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A Psychophysical Investigation of Recognition Strategy and Function Modeling for the Human Face-responsive Neural System

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Abstract

A Psychophysical Investigation of Recognition Strategy and Function Modeling for the Human Face-responsive Neural System

Miao Song

Human face is not only a common visual stimulus in everyday life but also an important message to recognize a personal identity and an emotional state in human social communication. Thus, it has been a long history for researchers in physiological, psychological and psychophysical fields to investigate the mechanism about how the brain recognizes the faces. This issue will provide the further insight into the neural mechanism of human high-level visual system. Also, a better understanding about human face recognition helps to improve the design of automatic face recognition in computer system.

This thesis systematically explored the three important issues about the face and expression perception, which have not clearly been addressed in the previous literatures.

The first issue is associated with how facial attractiveness influences the smile and angry expression perception. As we know, both attractiveness and expression are important channels of the face in the nonverbal communication, this issue is the key to understand the behavior pattern and perception bias of the human when the human present or interpret the expression in the social communication.

The second issue focuses on the relationship between the low-level visual system and a high-level face-responsive system using a visual adaptation experimental paradigm.

This issue is crucial to understand a neural coding and transmission mechanism theoretically in different neural level.

In the third issue, we used the high-level facial adaptation to investigate the relationship between the expression system and facial identity system, which is a long term controversy in the previous studies.

The major contributions of the thesis can be summarized briefly as: (1) This thesis systmetically performed a comprehensive survey on the latest studies and findings related to the face recognition. (2) We conducted the experiments to investigate the three important issues, the experimental results provide the further insight into the neural mechanism of human high-level visual system and towards a better understanding about the human face recognition system. In terms of our results, I proposes an account of the functional model for identity system and expression system in terms of our own psychophysical measurements and previous luminous findings. (3) I summarize the theoretical interests and application of my findings and discuss the possible future inquiry.

key words Human visual system, Face perception, Expression perception, Visual adaptation, Facial attractiveness

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Chapter 1

Introduction

1.1 Two influential models in the face perception

The face perception is one of the most important visual perception skills for the human survival and social communications. Across the life span, the human will spend the more time to looking at the faces than that of the other objects. The face provide the basic information channels during social interactions, it provided a wealth of face information that facilitate the commnuications. The face perception allow us to recognize the person (Calder and Young, 2005), infer his or her emotional state (Calder and Young, 2005; Buck, 1994), better understand what the person is saying (Schweinberger and Soukup, 1998), and derive general information, such as age and gender (Johnston, Kanazawa, Kato, and Oda, 1997). This unique visual stimulus has generated a wealth of research, and subsequently theoretical and methodological debate.

Psychologists and physiologists have long time explored the mechanism of face perception and achieved the numerous luminous findings. We introduce two influential model in the following sections, which are the functional model proposed by Bruce and Young (1986) and the neural model proposed by Haxby et al. (2000). These two models are generally considered to be the most accepted theoretical frameworks for the face studies.

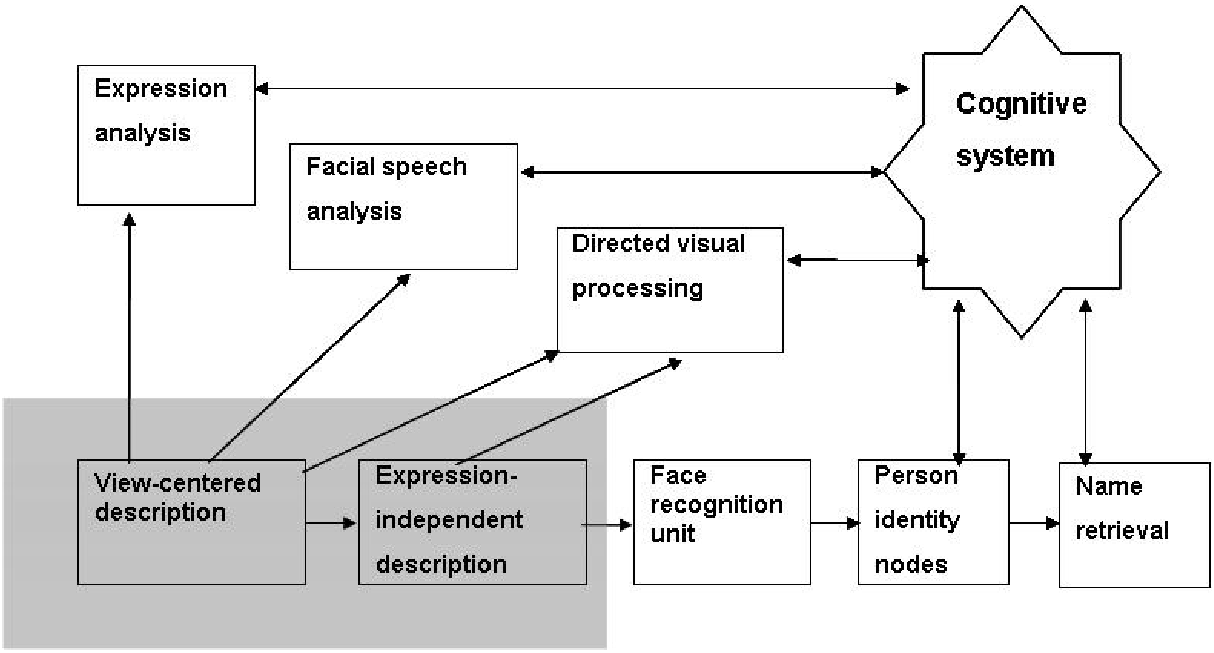

Fig. 1.1 The Bruce functional model for face perception (Bruce, 1986).

1.1.1 The Bruce functional model

The Bruce model is functional model in favor of functional components in the human face perception system, it provided researchers with a general framework to account for the perceptual and cognitive processes involved when people recognize face. without regard to whether or not these functional components are localized to specific areas of the brain.

In understanding face processing, it is crucial to determine what the human need to make use of the information in the process of face perception. The Bruce and young model described seven distinct types of information the faces being derived from the faces, which are 1) pictorial, 2) structural, 3) visually derived semantic, 4) identity-specific semantic, 5) name, 6) expression and 7) facial speech codes, respectively.

In terms of these seven information, Bruce proposed that the human face system may involve several independent functional component to process these different informations, as shown in the Fig. 1.1. We brief introduce these functional components as follows.

Structual encoding produces a set of description of presented face, which include ***view-centered descriptions*** as well as more abstract descriptions both of global feature and of features. ***View-centered descriptions*** provided information for the ***analysis of facial speech*** and for ***the analysis of expression***. The visible movements of the mouth and tongue are categorized in the analysis of facial speech, while the configuration of different facial features leads to the expression categorization.

The More abstract, expression-independent description provide information for the ***face recognition unit***. Each of these three components (analysis of facial speech, the analysis of expression, face recognition unit) serves a different kind of perceptual classification function. Each face recognition unit contains stored structural codes describing one of the faces know to persons, which allows it to be compared to other faces in memory, and across views. This explains why the same person seen from a novel angle can still be recognized.

The structrual code in ***face recognition units*** are transfered to ***personal identity nodes*** to identify a person through information from semantic memory. This idea is that there is one person identity node for each person known, and that this contains the identity-specific semantic codes that allow use to feel we have successfully identified the person concerned. ***Name node*** can be further accessed by ***the personal identity nodes***.

As descirbed above, we may find that Bruce's model emphasized the distinction between processes involved in the recognition of facial identity and those involved in the recognition of expression and other facial movement such as speech, gaze. For example, the Bruce and Young model predicts that processing of familiar faces should be more automatic and rapid than the processing of unfamiliar faces. Additionally, the

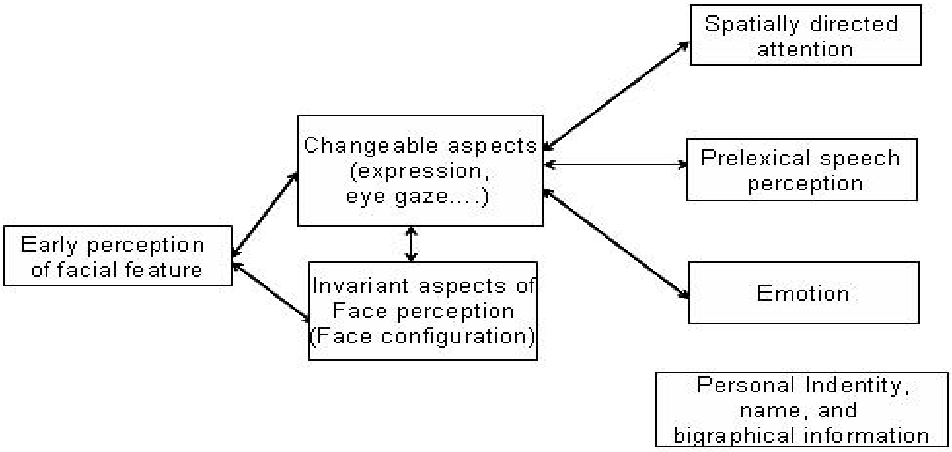

Fig. 1.2 The illustration of the distributed human neural system for face perception (Haxby, Hoffman, and Gobbini, 2000).

model predicts that the process of facial expression and identity should be parallel, and judgments about facial expressions should not be influenced by the familiarity of the face.

These predictions was supported by experiments by Young et al. (1986). In an identity-matching task, subjects had to decide whether simultaneously presented photographs of faces were pictures of the same or different persons. As predicted by Bruce and Young model, subjects were faster to make the judgments when they were familiar than when they were unfamiliar. In an expression matching task, the results also agreed with the prediction of the model, there was no difference in reaction times for expression judgment of familiar and unfamiliar faces. These results support independence in processing facial identity and expressions.

1.1.2 Distributed neural model for face perception

The Bruce model mainly focus on the functional processing for face perception, however, without regard to whether or not these functional components are localized to specific areas of the brain. Haxby et al. (2000) proposed a distributed human neural model for face perception, this model provided the possible functional localization for the face perception in the human brain in terms of previous behaviour and physiological observations. The illustration of neural model for face perception is shown in the Fig. 1.2.

The neural model emphasized a distinction between the representation of invariant and changeable aspects of faces, The representation of invariant aspects of faces refers to the recognition of individuals, and the representation of changeable aspects of faces, such as eye gaze, expression, and lip movement, refers to the perception of information that facilitates social communication. This distinction is somehow similar with functional model by bruce.

Generally, the face perception is mediated by a distributed neural system in the human brain, comprised of multiple bilateral regions (Haxby, 1999; Kanwisher, McDermott, and Chun, 1997; McCarthy, Puce, Gore, and Allison, 1997). Specifically, The haxby model divided the face system into a core system and an extended system. The core of the human neural system for face perception is comprised of three bilateral regions in occipitotemporal visual extrastriate cortex. These three regions are inferior occipital gyri,the lateral fusiform gyrus, and the superior temporal sulcus as shown in the Fig. 1.3.

In the core system, the lateral fusiform gyrus is critical area to process the invariant aspects of face such as identity recognition (Hoffman and Haxby, 2000), and the activation of superior temporal sulcus (STS) is associated with the perception of changeable aspects of faces such as gaze direction (Hoffman and Haxby, 2000; Engell and Haxby, 2007), mouth movements (Puce, Allison, Gore, and McCarthy, 1998), and expression perception (Engell and Haxby, 2007; Haxby, Hoffman, and Gobbini, 2000). The anatomical location of the region in the inferior occipital gyri suggests that it may provide input to both the lateral fusiform and superior temporal sulcus regions.

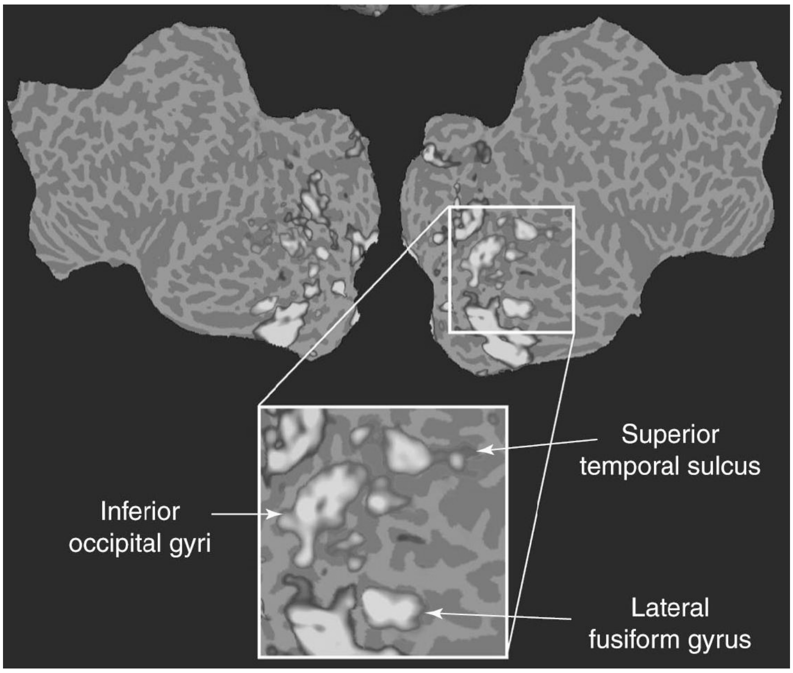

Fig. 1.3 Cortical regions that comprise the core system for visual analysis of faces (Haxby, Hoffman, and Gobbini, 2000).

The functional localizations described above mainly come from functional brain imaging technology. For example, the lateral fusiform gyrus can selectively respond the facial identity, and the activity in response to faces is stronger than that evoked by the perception of the other non-face object stimuli (George, Dolan, Fink, Baylis, Russell, and Driver, 1999; Sergent, Ohta, and Macdonald, 1992). Thus, it is generally regarded that this region is a neural module specialized for face perception and the location of this region has been highly consistent across numerous studies. However, it is also found that the perception of changeable aspect of the face, for example, eye gaze direction reduces the magnitude of the response to faces in the lateral fusiform gyrus (Hoffman and Haxby, 2000). This suggests that the lateral fusiform gyrus may not be involved in all key functions of face perception. In addition to these areas, functional imaging studies have identified other face-responsive regions, usually consistently located in the lateral inferior occipital gyri and the posterior superior temporal sulcus.

The extended system consists of brain regions for other cognitive functions that can be employed to act in concert with the regions in the core system to extract face-related informations from faces. The regions in the extended system, such as the amygdala and the intraparietal sulcus, may have some capacity for visual analysis of faces.

1.2 Research motivations

The classical functional model by Bruce and neural model by Haxby have considerably advanced the recent face studied, from a collection of isolated empirical facts to relatively coherent the theoretical framework within functional subsystem. Despite the success of these model in guiding research efforts into many aspects of face processing, They provided less guidance in understanding the below three important issues.

