)




(c3)




(c4)

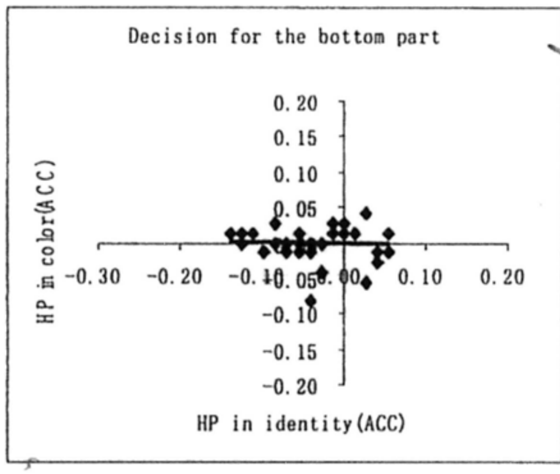
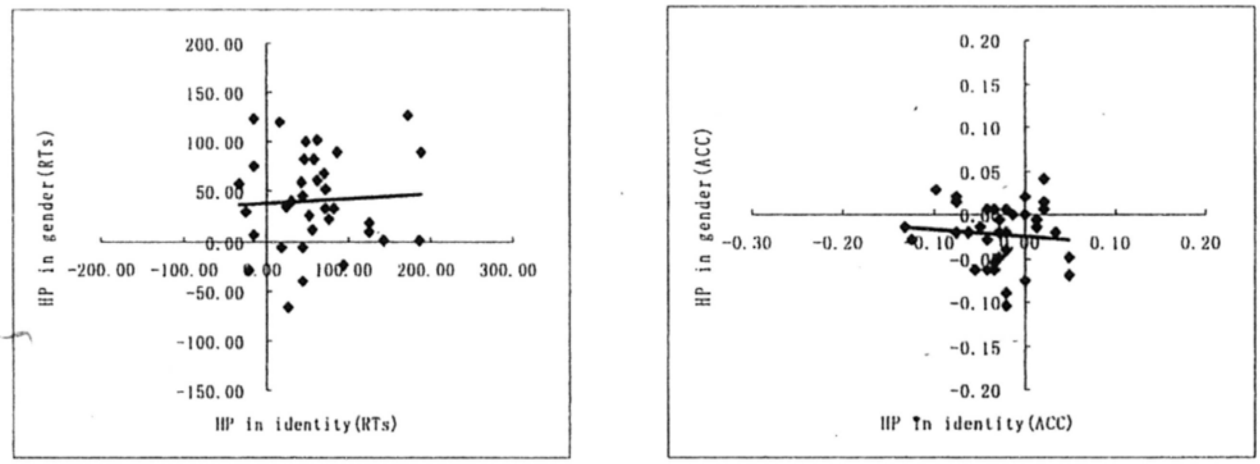


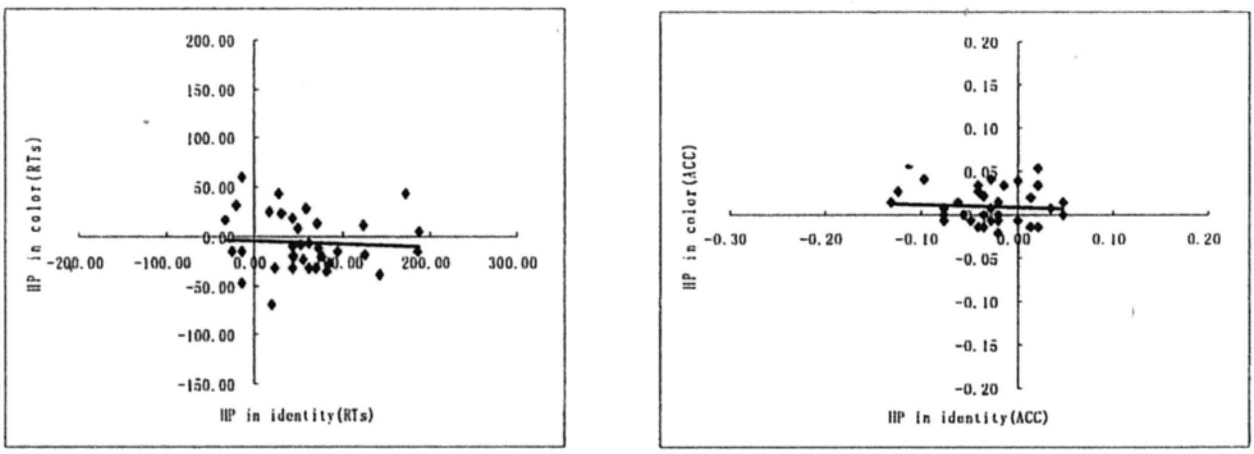

Figure A2. Correlations on holistic processing among facial identity, expression and color perception in Study2: (a1 to a4) Holistic effect for the top or bottom part of facial identity in RTs (Accuracy) for individual participants as a function of holistic effect for the top or bottom part of facial expression in RTs (Accuracy); (b1 to b4) Holistic effect for the top or bottom part of facial identity in RTs (Accuracy) for individual participants as a function of holistic effect for the top or bottom part of color perception in RTs (Accuracy); (c1 to c4) Holistic effect for the top or bottom part of facial expression in RTs (Accuracy) for individual participants as a function of holistic effect for the top or bottom part of color perception in RTs (Accuracy).

**Appendix B1:** Scatter plots for correlations among facial identity, gender and color in Study 3

(a)




(b)




(c)

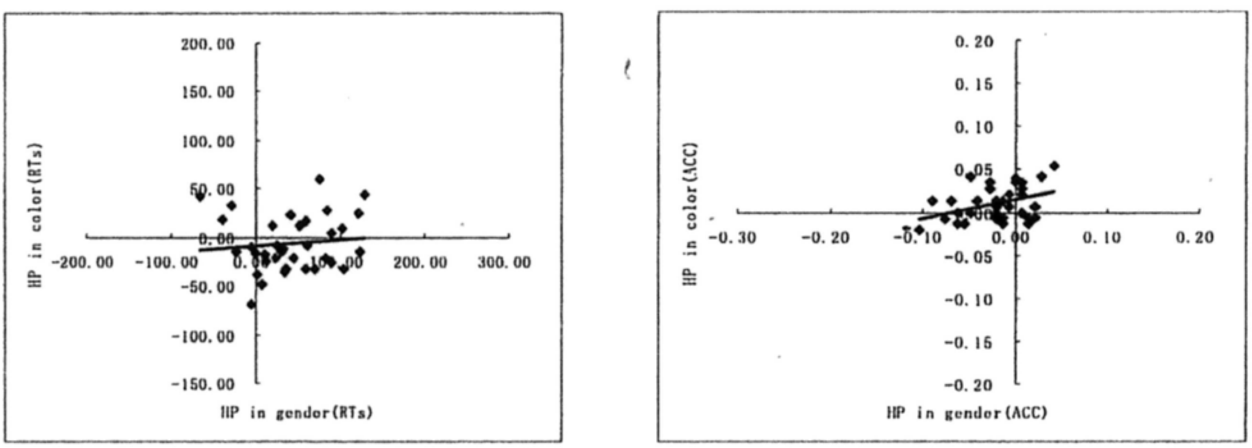
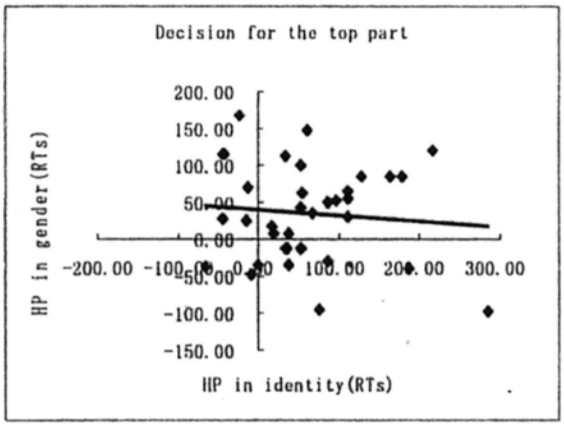


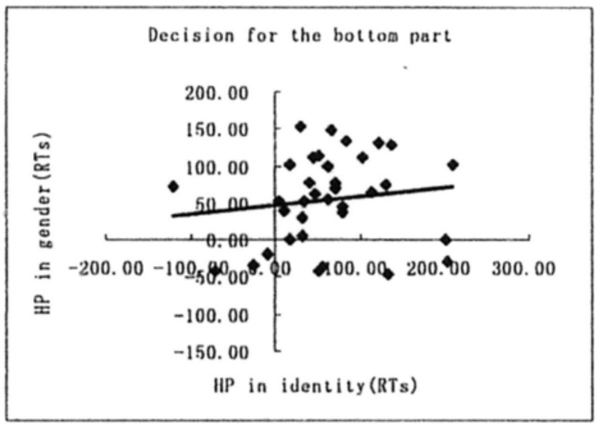
Figure B1. Correlations on holistic processing among facial identity, gender and color perception in Study3. (a) Holistic effect for facial identity in RTs (accuracy) for individual participants as a function of holistic effect for gender categorization in RTs (accuracy); (b) Holistic effect for facial identity in RTs (accuracy) for individual participants as a function of holistic effect for color perception in RTs (accuracy); (c) Holistic effect for gender categorization in RTs (accuracy) for individual participants as a function of holistic effect for color perception in RTs (accuracy).