1. The relationship between low-level visual system and high-level face perception system
2. The influence from the facial attractiveness on the facial expression perception
3. The mutual influence between facial identity recognition and expression recognition

The first issue is associated with the relationship between the low-level visual system and a high-level face-responsive system. As we know, human visual neural system is organized hierarchically(Felleman and Van, 1991), with the neural systems in the lower level cortex processing the primary visual property of object (color, form, motion and so on) (Livingstone and Hubel, 1988) and the systems in the higher level cortex processing the complex visual stimuli such as face perception. The schematic illustration of the hierarchy in human visual system is shown in the Fig. 1.4. The better understanding about relationship of neural representation in different neural level would help to clarify the neural coding and transmission mechanism in the human visual system.

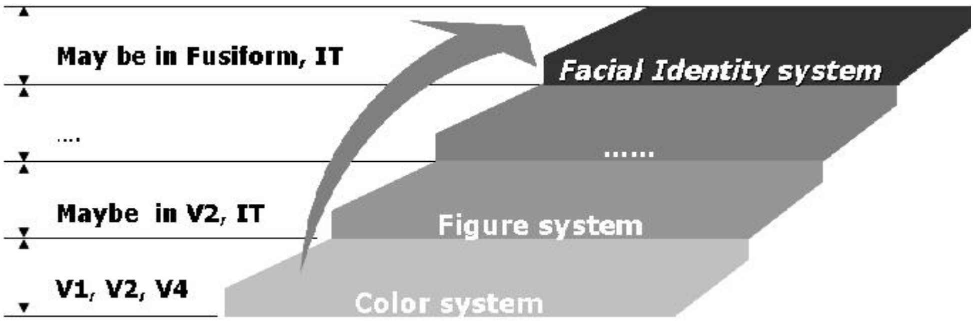

Fig. 1.4 The schematic illustration for hierarchical organization in the human visual system.

The second issue is associated with the relationship between the expression system and facial identity system, which is a long term controversy in the previous studies. As shown in the section 1.1, The classical functional model and neural model suggest the parallel processing between facial identity and facial expression functionally and anatomically. However, there were also several lines of evidence that was inconsistent with this parallel hypothesis.

I aim to systematically investigate this issue using the visual adaptation paradigm and to build an account of the functional model for identity system and expression system in terms of our own psychophysical measurements and previous luminous findings.

The third issue focuses on how facial attractiveness influences the smile and angry expressions. Facial attractiveness is one of the most perception impression in the face stimuli and it plays an important roles in the social communication. It can have a significant effect on how people are evaluated in almost every aspects of social communication, involving social evaluation (Miller, 1970), mate selection (Thornhill and Furlow, 1998), employment decision (Watkins and Johnston, 2000), and even voter preferences for political candidates (Efran and Patterson, 1974). The classical functional model and previous studies do not clarify the influence from facial attractiveness on the perception of other facial dimensions, In these dissertation, we investigated the influence from the facial attractiveness on the facial expression perception. This issue is the key to understand the behavior pattern and perception bias of the human when the human present or interpret the expression in the social communication.

The explorations to these three important issues are the main part of the dissertation. We hope our investigation can enrich the knowledge of current face recognition theoretical framework, to some extend.

Chapter 2

The Visual Adaptation Paradigm

Visual adaptation is a universal phenomenon associated with the human neural system. The most well-understood type of adaptation in the human visual system is light adaptation, which adjusts the sensitivity of the retina to different brightness levels. If one walks from bright sunlight into a dimly lit area, there is an initial period of near blindness while the visual system adapts to the new environment. This light adaptation is a highly beneficial function in the visual system and it can continually resets the retina's sensitivity to match prevailing luminance level.

More generally, the adaptation refer to that the recent sensory experience affects both perception and the response properties of visual neurons, in other word, the adaptation will induce a temporary change of the neural response to a stimulus as the result of preceding stimulation. The visual adaptation is of interest for the following reason. Because the recent sensory history forms an immediate temporal context in which perceptual experience is interpreted, the neural effects of adaptation are a realization and encoding of this context in the brain and thus represent a fundamental component of sensory information processing (Kohn, 2007).

The visual adaptation has been used for a long history as a psychophysical tool for dissecting the perceptual mechanisms of vision. In this dissertation, We will use the

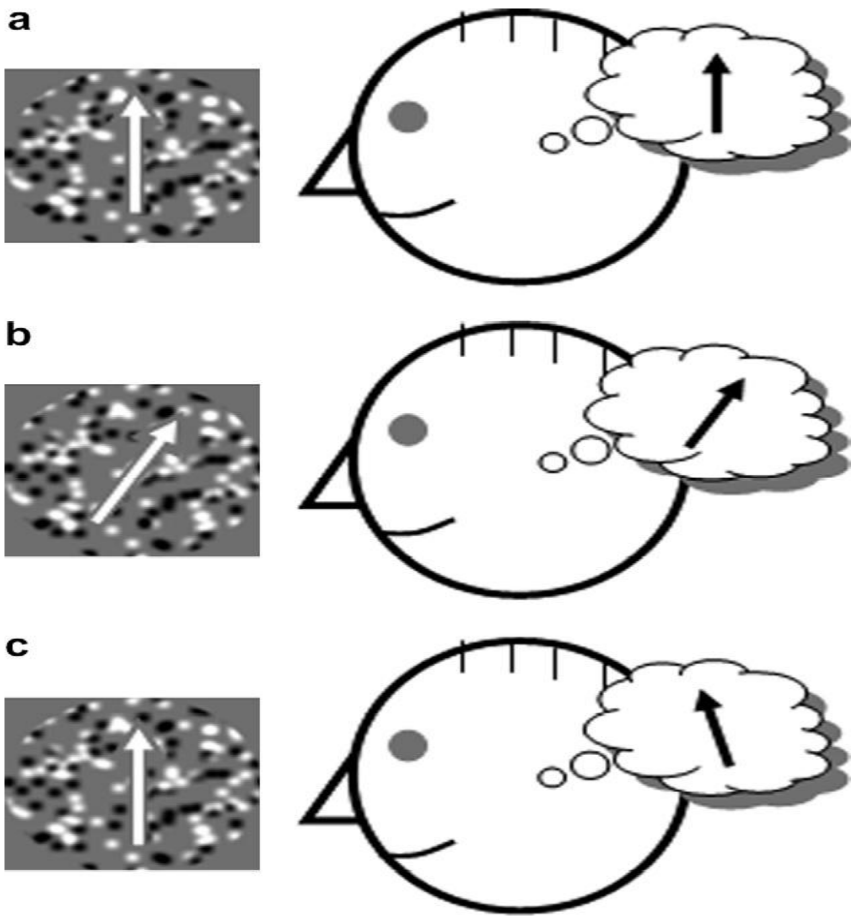

Fig. 2.1 Schematic of the repulsive direction aftereffect (Levinson and Sekuler, 1976). (a) The moving direction of dots pattern is perceived veridically before adaptation. (b) The prolonged exposure to a dots pattern in an oblique direction generate the adaptation effect. (c) After adaptation, the perceived moving direction of dots pattern is perceived being repelled away from the adapting direction of motion.

visual adaptation to investigate the relationship between the low-level color and figure system and the high-level face system, and the relationship between the facial identity and expression systems.

In the following two sections, I will briefly introduce the physiological mechanisms and the time scales about the visual adaptation, these two issues are important for the following experimental design in the chapter 3 and chapter 4.

2.1 Physiological mechanism for adaptation

Adaptation induces two fundamental changes on subsequent perception of observes for presented stimuli (Clifford, 2002). Firstly, it leads to a perceptual bias where the estimate of the stimulus parameter is repelled from the value of the adaptor(Levinson and Sekuler, 1976; Clifford, Webster, Stanley, and et al., 2007)(See Fig. 2.1). Secondly, the ability of the observer will be changed in the discrimination of stimulus parameters, for example, the discrimination thresholds would decrease for patterns very similar to the adapt stimuli, however increase for patterns rather different from the adapting stimuli.

Generally, the visual system could be adapted from the recent sensory input at a neuronal level. Alternatively, the adaptation can occur in a neural processing hierarchy, for example, the adaptation can also occur early in the processing stream and this effect can be passed to downstream areas. Previous Studies have revealed that both these two mechanism possibly occur in the human visual system.

At the neuronal level, various types of adaptation have been observed at multiple stages of processing in early sensory pathways. For example, the adaptation to the mean luminance and contrast of sinusoidal visual stimuli have been found to occur in the retina (Chander and Chichilnisky, 2001), and similar functional effects have subsequently been observed in the thalamus and cortex. Because of the diverse forms of adaptation for sensory, some previous study proposed that the neurons can adapt, at least partially, to any statistical parameter.

Besides the neuronal level, the adaptation can also occur in along the neural processing hierarchy, for example, recent studies have found that the adaptation of cortical areas linked more closely to high level perceptual experience such face perception. The complex nature of some perceptual aftereffects suggests that higher levels of the visual system also adapt along a neural processing hierarchy. This issue is important to understand the relative relationship between low-level and high-level effects. Tracing the effects of adaptation through the sensory system will undoubtedly also elucidate the functional organization of the visual system more generally. In the chapter 3, we will explore this issue.

We further discuss how does such adaptation benefit the neural coding mechanism? One possibility is that the adaptation at the early stages of processing can help to improve the efficiency of encoding, for example, the amount of information about the stimulus conveyed by spike times. If neurons performed only linear transformation of incoming signals, then knowledge of input statistical properties would permit exact description of the filtering operations that would maximize the amount of information transmission (Clifford, Webster, Stanley, and et al., 2007).

A important characteristic of adaptation is that the strength of adapting effects is modulated by the similarity between the test stimulus and the adapter. for example, in the classical aftereffect, when subject was adapted to a grating pattern of medium spatial frequency, a higher frequency grating will be perceived as an even higher frequency, and a lower spatial frequency grating will be judged to be more lower. However, this effect only occurs when the test pattern is within 2 octaves of the adapting frequency on either side. If the test pattern is too dissimilar to the adapting pattern, the aftereffect disappears (Blakemore and Sutton, 1969).

2.2 Time scales of adaptation

The response changes for neuronal properties can be quick or relatively long, from the tens of milliseconds to many seconds occur after adaptation. The previous study has attempted to measure the time scale over which effects arise during the presentation of the adapter and found that the more prolonged adaptation will result in stronger effects under a wide range of time scales (Hershenson, 1989).

So far, in the extensive exploration of the role of adaptation duration, it is found repulsive shifts in V1 orientation tuning occurs after adaptation ranging in duration from 10 seconds to 10 minutes and the latter will induce the strongest effects (Dragoi, Sharma, and M., 2000). On the other hand, Studies examining the tilt or motion adaptation have also found that adaptation duration would influence the strength however not the nature of perceptual experience. (Magnussen and Johnsen, 1986).

Although the statement that more prolonged adaptation leads to stronger effects is a useful rule for experimental adaptation paradigm, both the physiological and perceptual studies suggested that the distinct effects can be generated by the very brief adaptation. On the physiological level, for example, the decay of firing rate in the MT cells can occurs as briefly as tens of milliseconds of stimulus onset, however, the reduced responsiveness induced by a brief presentation of moving stimuli (e.g. < 64 ms) in at one location affects the neuron response presented elsewhere in the RF area, it indicated an effect intrinsic to MT area. This finding is inconsistent with that observed after more prolonged adaptation, in which the adaptation effects are specific within the RF area (Kohn and Movshon, 2003).

On the perceptual level, the higher-level shape aftereffect can occur with a very brief adaptation (27 ms), even in the case that test stimuli and adapting stimuli do not occupy the same location. However, such brief adaptation can not induce the significant orientation-specific aftereffects (Suzuki, 2001). These studies seem to suggest that brief adaptation may be preferentially associated with target extrastriate areas. However, it does not indicate that all effects of prolonged adaptation only occur early in the visual system, the face adaptation effect can also be strengthened by the prolonged adaptation and this effect definitively involve high-level neurons (Leopold, Gillian, Kai-markus, and

Linda, 2005). To conclude, adaptation effects generally occur within a relatively wide range of time scales, but most of the change in tuning is limited to 100 to 1000 ms as a response of perceptual input and the effects strength will slightly increase with longer adaptation.

Chapter 3

The Influence from a Low-level Color or Figure Adaptation on a High-level Face Perception

3.1 Introduction

As we described in the chapter 2, adaptation implies that recent sensory experience would influence perception and response properties of visual neurons, which is a common characteristic in human visual system. For instance, an observer adapts to a moving visual stimulus for a minute and then looks at stationary stimulus, the stationary stimulus seems to move slightly opposite to the direction of the original stimulus, which is called motion aftereffect induced by the adaptation. The reason for this aftereffect is that visual adaptation can isolate and/or temporarily reduce the contribution of specific neural populations (Abbott, Varela, Sen, and Nelson, 1997) and thus bias the human perception. Based on this characteristic, adaptation could influence the perception of the low-level visual properties including color (Craik, 1938), motion (Lehmkuhle and Fox, 2004; Ashida and Osaka, 1995), orientation (He and MacLeod, 2001; Rajimehr, 2004a).

Human visual neural system is organized hierarchically (Felleman and Van, 1991) from neural systems in the lower level cortex processing the primary visual property of object (color, form, motion and so on) (Livingstone and Hubel, 1988) to systems in the higher level cortex processing the complex visual stimuli such as face perception. Recently, adaptation was also found to influence the process of face perception in the high-level visual system, such as facial identity (Leopold, O'Toole, Vetter, and Blanz, 2001; Afraz and Cavanagh, 2007), expression (Webster, Kaping, Mizokami, and Duhamel, 2004; Hsu and Young, 2004), attractiveness (Rhodes, Jeffery, Watson, Clifford, and Nakayama, 2003) and facial distortion (Yamashita, Hardy, and Webster, 2005; Zhao and Chubb, 2001). For instance, the selective adaptation to a specific facial dimension can bias the human perception to the opposite direction on this dimension. As far as facial identity is concerned, within a series of ambiguous faces morphing between two facial identities, adaptation to one identity will distort the perception of an observer to facilitate perceiving the ambiguous images as the other identity.

The possibility of adaptation at different levels of visual system raises the question whether the low-level adaptation could influence the high-level perception. Little is known about this issue, to the best of our knowledge. Only a very recent study (Xu, Dayan, Lipkin, and Qian, 2008) investigated whether low-level curve adaptation affects high-level facial expression judgments. This issue is however crucial to theoretically understand neural coding and computation mechanism, the better understanding for cross-level adaptation interaction will illuminate cross-hierarchy neural response transmission mechanism and implicates how the visual system integrates the complex stimuli from basic visual property. Also, tracking the effects of adaptation in cross-level system is increasingly important for interpreting imaging studies to use adaptation as a tool to assign computations to distinct cortical regions (Krekelberg, Boynton, and Wezel, 2006).

Additionally, the influence from low-level adaptation to high-level perception is a common phenomenon associated with everyday life and visual product design. For example, it may happen in an animation that the previous visual experience of low-level visual element such as the color or shape would influence the subsequent perception of a computer graphics(CG) face. The difference in CG faces is that they are much simpler than the real face, thus, face color and contour is critical for audience to identify faces. If face perception would be influenced by the low-level discrete color or shape adaptation, the identification would easily be affected and thus lead to a wrong judgment. The possible influence is not limited to the above example. Actually, this issue is widely involved in the development of visual product based on the time series, such as computer game, animation, media advertisement design. The predictive estimation of cross-level adaptation effects will help to exclude or strengthen the specific visual effect, thus providing the audience with the better visual experience.

In order to explore theoretical implication for this issue, we intend to investigate the relationship between low-level adaptation and high-level face perception by using cross-level adaptation paradigm, with adapting and test stimuli at different ends of neural hierarchy.

3.2 Purpose of the research

There are three purposes in this study. Firstly, we examine whether the adaptation to the lower-level visual property can contribute to the high-level aftereffect. The adaptation propagations along two neural routes are investigated, respectively. One is from color system to facial identity system (Experiment 1), the other is from figure system to facial identity system (Experiment 2). In experiment 1, the aftereffects are measured within the real face while adapted by the real face and other three kinds of color stimuli, i.e., house pattern, color chip, and glass pattern. The glass pattern are randomized dot arrays that produce the perception of a global pattern (Glass, 1969; Ohla, Busch,

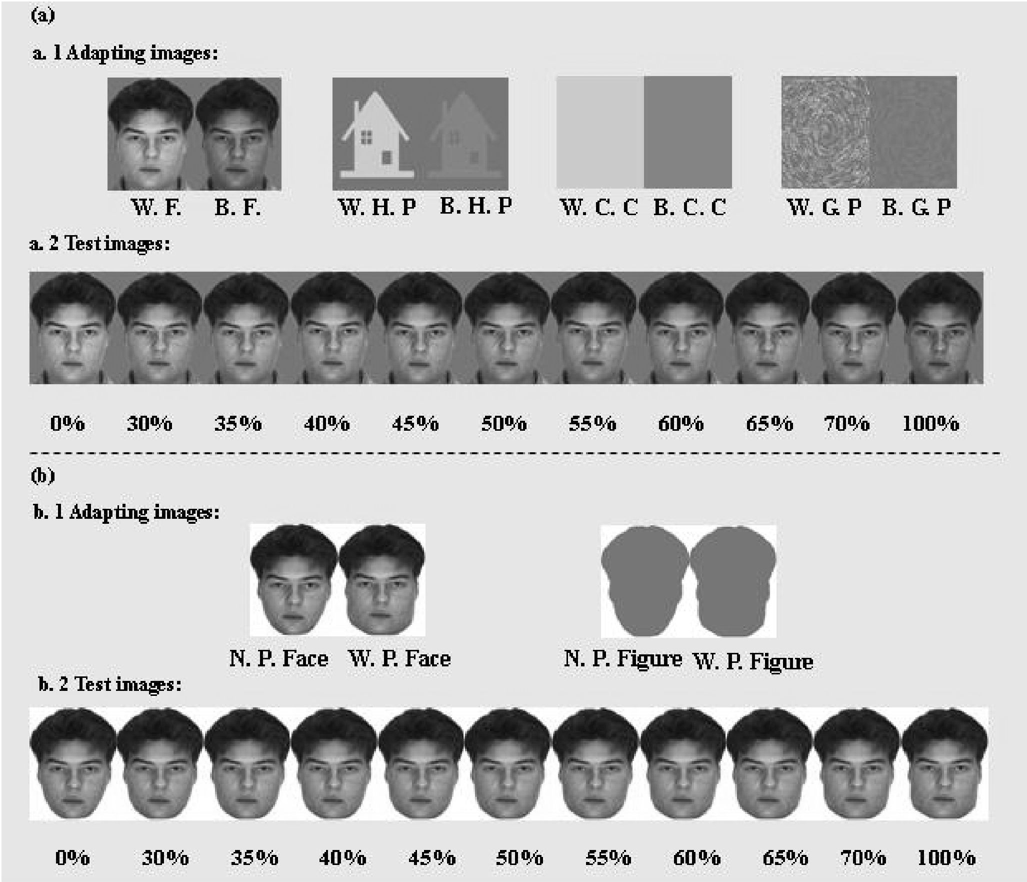

Fig. 3.1 (a) Stimuli in experiment 1. (a.1) Real faces, color chips, house patterns, glass patterns as adapting stimuli in the experiment 1, (a.2) The ambiguous test face series morphed between whitish skin face and brownish skin face. (b) Stimuli in experiment 2. (b.1) Real faces and figures as adapting stimuli in the experiment 2. (b.2) The ambiguous test face series morphed between narrow proportion face and wide proportion face. The numbers across the bottom in (a.2) or (b.2) illustrates the color strength or proportion strength, which indicated how far the face fell between the two originals (The images of 0% and 100% were not used as the test) along the array.

Dahlemc, and Herrmannb, 2005), it is an effective tool for psychophysicists to investigate how the information in the low-level visual system are converted to a global pattern responses in the higher level visual system (Wilson, Switkes, and Valois, 2004; Dakin and Bex, 2002). Difference in aftereffect size between real face adapting condition and

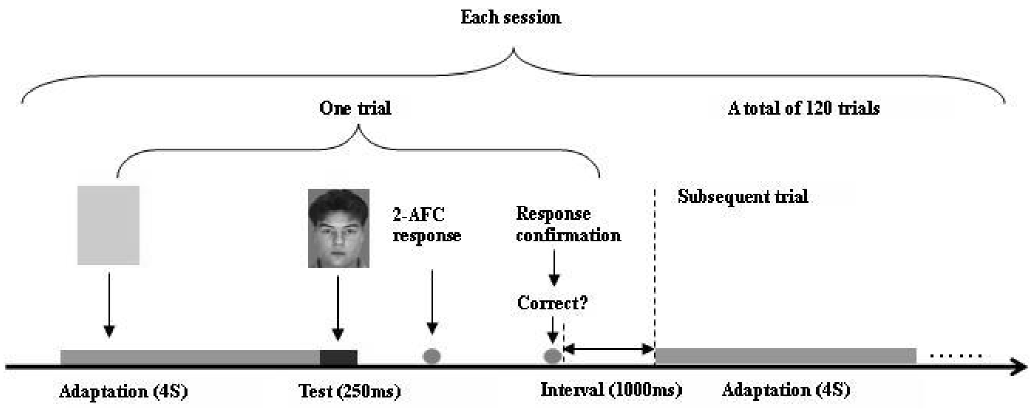

Fig. 3.2 Illustration of visual adaptation paradigm and experimental procedure

color stimuli adapting conditions will be used to evaluate the influence from low-level color system to high-level facial identity system. In experiment 2, we examine whether figure adaptation can contribute to the facial identity system, we adapted subjects by real face and face profile without inter facial components, and measured aftereffects in the real face. The aftereffect difference will be used to estimate the contribution from the figure system to the facial identity system.

Secondly, we also expect that our result can implicate how face is coded in the high-level visual system. We take a novel experiment paradigm to allow only one dimension to influence facial identity aftereffect. For example, in the experiment 1, only a facial color can be used to identify a face. Because the real face and three kinds of color stimuli are the same in terms of RGB color values, the different adapting stimuli will generate approximately identical contribution to the identity aftereffect from low-level neural representation[1][*1]. Thus, if there is still the significant aftereffect difference between the real face adapting condition and color stimuli adapting conditions, this difference can only be attributed to the face high-level neural representation.

[*1] The adaptation effect by the glass pattern is possibly weaker than that by the other adapting stimuli, because the total area of color in the glass pattern is smaller than in the other adapting stimuli.

3.3 General method

3.3.1 Subjects

Subjects were 5 Japanese undergraduate students at Kochi university of technology in Japan and 5 Chinese graduate students at Fudan university in China. All subjects have the normal or corrected-to-normal vision acuity and normal color vision. The 5 Japanese subjects participated in the real face and color chip adapting conditions in the first experiment, and the real face and figure adapting conditions in the second experiment. The 5 Chinese subjects participated in the house pattern and glass pattern adapting conditions in the first experiment, they also participated in the control experiment that examined the influence from the facial hair on the adaptation effect.

In consideration of assuring the accuracy of subject's response, it is crucial in these two experiments to keep every participant naïve to the experimental goal. Because once the subjects learn that the adapting face would bias the perception to the opposite direction within the series of test images, this knowledge will influence the subject's decision in cognitive level rather than perceptual level (Leopold, O'Toole, Vetter, and Blanz, 2001).

Three ways were used to avoid this situation. Firstly, all subjects were interviewed to ensure naïve on adaptation paradigm before the participation. Secondly, we had analyzed the data for each subject independently, if the interference from the cognitive level occurred, it could be predicted that the psychometric curve appears odd and showed lower fit than other subjects' curves. The third way was similar with what Leopold et al. (Leopold, O'Toole, Vetter, and Blanz, 2001) used in their study. The subjects were presented with some extra, unanalyzed trials in which some irrelevant adapting stimuli of color chips, grey figures and real faces was shown. This way was used to avoid subject associating the adapting stimuli with test facial images.

3.3.2 Apparatus

The images were presented on 19 inch LCD (DELL Monitor, Model 1905FP) controlled by the computer (DELL Xeon 2.8G Hz and NVIDIA Quadro FX 1400), with the vertical refresh rate adjusted to 85 Hz and the spatial resolution set to 1024*768 pixels. Subjects were instructed to view the monitor from the distance of 50cm, the visual stimuli was shown in the center of screen and subtended a visual angle of approximately 12 degree (horizontally) by 15 degree (vertically) in this distance. All the experiments was run by Matlab platform with Cogent Psychophysics Toolbox extensions.

3.3.3 Procedure

Because the two faces with different colors or figures are of the identical face, in order to prevent the subjects from being confused, we firstly instructed the subjects to imagine that these two faces are of the twins and the facial color (Experiment 1) or figure (Experiment 2) can be used to identify them. Then, before every main session, the two face images that would be used in this session were simultaneously shown side by side in the screen and the subjects were instructed to memorize these two faces and the corresponding buttons for response. A short validation session of 8 trials was performed to examine whether the subject make the correct association between the response and face by using the 0%, 30%, 70%, 100% strength of face images(See Fig. 3.1a.2 and Fig. 3.1b.2). This validation session will be repeated until subjects succeeded to reach the 100% correct ratio. All subjects learned the adaptation task through the oral instruction and the short practice session.

In each trial, the adapting image and test image were sequentially presented in the center of the screen, After the presentation of test image, the subjects were instructed to perform a two-alternative forced choice (2-AFC) task by pressing one button to classify the presented image into one of two categories (i.e., between two different identities). Feedback for pressing each button was given after each trial to confirm subject's button response. The durations of adapting stimuli and test stimuli were determined to 4000 and 200 ms, respectively, without interval between adaptation and test stage (See Fig. 3.2). This paradigm was expected to produce the stronger aftereffect. For the relationship between facial aftereffect size and adaptation time configuration, see Leopold et al. (2005).

The subject was instructed to attend to the stimuli but no specific fixation point was given. For the role of visual attention to modulate the identity aftereffect, see (Moradi, Koch, and Shimojo, 2005). The reason of not giving the fixation point is to prevent the subject overly attending to the local facial feature(for example, nose, eye) near to the fixation point and generate the unpredictable influence on the identity aftereffect of the whole face.

There are four adapting conditions (color chip, glass pattern, house pattern and real face adapting conditions) in the first experiment and two adapting conditions (figure and real face adapting conditions) in the second experiment. Each adapting condition has two adapting images and only one image was presented in one trial. Nine images in nine strength levels were used as the test and 20 trials was performed at each strength level, thus resulting in a total of 2160 trials for all the experiments in one subject (20 (trials) * 9 (test levels) * 2 (adapting images) * 6 (adapting conditions) = 2160 trials, the trials of control experiment, practice trials, and unanalyzed trials were not included). Every 120 trials compose session and lasts for 30 minutes. The short period of each session prevented the subjects becoming too tired to lose the attention to the adapting stimuli, which will impoverish the effect of adaptation.

3.3.4 Criteria for constructing the stimuli

Numerous facial dimensions (nose, mouth, jaw, even hair line) will influence the identity perception and further affect the identity aftereffect. Thus, it is crucial for our experiments to exclude influence from other facial dimensions regardless of facial color (experiment 1) or face profile (experiment 2). Otherwise, we can not distinguish which neural representation would be responsible for aftereffect difference in various adapting conditions.

Three criteria were defined for these experiments to avoid this confusing situation. 1) Two adapting faces for tests should share the identical face configuration except facial color in experiment 1 and face profile in experiment 2 to exclude influence on identity aftereffect from the other facial dimension. 2) One adapting face and one adapting stimuli only share the same color or face profile. 3) All adapting and test stimuli share spatial location at the retinal to activate the same neural representation in the low-level visual cortex area.

3.4 Experiment 1: Adaptation propagation from color system to identity system

3.4.1 Stimuli for experiment 1

The face stimuli of frontal-view in the experiment 1 was selected from ALEIX face database (Martinez and Benavente, 1998). We converted the image face to the size of 340 * 500 with grey background $((x, y) = (0.33, 0.36), L = 27cd/m^2)$. The most of neck and clothing area were excluded but hair and jaw contour were included as shown in the Fig. 3.1a. Then, we constructed two faces with different skin colors from this image person using FaceFilter studio ver 2.0, as one face having a whitish skin (Referred to