**Appendix B2:** Scatter plots for correlations among facial identity, gender and color for either top or bottom part in Study 3

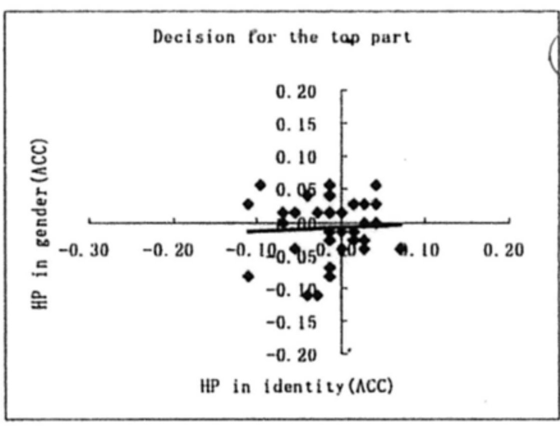
(a1)



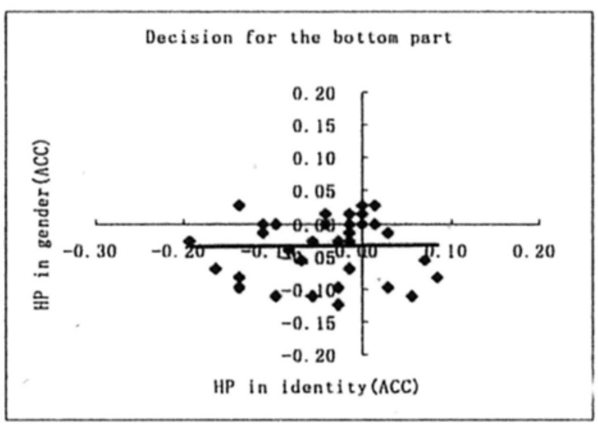

(a2)




(a3)

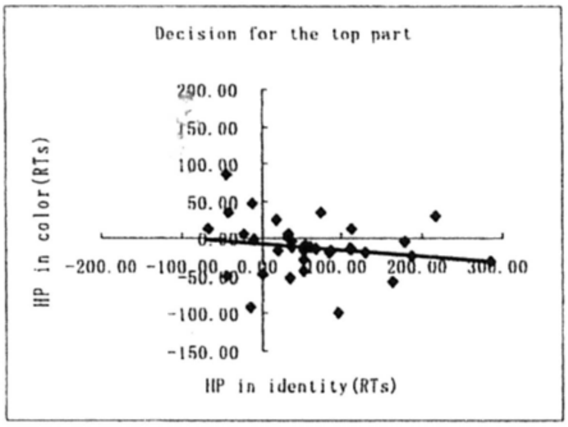



(a4)

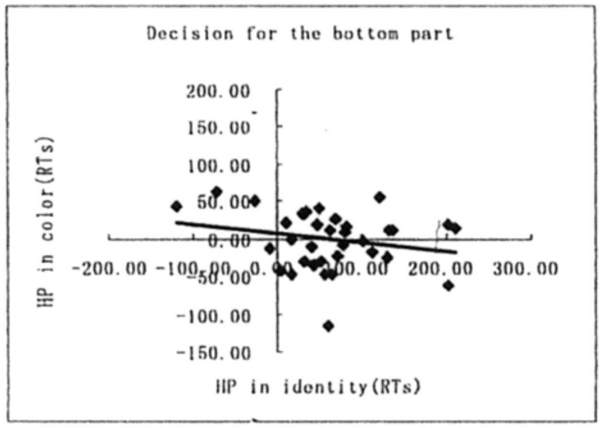



(b1)

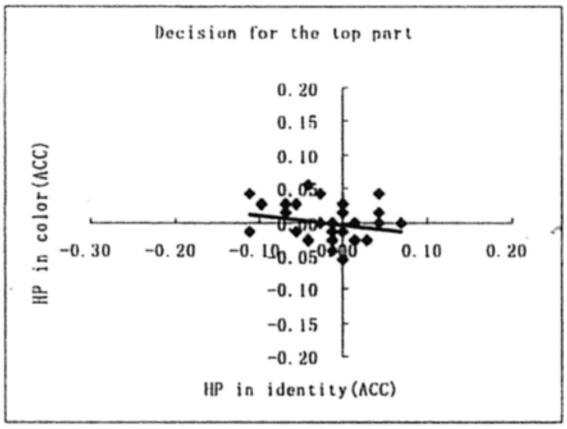
(b2)