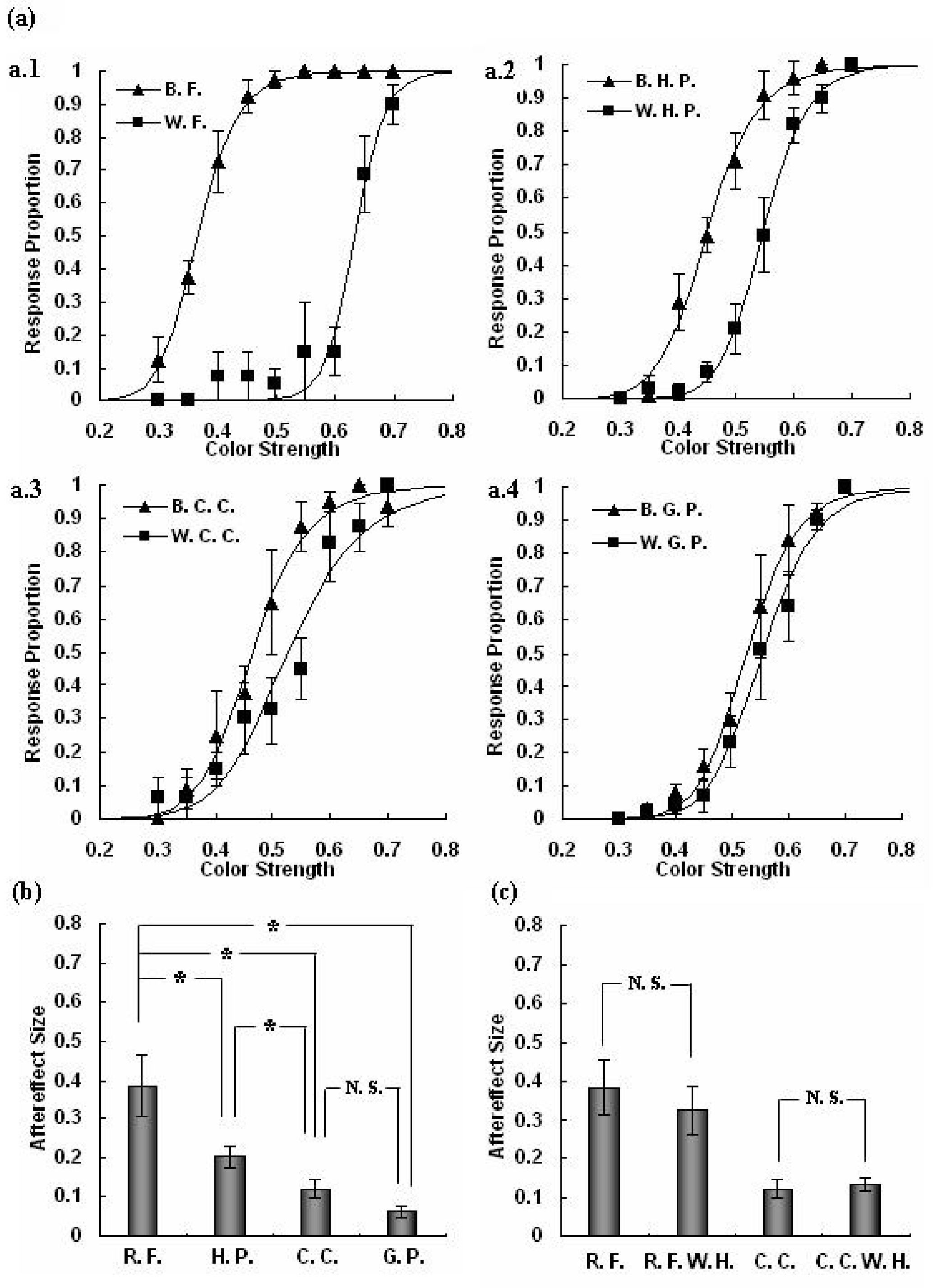

Fig. 3.3 Results for experiment 1. (a) The response proportion as the function of color strength in the real face (a. 1), the house pattern (a. 2), the color chip (a. 3), and the glass pattern (a. 4) adapting conditions. The data are fitted with logistic functions averaged in all five subjects. (b) The aftereffect size corresponding to four different adapting conditions . (c) The aftereffect size in the control experiment examining the hair influence on adaptation effect. In (b) and (c), error bars denote S.E.M. and the asterisk (*) indicates statistical significance.

"W. F.") and the other face having a brownish skin (Referred to "B. F.").

We sampled two colors from these two faces to construct the color chips (Referred to "'W. C. C." and "B. C. C."), the house patterns (Referred to "'W. H. P." and "B. H. P."), and the glass patterns (Referred to "'W. G. P." and "B. G. P.") as shown in the Fig. 3.1a. These three kinds of color stimuli served as the adapting stimuli, respectively. Each kind of color stimuli included two identical patterns with colors, one of those is in the brownish color $((x, y) = (0.52, 0.40), L = 40cd/m^2))$ and the other is in the whitish color $((x, y) = (0.41, 0.38), L = 90cd/m^2))$, these two colors are the same with that of two adapting faces in terms of RGB color values.

The color chips and the house patterns were constructed using Adobe Photoshop CS and the glass patterns were constructed by the matlab software version 6.5. All color stimuli were constructed as the same size with the face image frame. The window, door, and background of the house image was set to the grey which is the same as the background of face image. The method to construct the glass pattern is similar with what the Dakin (Dakin and Bex, 2002) used in his study, except that the number of paired dots, the color, the size of the stimuli were different. Briefly stated, the glass pattern consisted of 1000 dots in a circular annulus and each dot is $0.06° * 0.06°$ in size, giving a density of 5.1%. The 500 dot pairs (1000/2=500) were randomly placed within the pattern, but the orientation of the pair was always tangent to a circle centered on the pattern, resulting in a concentric form.

We morphed the ambiguous image series between these two faces ("W. F. " and "B. F.") using FantaMorph ver3.0, with the series of images from 30% to 70% in terms of skin color serving as test stimuli (See Fig. 3.1a.2)). This series of ambiguous images was used to measure the corresponding aftereffect in both face adapting condition and color chip adapting condition.

3.4.2 data analysis

We firstly determined the response proportion that were given for one of two choices at each test level (e.g., how many times does the subject response "B. F.") for each subject. The adaptation effect in each test level is calculated by subtracting the response proportion adapted after one face (e.g. "W. F.") from the response proportion adapted after the other face (e.g. "B. F.") at this test level. The aftereffect size for each adapting condition was determined by averaging the difference of response proportion of all test levels in five subjects for this condition.

We used the paired-samples t-test in SPSS 13.0 statistical software (www.SPSS.com) to performed the statistical test and the significance level was set at $p < 0.01$. In all statistical tests, we used the response proportion of every subject instead of the average in five subjects and the sample capacity for each adapting condition is 45 (9 level * 5 subjects = 45, df = 44).

3.4.3 Result

We examined whether there is a reasonable fit among the responses of subjects before the further analysis. The response proportions of each subject were compared with that of each of the other four subjects in each adapting condition. The statistical comparisons were performed by the paired-samples t-test, with the difference of response proportions obtained from two adapting images at each test level between every two subjects in this adapting condition as the paired variables. A subject's responses were defined as the low fit if they were significantly different from those of the other four subjects in this adapting condition. We initially expected that the data of low fit will be excluded from the further analysis. Fortunately, we do not find the case matched to this point, thus, all data of subjects were used in the further analysis.

All four adapting conditions produced measurable aftereffect (See Fig. 3.3b) with statistical significance. As expected, in the face adapting condition, the possibility of reporting one face (e.g., "W. F.") in the ambiguous faces was increased if the subjects were adapted to the other face image (e.g., "B. F."). It indicates that subjects' responses were biased to the opposite direction ($t_{44} = 7.013, p < 0.0001$), with the aftereffect size 38.3% ($S.E.M. = 7.4\%$). We also observed the significant adaptation effects on the face test images by the house patterns, the color chips and the glass patterns, the table 3.1 shows the Mean and S.E.M of aftereffect size and the statistical test in four adapting conditions. These observations suggest that adaptation to the color stimuli can influence the high-level face perception, indicating an effect propagation of adaptation along different neural hierarchy. Furthermore, because the color dots in glass pattern have the relatively small visual receptive field and adaptation effect by the glass pattern is significant, it appears to suggest that the identity aftereffect by the color stimuli is initially generated from the visual cortex area at the "front end" in the human visual system (for example, V1 areas), because the neurons or neuron populations in these "front end" areas would respond to the color dots with small receptive field in the glass pattern in high possibility.

We further use paired-samples t-test to compare the aftereffect size between every two adapting conditions, with the difference of response proportion of every subject in each test level as the paired variables. The three observations is worth noting. Firstly, the adaptation effect by the real faces is much stronger than that by the house patterns ($t_{44} = 4.852, p < 0.0001$), color chips ($t_{44} = 6.838, p < 0.0001$), and glass patterns ($t_{44} = 7.134, p < 0.0001$). It suggests that the high-level aftereffect can not only be attributed to the effect propagated from the adaptation to low-level neural representation. Thus, it indicates an additional adaptation to high-level neural representation. Secondly, we interestingly find that the adaptation effect by the house pattern is significantly

Table 3.1 Mean and S.E.M of aftereffect size and the statistical test for real face, color chip, glass pattern, and house pattern adapting conditions

adapting condition	aftereffect size (Mean±S.E.M)	stastical test (df = 44)
real face	38.3% ± 7.4%	t = 7.013, P < 0.0001
house pattern	20.2% ± 2.8%	t = 6.046, P < 0.0001
color chip	11.9% ± 2.3%	t = 3.155, P < 0.003
glass pattern	6.2% ± 1.5%	t = 3.123, P < 0.003

stronger than that by the color chips ($t_{44} = 3.206, p < 0.003$) and the glass patterns ($t_{44} = 4.402, p < 0.0001$). This observation seems to suggest that the house pattern can also produce the additional adaptation effect in the higher neural representation, besides the adaptation effect from the low-level color neural representation. Thirdly, we do not observe the significant difference of adaptation effect between glass pattern adapting condition and color chip adapting condition ($t_{44} = 1.293, p = 0.20$).

Finally, we examined the influence from hair area on the adaptation effect by color stimuli. In this experiment, we did not exclude the facial hair because the hair is considered to be one of the important external features for shaping the facial contour and contribute to the identification. However, on the other hand, because the hair area is large in the face stimuli (See Fig. 3.1a) and hair color is black, it is possible that the hair area would weaken the adaptation effect of color stimuli, to some extend. To evaluate this possibility, we repeated the experiment of the real face and color chip adapting conditions using the facial stimuli without hair area as the adapting stimuli and test. These real face and color chip adapting conditions using the face without hair are referred to as the R.F.W.H and C.C.W.H., respectively. The result do not suggest the significant differences in both the real face and the color chip adapting conditions between the control experiment and the previous experiment. The adaptation effect in R.F.W.H and C.C.W.H are 30.4% ($S.E.M = 6.3\%$) and 13.2% ($S.E.M = 2\%$) respectively, without the significant difference from corresponding adaptation effects in the real face ($t_{44} = 0.080, p = 0.937$) and color chip ($t_{44} = 1.222, p = 0.228$) adapting conditions in previous experiment (See Fig. 3.3c). These observations suggest that the difference of adaptation effect between color stimuli and real face can not be attributed to the hair area.

3.5 Experiment 2: Adaptation Propagation from Figure System to Identity System

In experiment 1, we found that the low-level color adaptation can contribute to the high-level facial identity aftereffect. Here, we further examined whether the figure adaptation can contribute to the facial identity aftereffect or not. We employed the identical adaptation paradigm and experimental procedure in experiment 1.

3.5.1 Stimuli for experiment 2

We have constructed two faces with different facial proportions from the same face used in the experiment 1 by the FaceFilter studio ver2.0, with one profile having narrow proportion (Referred to "N. P. Face") and the other version having wide facial proportion (Referred to "W. P. Face"). Then, we generate two grey face profiles ("N. P. Figure" and "W. P. Figure") without internal facial component using Adobe Photoshop CS. To avoid the color contrast effect at the border for figure stimuli, we used white background ($(x, y) = (0.32, 0.35), L = 132cd/m^2$) for these figure stimuli. These two faces and profiles served as the adapting stimuli in the face adapting condition and figure adapting condition, respectively (See Fig. 3.1b.1). Finally, we construct the ambiguous test image series by morphing between "N. P. Face" and "W. P. Face" (See Fig. 3.1b.2), using FantaMorph ver3.0.

3.5.2 Result

The identical method to the experiment 1 was adopted to calculate the response proportion and corresponding aftereffect size. We obtained the similar data pattern as the experiment 1 as shown in Fig. 3.4.

Two adapting conditions generated measurable identity aftereffect (See Fig. 3.4a) with statistical significance. In the face adapting condition, the aftereffect size is 29.5% ($S.E.M. = 5.7\%$), which indicates the bias of subjects' perception by the adaptation ($t_{44} = 8.150, p < 0.0001$). There is also a significant aftereffect ($t_{44} = 3.400, p < 0.001$) in the figure adapting condition with the aftereffect size of 9.6% ($S.E.M. = 5.8\%$), which suggests that the adaptation to the grey figure can also contribute to high-level identity aftereffect, implicating a propagation from the figure system to the identity system.

We further compared the aftereffect size between these two conditions. There is a significant aftereffect difference between the face adapting condition and the figure adapting condition ($t_{44} = 5.595, p < 0.0001$) by paired-samples t-test. The aftereffect size on face adapting condition is still stronger than that on the figure adapting condition(See Fig. 3.4b).

3.6 Discussion

3.6.1 Scientific findings

There are two major findings in these experiments: 1) The adaptation to color and figure contributes to the high-level facial identity aftereffect. It indicates that adaptation

3.6 Discussion

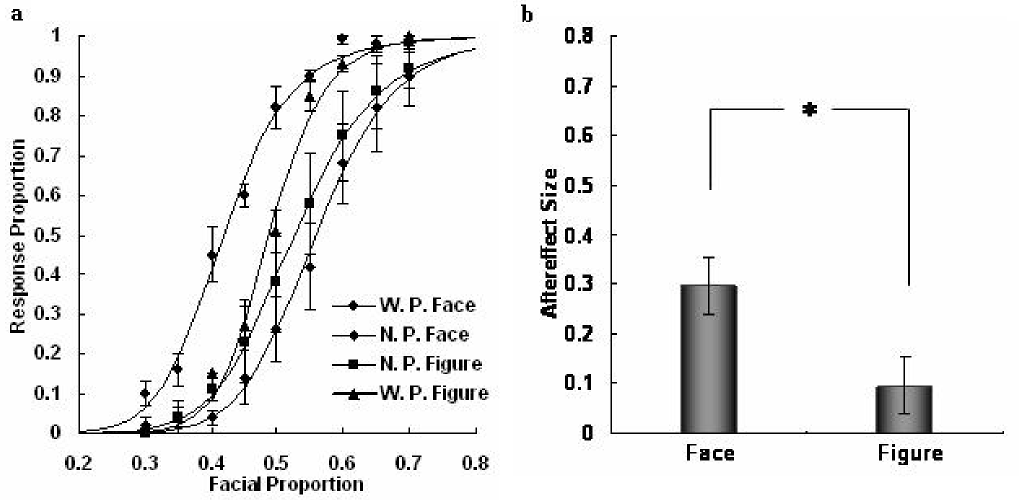

Fig. 3.4 Results for experiment 2. (a) The Response proportion as the function of facial proportion (W. P. Face: Adapted by wide proportion face, N. P. Face: Adapted by narrow proportion face, W. P. Figure: Adapted by wide proportion figure, N. P. Figure: Adapted by narrow proportion figure). The data fitted with logistic functions averaged in all five subjects. (b) The aftereffect size corresponding to two different adapting conditions. Error bars denote S.E.M. and the asterisk (*) indicates the statistical significance.

effects can propagate from neural systems in the lower visual areas(e.g., V1, V2, V4 for processing color) to a distributed face recognition system (maybe Fusiform Face Area, See Kanwisher et al. (1997); Haxby et al. (2000)) and from figure systems (e.g. in IT area) to the face recognition system. 2) Although both of adaptations by isolated facial dimensions (skin color or facial profile figure) and by whole faces generate significant facial identity aftereffect, the aftereffect size of latter is much stronger than that of isolated facial dimensions. What neural mechanism would be responsible for these two observations? We intend to discuss possible explanations for these two observations in terms of their theoretical implication for understanding the high-level facial neural presentation and the propagation of adaptation effect along hierarchies in human visual system.

3.6 Discussion

Several previous behavioral researches (Tanaka and Martha, 1993; Tanaka and Sengco, 1997; Young, Hellawell, and Hay, 1987; Catherine, 2007) suggest a specific holistic strategy in face recognition. It means that face is represented as the whole rather than isolated parts (facial frame, eye, mouth, nose and so on). This holistic hypothesis primarily comes from the following two lines of evidences. One is composite face effect (Young, Hellawell, and Hay, 1987; Catherine, 2007) and the other is effect of configuration context (Tanaka and Martha, 1993; Tanaka and Sengco, 1997). Concerning to composite face effect, if the stimulus face is separated into two parts along the horizontal midline, with the upper part showing one person and the lower part showing another person, the subjects will spend longer to identify the image person in the case that these two halves are aligned to construct a composite face than in the case that two halves are misaligned to construct a non-composite face. The effect of configuration context illustrates that a subject will obtain the higher recognition performance when facial components are shown in the whole face context than when the facial component are shown in isolation. These two line evidences indicate a holistic neural representation in the high visual cortex that will respond the unique collection of feature to identify the certain face.

The observations in this study could be implicitly interpreted by this hypothesized holistic neural representation. In conditions of adaptation to the isolated facial dimensions such as color and figure, only the perception system directly related to these visual properties will be adapted. Then, the adaptation contributions will be propagated to the high-level face neural representation system to produce aftereffects in the test stage. In contrast, when we use the whole face as the adapting stimuli, besides these isolated visual properties were adapted, the high-level holistic facial neural representation will also be adapted and thus produce the much stronger aftereffect.

One may ask whether there is a possibility that color stimuli or figure stimuli directly adapts the high-level face neural representation and generate the corresponding identity aftereffect, rather than the effect propagation of adaptation from the low-level system to high-level face system. Because skin color and face profile have holistic attribution in contrast to other facial dimensions and possibly provide a more fundamental reference in the integration by the metric way (About the neural coding of face in metric way, see young (1992)). In our sense, it seems unreasonable for a pure color chip or glass pattern to directly influence the high-level face neural representation. Because the color is not a specific visual element of face, it is widely involved in various different tasks of visual perception even in the case that RGB value of the color chip approximates that in the face. The direct influence from the color chip or glass pattern on the high-level face system disrupts the hierarchically coding mechanism of human visual system and do not fit the efficient coding principle of the brain. Also, to the best of our knowledge, we do not find any evidence for direct influence from the color chip stimuli on the high-level face perception system in previous literatures. Thus, we infer that the identity aftereffect by the color chip is the effect propagation of adaptation from the low-level color system to the high-level face system.

The case for house pattern is somehow different from that for the color chip or the glass pattern. The result in experiment 1 shows that the adptation effect by the house patterns is significantly stronger than that by color chips or the glass patterns. We suggests the below two possibilities for this observation, one possibility is that the house pattern could adapt the high-level facial neural representation, to some extend. As we know, the previous findings suggest that the fusiform face area is also involved in the within-category object recognition (e.g., recognize the house, bird, chair). if it is the case, the high-level face area is likely to be adapted by the house patterns and then produce the stronger aftereffect than the other color stimuli. The other possibility is that the house pattern can adapt the certain shared neural representation between the face and house pattern along the ventral neural route. The ventral stream is generally considered to be responsible for the object recognition or representation (Ungerleider and Haxby, 1994), begins with V1, goes through visual area V2, then through visual area V4, and to the inferior temporal cortex. it is possible for house pattern to adapt the certain visual area (for example, V4 area) that can also be activated by the face stimuli, thus producing the stronger aftereffect.

As far as the figure adapting condition is concerned, the situation is also slightly complicated. The grey figure is to some extend similar with face profile, it appears that the figure may possibly activate the high-level neural representation and generate the adaptation effect. We reason that if the grey figures can directly adapted the high-level face system, the aftereffect size in the figure adapting condition may differentiate that in the color chip adapting condition. However, we do not observe the significant difference of aftereffect size between color chip adapting condition and grey figures adapting condition. Thus, although we can not make the explicit prediction about this issue, we tend to hypothesize that identity aftereffect by the grey figure is also the effect propagation of adaptation from the figure system to the high-level face system. We expect the explicit physiological evidence in the future to emerge to clarify this issue. This issue can be investigated by using the single cell recoding technology (Sharp, 2002) or functional magnetic resonance imaging (FMRI) adaptation paradigm. FMRI adaptation refers to the observation that repeated presentations of a visual stimulus will activate the lower blood-oxygen-level dependent (BOLD) responses than the presentations of a novel stimulus. It is convenient to examine whether the neurons in the face-responsive cortex could selectively respond to the grey figure that is similar with the face profile, or whether the grey figure can activate the face-responsive cortex or not. The better understanding to this issue helps to address to what extend the identity aftereffect is generated by the high-level face neural representation and to what extend it is a effect propagation from the low-level system.

We expect our result to be able to implicate the neural coding mechanism for the hypothesized facial neural representation. Here we discuss two appealing neural coding mechanism, a grand-mother cells coding mechanism and a population coding mechanism. The grand-mother cell coding theory (Gross, 2002; Rose, 1996) holds that the face is coded by the small amount of grand-mother cells. Each grand-mother cell will generate the same neural response for feature collections of a certain facial identity. This hypothesis, however, conflicts to our result. Psychometric curves in our experiments show the shape of logarithmic function, however, for a single grand-mother neuron, it is difficult to exhibit this kind of output. This kind of decision cells is expected to be fitted to the discrete function instead, that is with about 0% of response proportion for lower strength image and 100% for the higher strength image exceeding the threshold.

Concerning to population coding mechanism (Georgopoulous, 1986; deCharms and Zador, 2000), it suggests that the face is coded by the certain pattern of neural activities over population of neurons. Our result can be interpreted by this mechanism. However, it will depend on the coding strategy and the layer of population neural representation to account for the observation. Thus, we can not make further detailed hypothesis only from our results and current literatures. It is clearly important for physiology and psychological studies to provide a more intensive evidence to clear this issue.

3.6.2 Significance in visual product design

Besides the theoretical implication described above, we discuss how our result can improve the quality of a visual product design. The influence from the low-level adaptation to face identification can play negative and positive roles in the visual product design. For example, the simplified CG face, as stated in the introduction, is more resistless to negative influence from the low-level adaptation. In order to avoid the biased perception for CG faces, our result suggests that the proper evaluation way should be performed in the design process to exclude the negative influence.

On the other hand, an appropriate use of low-level adaptation will help to elicit intended high-level perception for a product theme. For example, in developing an animation of a cosmetic advertisement, the face will normally be shown to illustrate cosmetic's effects. If a designer can subtly adapt the audience by color and/or figure discrete elements in previous animation frames, it will lead that the audience would obtain the optimal visual impression for presented face. The psychophysical curve can be used in the designing process to obtain the explicit designing parameter. Actually, the positive influence shown here indicates an extensive application possibility that the designer can use low-level adaptation to influence the high-level visual perception in visual product development. The implementation method may be different for various products. We hope the practical evaluation criteria and various implementation methods to be explored based on this result in the future.

3.7 Conclusion

We found the adaptation propagation between color system or figure recognition system and facial identity system. The findings provide further insight into neural representation of hierarchy in human visual system and implicate the high-level neural representation for the face. Our results have the theoretical implications in understanding human sensory neural system.

Chapter 4

The Hierarchical Structure Between Expression System and Identity System

4.1 Introduction

Human is expert at recognizing facial features and movements. Observers can be highly sensitive to subtle differences of face identities and easily distinguish different expressions with near-ceiling accuracy and speed. Yet, so far, the issue about how human neural system is organized to facilitate the recognition of facial identity and expression still can still not be answered.

The current dominant face recognition theories such as the functional face-recognition model (Bruce, 1986) and neurological model (Haxby, Hoffman, and Gobbini, 2000) suggest a parallel process route functionally and anatomically between facial identity and expression recognition. This parallel hypothesis primarily comes from four aspects of observations. Firstly, studies on brain lesion patients (Bruyer et al., 1983; Humphreys, Donnelly, and Riddoch, 1993; Young, Newcombe, de Haan, Small, and Hay, 1993) have revealed that brain injury could cause a selective impairment of ability to recognize either facial identity or expression, thereby potentially indicating a double dissociation between these two systems. Secondly, behavior studies on healthy subjects (Bruce, 1986; Ellis, Young, and Flude, 1990) have provided the evidences that the familiarity of an identity would not affect the ability to classify the expression and the familiarity of expression also would not affect the ability to recognize the identity. Thirdly, neuroimaging studies (Rossion, chiltz, Robaye, Pirenne, and Crommelinck, 2004; Winston, Henson, Fine-Goulden, and Dolan, 2004) have identified distinct brain areas related to identity or expression perception, the face identity is normally processed in lateral fusiform gyri located in inferior occipitotemporal cortex, and the expression is preferentially processed in the superior temporal sulcus(STS) located in lateral occipitotemporal cortex. Finally, the single-cell recording for macaque monkey (Hasselmo, Rolls, and Baylis, 1989) also have revealed that specific neurons in the inferior temporal gyrus would respond to identity independent of the expression, whereas specific neurons in superior temporal sulcus respond the expression independent of facial identity.

Although a large amount of evidences have suggested a functional independence and anatomical separation between identity and expression system, the possibility that these two systems may be overlapped or interconnected can not be completely excluded. One inconsistent evidence comes from the single-cell recording (Sugase, Yamane, Ueno, and Kawano, 1999), which suggested that specific cells in the STS will respond to both facial identity and expression with different latency. Also, Behavior research (Baudouin, Martin, Tiberghien, Verlut, and Frank, 2002; Ganel and Goshen-Gottstein, 2004; Schweinberger, Burton, and Kelly, 1999; Schweinberger and Soukup, 1998; Endo, Endo, Kirita, and Maruyama, 1992) further provide a line of evidences for an alternative view about parallel hypothesis. For example, Baudouin et al. (2002) reported an asymmetric interference from the expression to the process of facial identity. In a speeded classification task for identity and expression, it is found that the identity variance does not influence the performance of expression classification but expression variance would significance influence the performance of identity classification. In contrast, Ganel and Goshen-Gottstein (2004) have found a symmetric interaction for reaction time between identity recognition and expression identification using a Ganer's speeded-classification task, which is commonly used to evaluate the mutual interference between two dimensions. Although these two results are not completely consistent, both of them implicitly suggested an interaction between facial identity system and expression system.

How to reconcile this discrepancy? In terms of the observations so far, we can find that the key issue is not whether there is an existence of dissociation between the identity and expression system, Because FMRI and single cell recording studies have already identified the different cortex area for expression and identity, the anatomical dissociation between identity and expression system can be determined, to some extent. The key issue rests with whether the identity and expression system are complete parallel neural route without mutual interaction or not, and how define the relationship between identity and expression system to best fit the current existed evidences.

Here, we intend to systematically investigate this issue by inducing the facial identity and expression adaptation paradigms. Adaptation paradigm is an effective tool to isolate and temporarily reduce the contribution of specific neural populations (Abbott, Varela, Sen, and Nelson, 1997), therefore, it has been all along adopted by psychologist to probe low-level visual property of neural representation including color (Craik, 1938), motion (Lehmkuhle and Fox, 2004; Ashida and Osaka, 1995), orientation (Blake and Fox, 1974; He and MacLeod, 2001; Rajimehr, 2004b). Recently, adaptation was also found to influence the process of complex visual patterns in the high-level visual system, such as facial identity (Leopold, O'Toole, Vetter, and Blanz, 2001; Afraz and Cavanagh, 2007), and expression (Webster, Kaping, Mizokami, and Duhamel, 2004; Hsu and Young, 2004), attractiveness (Rhodes, Jeffery, Watson, Clifford, and Nakayama, 2003) and facial distortion (Yamashita, Hardy, and Webster, 2005; Zhao and Chubb, 2001). Simplistically stated for facial aftereffects, the selective adaptation to specific facial dimension can bias the human perception to the opposite direction on these dimensions. For example, within a series ambiguous faces morphing between the smile and angry expression, Adaptation to smile will distort the perception of observers to facilitate perceiving the ambiguous images as the angry, and vice versa.

Based on the physiological mechanism of adaptation in the visual system, we can make the following predictions. Firstly, if face identity system and expression system are complete parallel neural pathways, since identical neural population will code the facial identity regardless of the expression variance and vice versa, it should be predicted that identity variance would not significant influence expression aftereffect and also the expression variance would not significantly influence the facial identity aftereffect. Secondly, if the expression system and facial identity system are the inextricably overlapped, it is probable that the interference can be found both from the identity change to expression aftereffect and from expression change to identity aftereffect. Finally, if there is one way information exchange between the facial identity and expression system, we expect to observe the asymmetrical influence between two systems.

4.2 General Method

4.2.1 Subject

Subjects were 5 Japanese undergraduate students paid and 5 Chinese doctoral students unpaid. All Subjects have normal or corrected-to-normal vision. The 5 Japanese students participated in the first and third experiments and all 10 students participate in the second experiment. It is crucial in these three experiments to keep every participant naïve to experimental goal. The way to assure the accuracy of subject's response is as the Section 3.3.1.

4.2.2 Apparatus and Method

The experimental apparatus is as described in the Section 3.3.2.

Before every main session, the two face images that would be used in this session were simultaneously shown side by side in the screen and the subjects were instructed to memorize these two faces and the corresponding buttons for response. A short validation session of 8 trials was performed to examine whether the subject make the correct association between the response and face by using the 0%, 30%, 70%, 100% strength of face images(See Fig. 4.1b and Fig. 4.3b). This validation session will be repeated until subjects succeeded to reach the 100% correct ratio. All subjects learned the adaptation task through the oral instruction and the short practice session.

In each trial, the adapting image and test image were sequentially presented in the center of the screen, After the presentation of test image, the subjects were instructed to perform a two-alternative forced choice (2-AFC) task by pressing one button to classify the presented image into one of two categories (i.e., between two different identities). Feedback for pressing each button was given after each trial to confirm subject's button response. The duration of adapt stimuli and test stimuli was determined to 4000 and 200 ms, respectively, with 150ms interval between adaptation and test stage. This paradigm was expected to produce the stronger aftereffect. For the relationship between facial aftereffect size and adaptation time configuration, see Leopold et al. (2005).