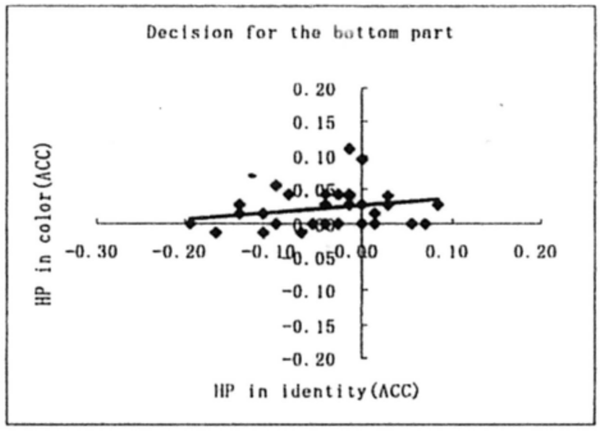

(b3)



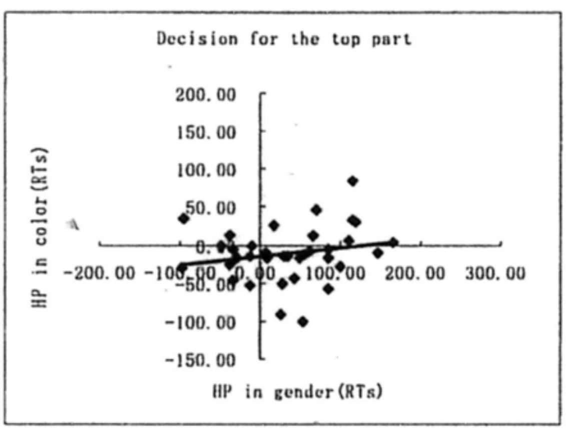

(b4)



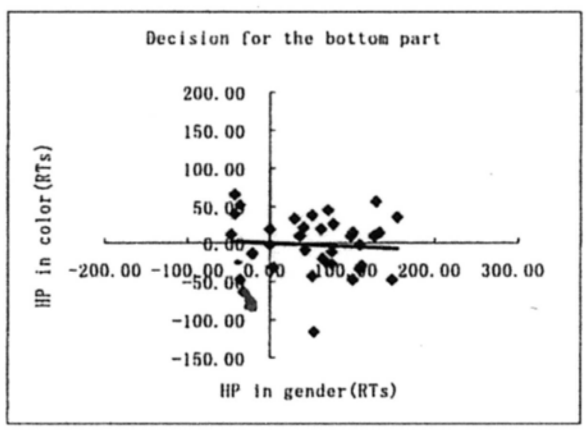

(c1)



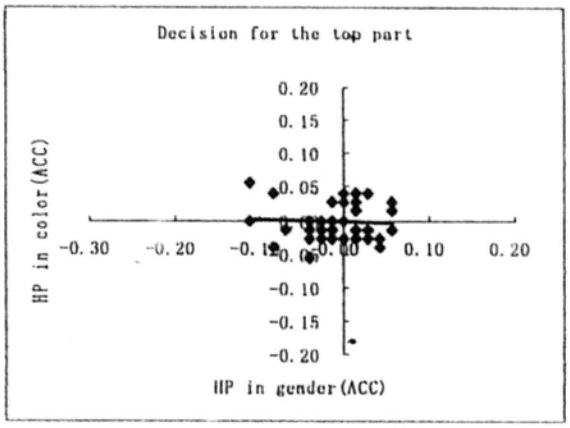

(c2)




(c3)




(c4)



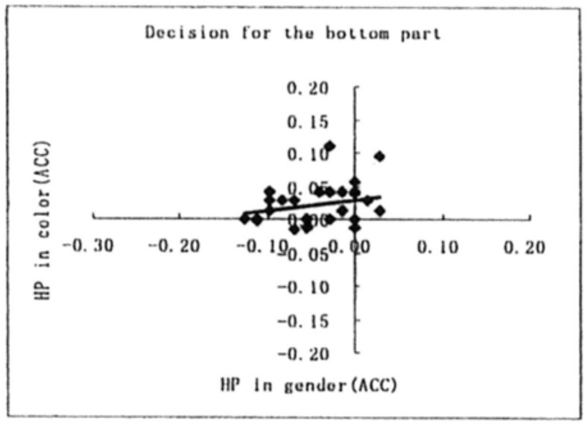




Figure B2. Correlations on holistic processing among facial identity, gender and color perception in Study 3: (a1 to a4) Holistic effect for the top or bottom part of facial identity in RTs (Accuracy) for individual participants as a function of holistic effect for the top or bottom part of gender in RTs (Accuracy); (b1 to b4) Holistic effect for the top or bottom part of facial identity in RTs (Accuracy) for individual participants as a function of holistic effect for the top or bottom part of color perception in RTs (Accuracy); (c1 to c4) Holistic effect for the top or bottom part of gender in RTs (Accuracy) for individual participants as a function of holistic effect for the top or bottom part of color perception in RTs (Accuracy).