4.2.3 Data analysis

In order to index aftereffect sizewe firstly determined for each subject the response proportion that were given for one of two choices at each test level (e.g., how many time does the subject response "smile"). Then, we calculated the aftereffect size by subtracting the proportion adapted after one of expression (e.g. smile expression,)

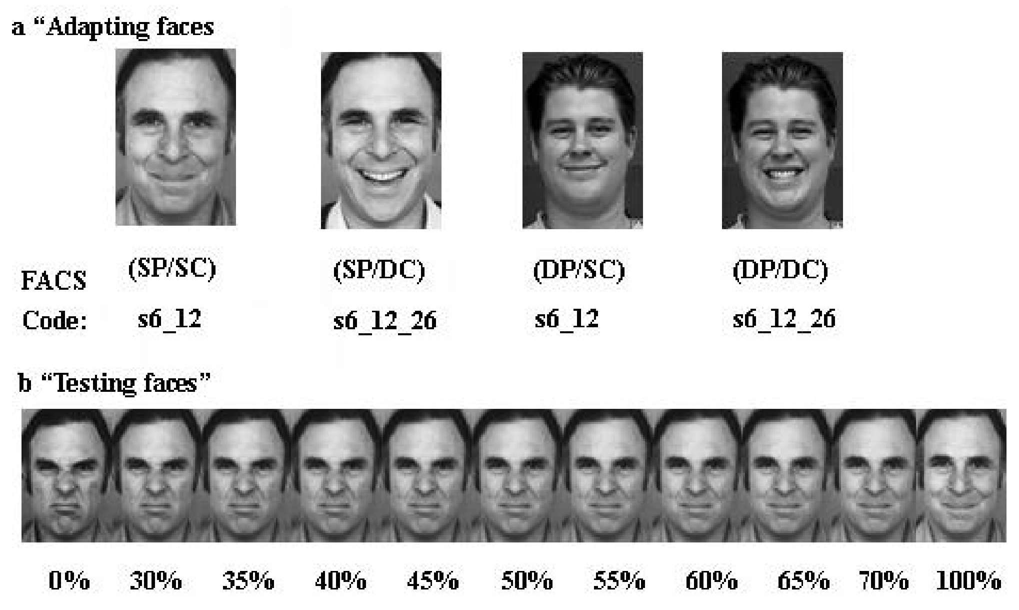

Fig. 4.1 Part of stimuli in study 1. (a)The stimuli employed in four adapting conditions, the number below each image shows the FACS code for this expression. (b)The ambiguous expression series morphed between angry and smile expression pair on the same person, the numbers across the bottom illustrates the expression strength, which indicated how far along the array the expression fell between the two originals (0%, 100%). The left and right images show the original expressions.

from the proportion adapted after the other expression (e.g. angry expression). The aftereffect size for each adapting condition was determined by averaging the difference of response proportion of all test levels for this condition. We used Paired samples t-test to examine the statistical significance for each adapting condition, with every two values of response proportions in each test level as the paired variables.

4.3 Experiment 1

The recent study (Fox and Barton, 2007) made a similar examination on how the identity variance influences the expression aftereffect. In this study, the expression aftereffect was measured in congruent condition (adapting face and test face are of the same person) and in incongruent condition (adapting face and test face are of the different person), respectively. It was found that the expression aftereffect could be obtained in both two conditions but aftereffect size significantly reduced in incongruent condition. Thus, Fox suggests that there are two neural representations involved in producing the expression aftereffect, with one specific to the facial identity, which will produce identity-dependent aftereffect in the congruent condition, and the other represents emotion across different facial identities, which will produce the identity-independent aftereffect both in the congruent condition and in the incongruent condition.

One key issue that Fox' study does not cover is the influence from expression geometrical configuration. In the congruent expression, the expression configuration between adapting person and test face was similar because of the identical facial features between adapting face and test face. However, in incongruent condition, if expression geometrical configuration is not explicitly controlled, Configuration difference between adapting face and test face would be much stronger even in the case that they show the same expression (See figure 4.1a). It raises a new possibility that the aftereffect reduction between congruent condition and incongruent condition is simply generated by the configuration difference between adapting images and test images.

In order to precisely assess the influence of expression configuration, we intend to further examine this issue using Facial Action Coding System (FACS), which is a versatile method for measuring and describing facial behaviors. FACS use Action Units (AU) that refer to one muscle or a combination of several muscles as basic measurement units, An observed expression can be decomposed into the specific combinations of AUs that produced the movement. Here, FACS was used to define the expression geometrical configuration and evaluate the similarity between adapting expression and test expression.

4.3.1 Stimuli in Experiment 1

We used four basic expression of smile, angry, fear and disgust in the experiment, these four expressions constituted two expression pairs, i. e. smile-angry expression pair and fear-disgust pair.

All face stimuli used in the experiment are selected from FACS affiliated image set and Cohn-Kanade AU-Coded Facial Expression Database. To take smile-angry expression pair as an example, we used expression images of two image persons as the adapting stimuli and each person showed both the smile and angry expression. Each expression included two different expression configurations characterized by Facial Action Coding System (FACS), which allowed us to select the approximately identical expression configuration between two image persons.

The visual stimuli of disgust-surprise expression pair is generated as the same way with the smile-angry expression pair. Finally, a total of sixteen expression images of four different persons are used in the experiment as the visual adapting stimuli. . We have morphed two series of facial images probe for these two expression pairs using one image persons, with one from smile to angry and the other from fear to surprise. These series of images varied from 30% to 70% serves as test stimuli (See Fig. 4.1b).

4.3.2 Result

The four adapting condition are respectively term as SP/SC, SP/DC, DP/SC, and DP/DC, where the first two letters indicates whether the identity of adapting face and test face are of the same person (SP: Same person) or not (DP: Different person), and last two letters indicates whether the expression configuration of adapting face are same with that of test face (SC: Same configuration) or not (DC: Different configuration). For example, SP/SC refers to the condition in which both identity and

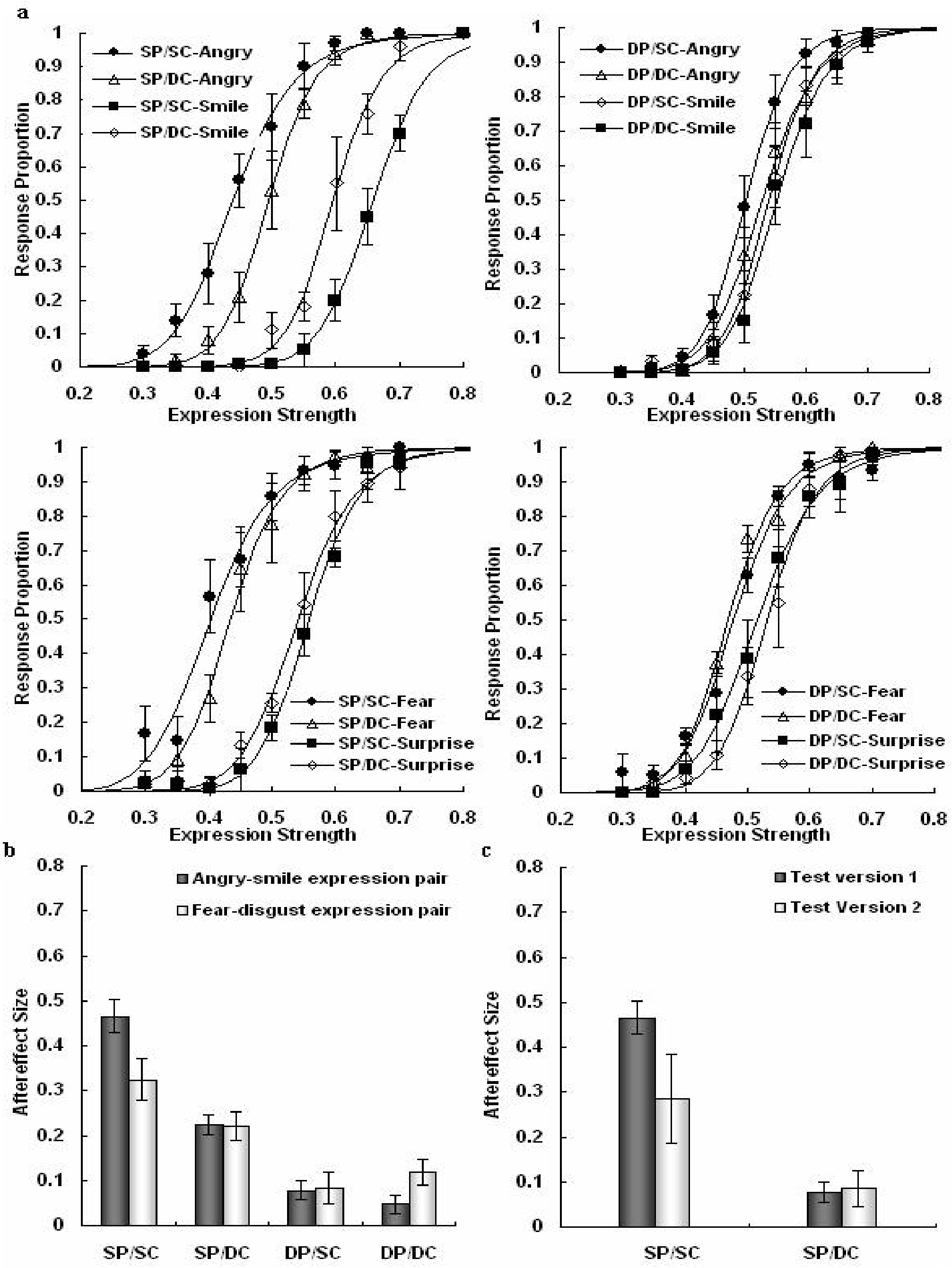

Fig. 4.2 (a) The response proportion as the function of expression strength in SP/SC, SP/DC, DP/SC and DP/DC conditions. (b) The histogram illustrates the aftereffect size corresponding to four different adapting conditions. (c) The comparison of aftereffect size between control experiment excluding the low-level adaptation influence and previous experiment. In (b) and (c), error bar denote the S.E.M.

expression configuration of the adapting face is identical to that of the test images. Whereas DP/DC means that the adapting face differentiates the test face both from the identity and expression configuration.

The results from 5 subjects judging the expression types are shown in the Fig. 4.2, We plotted the response proportions in the four conditions as the function of expression strength as shown in the Fig. 4.2a (Smile-angry expression pair) and Fig. 4.2b. (Fear-surprise expression pair), in which each line indicates the output of expression system influenced by the adapting images.

A two-way repeated measures analysis of variance (ANOVA) has been performed with proportion difference as dependent variable, adapting condition, identity, and configuration and expression pairs as fixed factors, Significance level was set 0.05. There is a significant main effect for different adapting condition ($F_{3,18} = 11.811, P < 0.000$), indicating an aftereffect size difference among these four different adapting conditions. There is no significant main effect for expression pairs ($F_{1,36} = 0.302, p = 0.584$), Also, No other two-way, three-way, four-way interaction between expression with other fixed factor was observed, thus, the data from different expression pair will be merged for the further analysis.

Paired samples t-test shows that all these four adapting conditions except the smile generate measurable aftereffect, which confirmed the expected aftereffect, i.e., an exposure to certain expression would significant will bias the perception to opposite direction within the series of test images.

We further use paired-T Test to examine the aftereffect size difference between every two adapting conditions. The significant reduction was found between SP/SC and DP/SC adapting conditions ($t_{17} = 6.195, p < 0.000$), as consistent with previous result that the identity variance would significant reduce the expression aftereffect. On the other hand, we find significant reduction between SP/SC and SP/DC ($t_{17} =$

$6.058, p < 0.000$) adapting condition, which suggests that expression aftereffect will also be modulated to some extend by the facial geometrical configuration. However, the influence from the variance of expression configuration can not be completely responsible for the huge size reduction across identity variance. Actually, expression aftereffect size in SP/DC condition is still much stronger than that obtained in the DP/SC condition ($t_{17} = 4.239, P < 0.001$) or DP/DC condition ($t_{17} = 4.418, p < 0.001$). This result suggests that the identity plays a more influential role on expression aftereffect than the geometrical configuration, it also rule out the possibility to interpret the significant expression aftereffect reduction across identity by the geometrical configuration, thus confirmed the identity-dependent expression aftereffect.

In order to evaluate the influence from the low-level adaptation on the high-level identity aftereffect, We use the test version 2 to repeat the experiments of the SP/SC and SP/DC adapting condition, with the adapting stimuli and test stimuli occupying the different spatial location. The results show that the test version 2 also generate significant identity aftereffect in the SP/SC ($size = 28.51 \pm 9.8\%, t_{26} = 4.967, P < 0.000$) and SP/DC ($size = 8.5 \pm 4.1\%, t_{26} = 2.880, p < 0.008$) adapting conditions, suggesting that the identity aftereffect can be obtained regardless of spatial location in the retinal, thus excluding the influence from the low-level adaptation on the high-level aftereffect. This conclusion is consistent with previous observations on this issue (Leopold, O'Toole, Vetter, and Blanz, 2001; L., Rhodes, and Busey, 2006).

Furthermore, we observed that the identity aftereffect in SP/SC adapting condition reduce much from test version 1 to test version 2, while it keep approximately identical in the DP/SC condition between two versions. The possible explanation for this observation may be attributed to the different roles of representational momentum in the different adapting conditions, representational momentum originally refer to the tendency to misjudge the stopping point of a moving object as further forward in the direction of movement (Freyd, 1983), recently, it is also been found to emerge in the perception of dynamic facial expression and dynamic trajectory of facial muscles could influence the judgment of expression and evaluation of expression intensity (Sato and Yoshikawa, 2008). Specifically, in the SP/SC condition of test version 1, because the adapting face and test face are of the same person and occupy the same location, it will inevitably generate the motion track of expression to a certain extend (although we used the interval between adapting stimuli and test to reduce this motion trajectory, it could not be completely excluded.). This dynamic trajectory will induce the subjects to judge the expression as contrary to the previously expression in the adapting image, thus increasing identity expression aftereffect. However, In the SP/SC condition of test version 2, this motion trajectory will be disrupted because of the different facial configuration between adapting face and test face, thus decreasing the expression aftereffect in the test version2.

On the other hand, because the adapting images and test are not of the same person, the motion trajectory would be disrupted by the different facial configuration regardless of the test version, thus, the aftereffect was not much reduced in the SP/DC conditions in the test version 2.

4.4 Experiment 2

In the experiment 2, we further examine whether the expression variance would influence the identity aftereffect. For the convenience of result contrast between two experiments, the identical adaptation paradigm and experiment procedures in experiment 1 were also used in study 2.

4.4.1 Stimuli in Experiment 2

The smiling, blank, and angry expression images of two female image persons were selected from Cohn-Kanade AU-Coded Facial Expression Database to construct the visual stimuli. We generated the series of faces with ambiguous identities between these two female persons with smile expressions, using FantaMorph3 software. This series of images of ambiguous identities varying from 30% to 70% served as test stimuli. The smiling, blank and angry expressions of the two female persons were employed as the adapting stimuli as shown in Fig. 4.3, respectively.

Additionally, we also generated a warp face from a blank expression face images using a Twirl filter tools in the Photoshop CS software. This warp face was also used as the adapting stimuli. The reason to use the warp face as the adapting stimuli is that expression can be regarded as the certain spatial distortion of facial configuration, we would like to examine the difference between the warp face adapting condition with the other normal adapting conditions.

4.4.2 Result

The results from 5 subjects judging the identities are shown in the Fig. 4.4, We plotted the response proportions in these four conditions as the function of identities strength in the similar way of the experiment 1.

All these four adapting conditions except the smile generate significant aftereffect as indicated by the Paired-samples t-test, which confirmed the identity aftereffect, i.e., an exposure to certain identity would significant will bias the perception to opposite direction within the series of test images.

In contrast to the significant influence on expression aftereffect from the identity variance as shown in the experiment 1, we did no observe the significant difference for

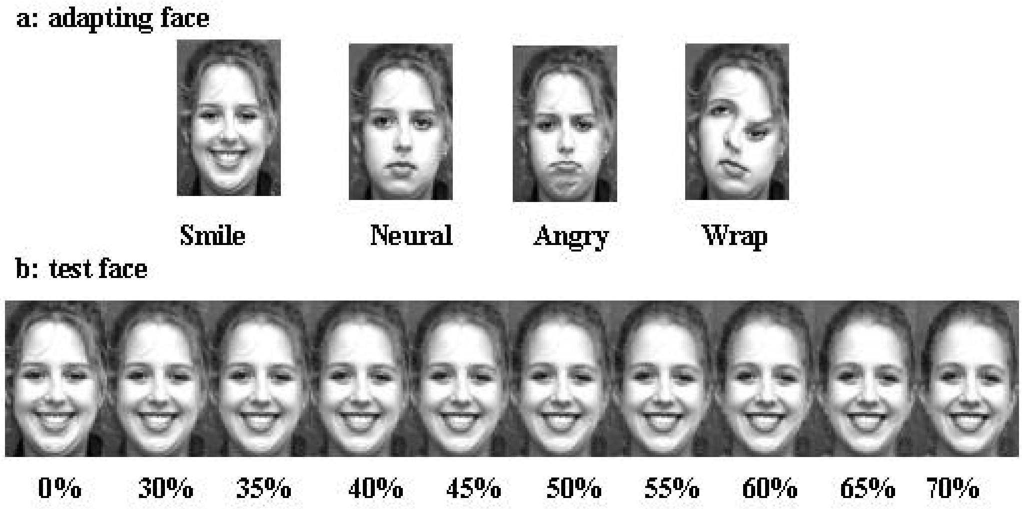

Fig. 4.3 Part of stimuli in study 2. (a) The stimuli used in smile, angry, natural and wrap adapting conditions (b) The ambiguous expression series morphed between two smiling faces with different identities, the numbers across the bottom illustrates the identity strength.

these four different adapting condition ($F_{36} = 0.215, p = 0.886$). The aftereffect in smile adapting condition is approximately identical to that in the angry adapting condition ($t_8 = 1.294, p = 0.232$), blank expression condition ($t_8 = 0.764, p = 0.467$) and wrap face adapting conditions ($t_8 = 0.903, p = 0.397$). These results suggest that identity aftereffect can be robust with expression change, indicating a existence of expression-independent identity neural representation.

Finally, we adapt the subjects by the smiling, angry expressions within the same test images in the test version 2 to examine the influence from the low-level adaptation on expression perception. We observed the significant adaptation effects for smiling adapting condition ($t_8 = 3.184, p < 0.013$) and angry adapting condition ($t_9 = 4.148, p < 0.003$) in the test version 2, with aftereffect size of 17.7% (S.E.M. = 1.6%) in smiling adapting condition and aftereffect size of 22.2% (S.E.M. = 0.6%) in angry expression condition. Although the aftereffect for these two adapting conditions in the test version

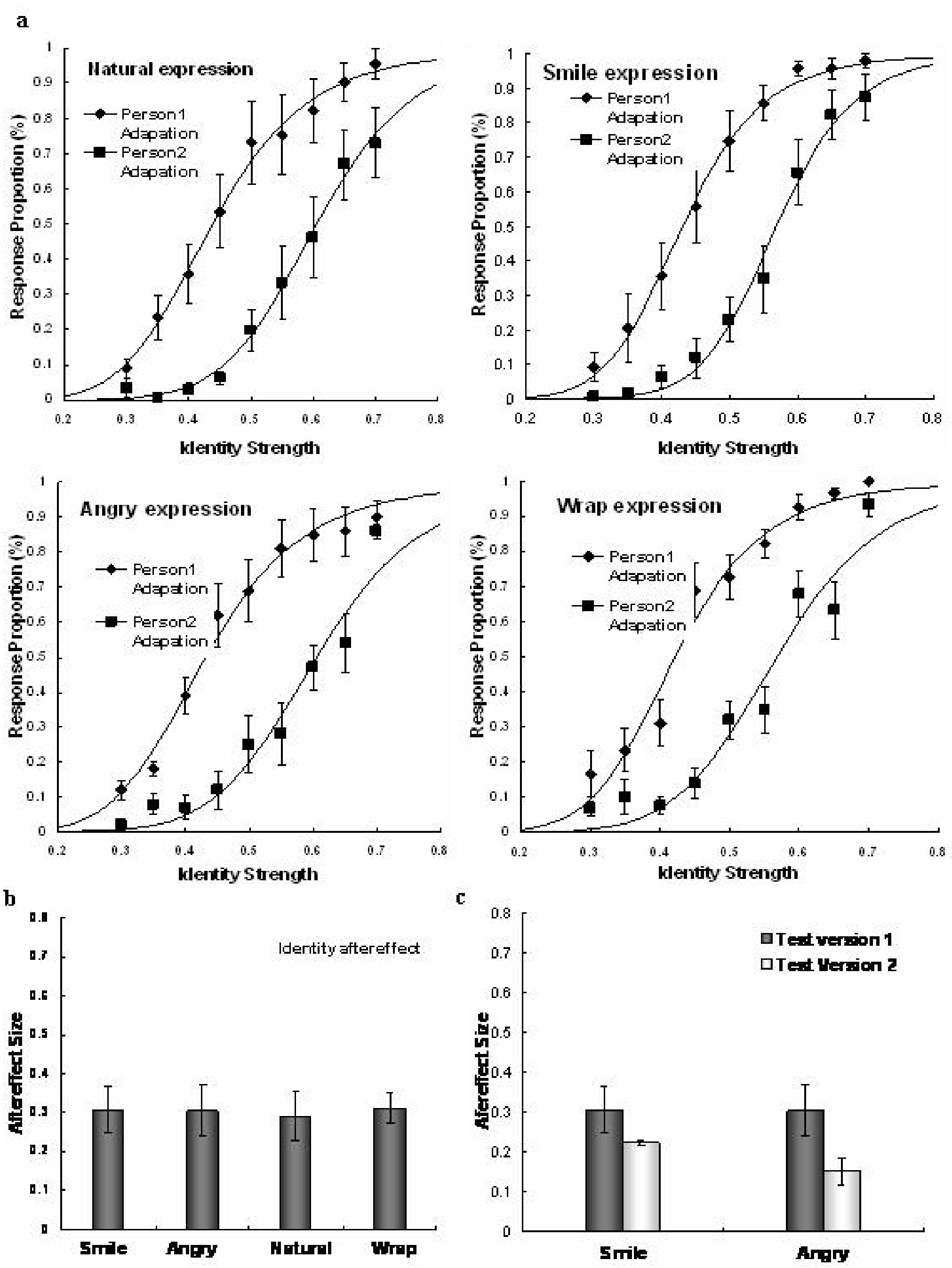

Fig. 4.4 (a) The corresponding aftereffects on natural expression, smile, angry and wrap adapting conditions, respectively. (b) The histogram illustrates the aftereffect size corresponding to four different adapting conditions. (c) is as Fig. 4.2.

2 is less than those in the version 1(See Fig. 4.4c), the aftereffect size in smiling adapting condition do not significantly differ from that in the angry adapting condition ($t_8 = 1.393, p = 0.201$) in the test version 2 , thus excluding the influence from the low-level adaptation. It suggests that the robustness of identity aftereffect can only attributed to the high-level neural representation.

Our result replicates the previous observation that the identity can be robust to the expression variance (Fox, Oruc, and Barton, 2008), moreover we provide the further evidence the robustness of identity aftereffect can generalize across also survive in the wrap condition besides the normal expression variance.

4.5 Experiment 3

The previous study (Fox, Oruc, and Barton, 2008) proposed that there are two different kind of adaptation effects in terms of congruency of facial identities between the adapting image and test image, i. e. identity-independent expression aftereffect and identity-dependent expression aftereffect. If the adapting image and test are of the same person, these two kind expression aftereffects were produced. If the adapting image and test are of the different persons, only identity-independent expression aftereffect was produced because identity variance between adapting face and test face will exclude the identity-independent expression aftereffect, thus, the expression aftereffect in congruent adapting condition was much stronger than that in incongruent condition. Although the existence of two different kinds of adaptation effect can account for this observation, the other possibility can not be well excluded.

The key issue rests on whether the facial identity variation in the behavioral level can completely excluded the identity dependent expression aftereffect in neural level. As we know, the adaptation effect is normally modulated by the similarity between adapting stimuli and test stimuli, because similar stimulus could involve the adapted neurons or populations in high possibility. Instead of the hypothesis that the adapting effect in incongruent adapting condition is produced by the abstract visual semantic neural representation of facial expression, we suggest that adaptation effect is possibly to be prouduced by the similar local facial component between adapting face and test face in the incongruent condition, if so, this adaptation effect is actually same with that in the congruent adapting condition, it means that there is only the identity dependent expression aftereffect instead of the existence of two different kinds of expression aftereffect.

We design two complementary experiments to investigate this issue as following, in the first experiment of two experiments, we use the expression on the face that is similar with the test face as the adapting stimuli to measure the adaptation effect in incongruent condition. Since hypothesized identity independent expression aftereffect is assumed to be regardless of identity, the expression image of different facial identity will be expected to generate approximately equal expression aftereffect. Thus, the observation that the similar face generates the larger aftereffect than dissimilar face will oppose to the existence of identity-independent neural representation, whereas the observation that similar persons will also generate the equal aftereffect will support the existence of hypothesized identity-independent aftereffect.

In addition, if the aftereffect in incongruent condition is produced by the identity independent neural representation, it can be reasoned that this residual aftereffect will not further reduce when adapted to the expression image in which the facial identity are weakened while expression cues is kept. In experiment2, we compared the aftereffect produced by the adapting stimuli of WIKE face(weakening identity while keeping expression cue) with the that produced by stimuli of normal face. The observation that the WIKE face generates much less aftereffect than normal face will oppose to the exis-

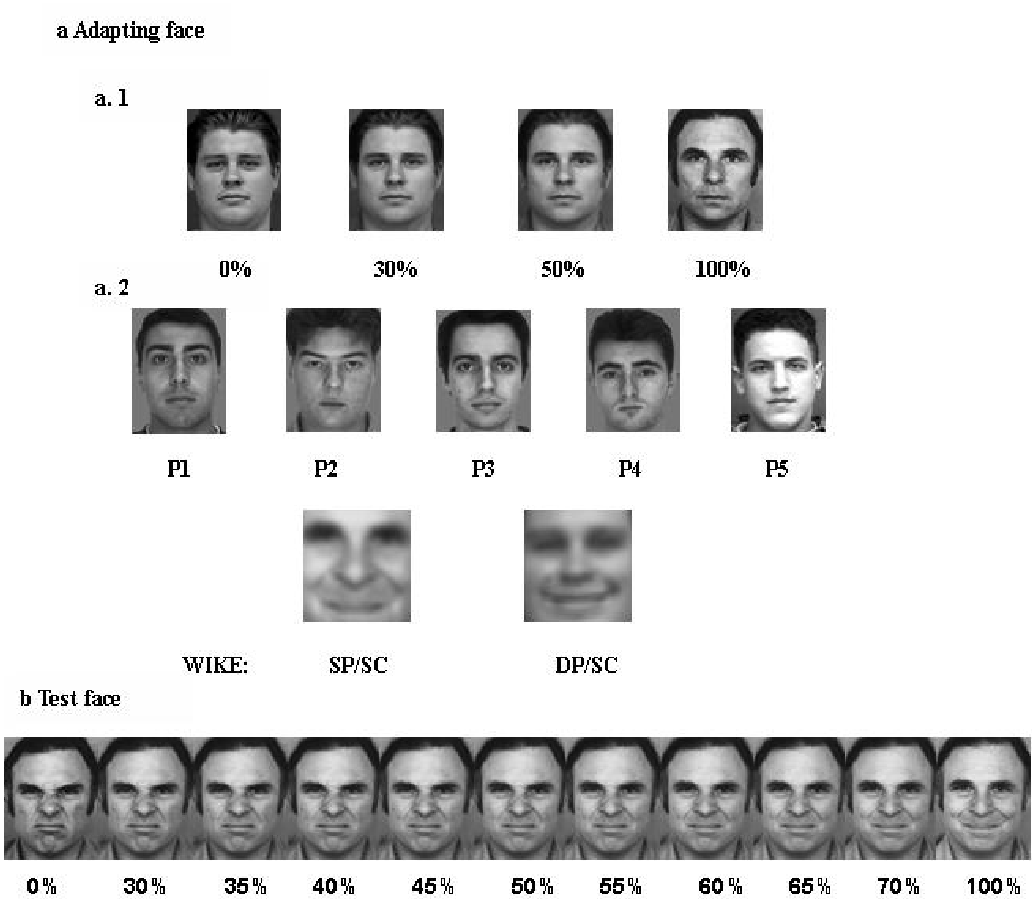

Fig. 4.5 The example of stimuli in study 3. (a)The adapting stimuli of two similar faces(a.1, 0% and 100% are not used as the adaptors), five faces with different identities (a.2), two WIKE faces (a.3). (b)The ambiguous expression series morphed between angry and smile expression pair as the test images, as described in the Fig. 4.1b

tence of identity-independent neural representation. Conversely, if WIKE face generates approximately equal aftereffect as that of normal face or WIKE face only slightly reduce the residual aftereffect, the existence of hypothesized identity-independent neural representation will be supported.

4.5.1 Experiment 3.1 : Adapting effects by expression in the similar faces

In Experiment 3.1, we repeat the DP/SC adapting condition in the experiment 1 with the smile or angry expression images of two similar identities and five different identities, respectively. There are two aims here, 1) we would like to examine whether there is a significant difference between artificial similar faces and the normal face. 2) we also want to know whether the normal faces varying in identity can induce the significant different residual aftereffect.

Stimuli in the experiment 3.1

We used the morphing technology to create the similar faces, because the morphing faces resembled two original faces when the features of two face are blended together. Here, we created the similar faces by morphing the test face with adapting face in the DP/SC adapting condition using the Fanta morphing software (See Fig. 4.5a.1). We created the nine similar faces with identity proportion of test face from zero to 100% in steps of 10% in terms of the scale of the morphing software, with zero refer to that the created adapting face is dissimilar to the test face, while one denote the adapting face is absolutely same with test face, we select those face with proportion equal with 30%, 50% serves as adapting face. The reason not to select the face images with similarity strength greater than 50% as adapting face, because these faces are too similar with test face so that subject may consider them as the same person rather than similar person.

In addition, we select smiling and angry expression images of five different faces from the Aleix face database (See Fig. 4.5a.2), we would like to examine the expression aftereffect on these five different identities. For all adapting images, the test stimuli are identical to the previous ambiguous smile-angry image series used in the experiment 1.

4.5 Experiment 3

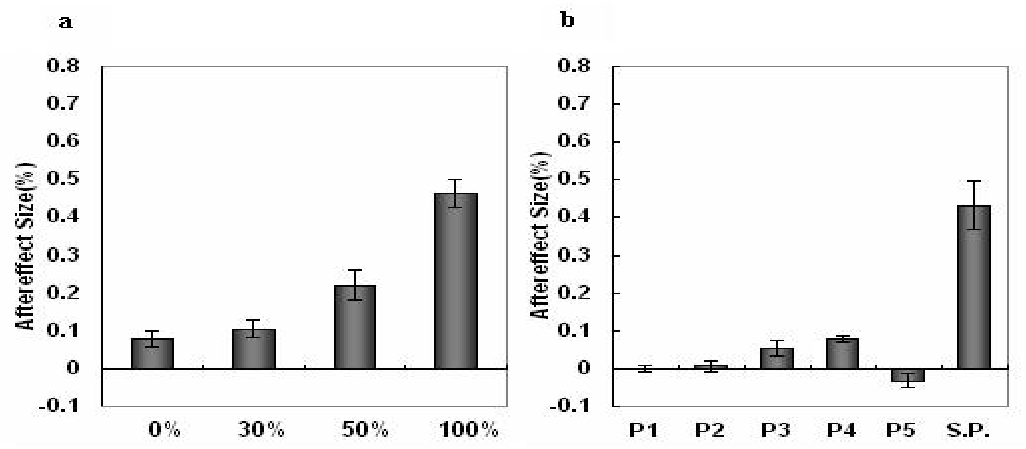

Fig. 4.6 The adapting effects by the similar faces (a) and five normal faces (b).

Result

The results from 5 subjects judging the identities are shown in the Fig. 4.6, We showed the adapting effect by the persons with different similarity strength.

The result reveals that identity similarity between the adapting images and test could significantly increase the expression aftereffect, as shown in the Fig. 4.6a and Table 4.1a. The adapting effects by 30% and 50% similar faces are 10.4% (S.E.M. = 2.3%) and 22.1% (S.E.M. = 3.9%), and the adapting effect by the 50% similar faces is significantly stronger than that by the 30% similar faces ($t_8 = 2.843, p < 0.02$).

We compared the adapting effect by 30% and 50% faces with the previous result in the experiment 1. The adapting effect by the similar faces is significantly weaker than that in the SP/SC adapting condition (100% similar faces), but significantly stronger than that in the DP/SC adapting condition (0% similar faces). It suggests that the expression aftereffect would increase as the function of identity strength, thus suggest that the expression aftereffect is identity-dependent.

On the other hand, we found that the expression aftereffect would vary in terms of the identities on the five normal faces as shown in the Table 4.1b, The P1, P2 (See Fig. 4.6b) do not obtain the significant expression aftereffect, this observation exclude

Table 4.1 Mean and S.E.M of aftereffect size and the statistical test for seven adapting persons

adapting persons	Aftereffect size	S.E.M.	statistical Test
P1	0%	0.7%	$t = 0.043, p < 0.967$
P2	0.6%	1.4%	$t = 0.482, p < 0.643$
P3	5%	2.1%	$t = 1.598, p < 0.149$
P4	7.7%	0.8%	$t = 2.398, p < 0.043$
P5	-3.2%	1.7%	$t = 2.018, p < 0.078$
30% Similar persons	10.4%	2.3%	$t = 2.838, p < 0.022$
50% Similar persons	22.1%	3.9%	$t = 3.504, p < 0.008$

the existence of identity-independent neural representation.

4.5.2 Experiment 3.2 : Adapting effects by WIKE faces

In Experiment 3.2, we repeat the SP/SC and SP/DC adapting condition in the experiment 1, with the WIKE faces as the adapting stimuli.

Stimuli in the experiment 3.2

In contrast to the mouth and eye which bring a wealth of expression cue, the face contour and face skins texture do not play a critical role on the expression perception, however, the face contour and face skin texture are critical to face identification on the other hand. We intend to keep the expression cue by maintaining the integrity of mouth and eye, weaken the identity by blurring the face skin and excluding the face contour.

The WIKE stimuli was constructed by the following method, Firstly, we separate the expression image into two parts, with one piece including eye and mouth and the other piece including face frame without eye and mouth. Our second step is to remove

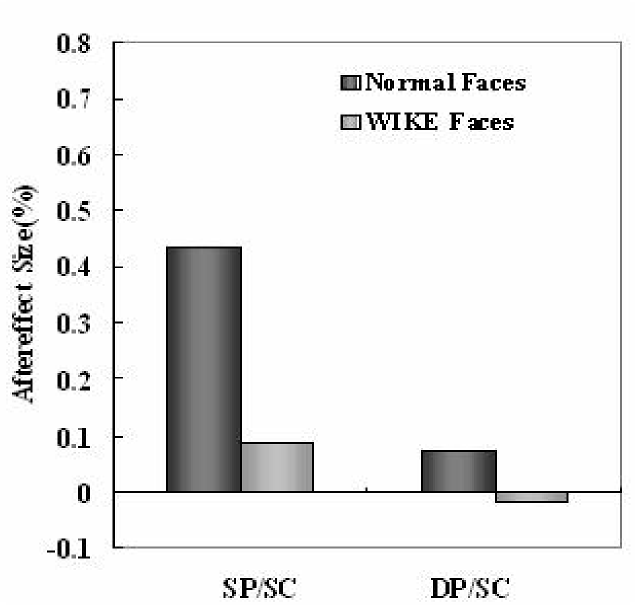

Fig. 4.7 The comparison of adapting effects between normal faces and WIKE faces in the SP/SC and DP/SC adapting conditions

the outer face contour and to blur the facial skin using Gaussian blur by Adobe Photoshop CS 7.0. Then, we further merged these two parts into one image as shown in Fig. 4.6c, In this way, we can minimize the identity cue and however retain the expression information. Finally, because the skin texture of mouth and eye appears inconsistent with that of other part in face, Gaussian blur was further applied to the face image to prevent inconsistency of skin color and texture from disrupting the normal face perception.

The standard facial identification and expression recognition tasks by five subjects confirmed that subject can easily identify the expressions but failed to recognize the expressions on the WIKE face, suggesting the impoverishment of facial identity informations and the integrity of expression information for the WIKE faces.

Result

In contrast with the significant adapting effects by the normal faces in the experiment 1, the WIKE face much reduce the expression aftereffect in the SP/SC and SP/DC adapting conditions. In the SP/SC condition, the aftereffect adapted by the WIKE face is 17.0% (S.E.M = 4.8%), which is significantly weaker than that by the normal faces ($t_8 = 5.554, p < 0.001$). In the SP/DC condition, we do not observe the significant adapting effect by the WIKE face (Size = - 0.7 %, S.E.M. = 4.1 %), which is also significantly weaker than that by the normal face ($t_8 = 2.456, p < 0.04$). As we described before, these two observations further exclude the hypothesized identity-independent expression aftereffect.

4.6 General discussion

The three major observations of this study are 1) The identity variance will significant influence expression aftereffect while expression invariance will not significant influence identity aftereffect, thus suggesting an asymmetric interference pattern on high level aftereffect between facial identity and expression. 2) The significant decrease for expression aftereffect in the congruent condition can not simply be attributed to the expression configuration difference between adapting face and test face, thus confirming the hypothesized identity-expression aftereffect. 3) The residual expression aftereffect in incongruent adapting condition will not only modulated by the identity similarity between adapting face and test face, but also will be reduced by the face stimuli with recognizable expression but weaken identity, providing no evidence for the existence of identity-independent expression aftereffect. We will discuss these findings in terms of their implication for psychological and neural computation models of facial identity and expression recognition and for understanding neural representation of facial identity and expression system.

4.6.1 The implication for functional dependency between identity system and expression system

As is demonstrated before, the findings probably indicated an asymmetric relation between neural representation of facial identity and expression system, This hypothesis is also supported by the evidences from several studies (Baudouin, Martin, Tiberghien, Verlut, and Frank, 2002; Schweinberger and Soukup, 1998; Schweinberger, Burton, and Kelly, 1999) examining the difference in the relative processing speed of identity and expression, which suggests that reaction time for expression classification were strongly influenced by irrelevant identity information, whereas Reaction time for identity classification were not unaffected by irrelevant expression information.

As far as biological status of facial identity and expression is concerned, identity perception appears to involve the static and in-spatial information such as salient features and geometrical configuration of face, in contrast, expression perception may be considered as the spatial dynamic distortion or transformation based on the identity. As a result of inter-individual variability in the expression, identity might provide a reference with respect to the more transient changes such as expressions or nonverbal speech (Schweinberger, Burton, and Kelly, 1999). Therefore, identity system seems to be more "primary" compared to the expression system. It is possible that the computation of expression recognition rests with the information conveyed by facial identity system, thus inducing this one-way dependent relationship between identity perception and expression perception.

Furthermore, our results in the experiment 3 do not find the evidence to support the hypothesized identity-independent expression aftereffect (Fox, Oruc, and Barton, 2008), the residual expression aftereffect appear to be produced by the neural representation of similar local facial component between different persons.

4.6.2 How does the model account for our result?

Furthermore, how does this dependent relationship account for the observation in our study? We proposed one possible neural mechanism as follows, it is possible that the expression is coded by neurons or population according to static spatial identity information propagated from the identity system. When test face is not identical to the original adapting face, the variance of static spatial location of identity will probably lead to change of neurons responding to identity, and thus changing the topological distribution for neurons tuning to expression via different neural connection from identity system, thus isolating the original neuron or populations that has been adapted, and leading to the fact the expression aftereffect are significantly reduced across the identity.

If the identity system and expression system are to some extent hierarchical organized and expression system depend on the identity system, the adaptation of expression inevitably involves the adaptation for both two systems. When adapting face and test face are not of the same person, the neurons or population of the neurons in the identity system that has already been adapted can not keep on effecting, thereby inducing the significant reduction in the expression aftereffect size. In contrast, the identity aftereffect can be generated regardless of expression system due to the one-way dependency , thus, the expression can not influence the identity aftereffect size.

Before this issue, we firstly make an illustration about neural representation for hypothesized dependency between two systems. So far, we can not make further conjecture about it in terms of our result and previous physiology evidences, Though overlap between two system appear to be more reasonable for accounting for the mutual influence in the aftereffect size, the possibility of the neural link can not be absolutely excluded, It will clearly be important for physiology studies to provide a more direct evidence between these two possibilities. Thus, in the next discussion, we only focus on in which brain cortex this dependency can exist but not involving the specific implementation for this dependency in neural representation.

4.6.3 The implication for physiological study

If we want to proceed further about first explanation, the question what brain cortex should be responsible for the observation in current study should be asked. As demonstrated by luminous studies (Haxby, Hoffman, and Gobbini, 2000), The process for expression stimuli appear to influence two neural system, with one system located in the Superior temporal sulcus (STS) processing the changeable aspects of a face and the other distributed system perceiving the various emotional status from the expressions.

The neural system responsible for the emotion perception appears to be highly distributed, As far as the four emotions associated with expressions used in our study, the angry are found to induce activation in right orbitofrontal cortex and bilateral activation in the anterior cingulated cortex (Blair, Morris, Frith, Perrett, and Dolan, 1999). Disgust appears to activate the insular cortex, as well as the other activation area including medial frontal cortex, right putamen, thalamus. (Phillips, Young, Senior, Brammer, Andrew, Calder, et al., 1997; Sprengelmeyer, Rausch, Eysel, and Przuntek, 1998), and fear expression always induced the activation in amygdale (Morris, Frith, Perrett, Rowland, Young, Calder, et al., 1996; Wright, Fischer, Whalen, McInerney, Shin, and Rauch, 2001). In contrast, The activation pattern so far for smile appear to be inconsistent, Gorno-Tempini et al. (2001) find that orbitofrontal area can be bilaterally activated in response to smile expression, Whereas Breiter, Etcoff, J., Kennedy, Rauch, Buckner, et al. (1996) found that left anterior amygdale will respond to smile rather than orbitofrontal area.

It is unreasonable for these highly distributed areas to directly interact with cortex for identity perception which appears to locate in the fusiform gyrus (Hoffman and Haxby, 2000; George, Dolan, Fink, Baylis, Russell, and Driver, 1999; Sergent, Ohta, and Macdonald, 1992). However, both expression pairs (Smile-Angry, Fear-Disgust) shows the similar reduction patterns of expression aftereffect size due to the identity change. How to handle this inconsistency? We suggest that superior temporal sulcus is one possible candidate responsible for the observed asymmetry between identity aftereffect and expression aftereffect. As described before, STS area seems to process changeable aspects of faces perception such as perception of eye gaze, expression and lip movements before further emotion processing. importantly, it is reported that the activation of superior temporal sulcus (STS) can not be reduced by the repeating identity across face pairs but also by the repeating emotional expression across pairs l, (Winston, Henson, Fine-Goulden, and Dolan, 2004) indicating a interaction possibility between two systems.

4.7 Conclusion

To conclude, we has demonstrated an asymmetric interference between facial identity aftereffect and expression aftereffect, which challenges the classical hypothesis depicting the functional separation between expression system and identity system. We further provide the evidences for confirming hypothesized identity-dependent aftereffect and opposing the identity-independent aftereffect. This result, together with previous result, potentially suggests an asymmetric relation between neural representation of facial identity and expression system.

Chapter 5

The Influence from Facial Attractiveness on Smile or Angry expressions

5.1 Research Background

5.1.1 Related works

Facial physical attractiveness (FPA) is one of the most salient features in interpersonal attraction and social communication. An attractive individual appears to benefit considerably from this physical trait in many aspects, involving social evaluation (Miller, 1970), mate selection (Thornhill and Furlow, 1998), employment decision (Watkins and Johnston, 2000), and even voter preferences for political candidates (Efran and Patterson, 1974). The generalization of these social advantages is called "what is beautiful is good" stereotype (Dion, Berscheid, and Walster, 1972). In contrast with attractiveness stereotype, the study (Griffin and Langlois, 2006) comparing judgments of positive and negative attributes between unattractive faces and attractive faces suggests that unattractiveness is sometime a disadvantage, which is consistent with negativity bias (Rozin and Royzman, 2001).

As it is similar with the powerful effect of facial attractiveness on social interaction, An expression, which is the main channel of human nonverbal communication, plays an even more important role on basic human survival and social interaction (Buck, 1994). Moreover, facial physical attractiveness and expression appear not to be mutual-isolated facial dimensions, and it is reported that smile expression can significantly enhance the perceived facial attractiveness (Berscheid and Walster, 1974; Mehu, Little, and Dunbar, 2008). More generally, expressive facial movement will influence the perceived attractiveness and a static face is rated less attractive than the moving face (Knappmeyer, Thornton, Etcoff, and Bülthoff, 2002; Morrison, Gralewski, Campbell, and Penton-Voak, 2007). Interestingly, these results are also consistent with a neurological observation. The activation of medial orbitofrontal cortex (OFC), a region involved in representation of a stimulus-reward value, could be produced by an attractive face and further enhanced by a smiling facial expression. This result suggests the common rewarding process between attractiveness and smile (O'Doherty, Winston, Critley, Perett, Burt, and Dolan, 2003).

These studies indicated an one-way influence from the expression on the attractiveness perception, however, little is known about how the facial physical attractiveness influence the expression dimension, conversely. As we know, one of the primary characteristic of perception is that human tends to perceive the impression about others into coherent and meaningful wholes (Asch and Zukier, 1984). Thus, it appears difficult for human to perceive the expression while ignoring the physical facial attractiveness. However, the complex and subtle interactions from attractiveness (The term of "attractiveness" from here refers to specifically "physical facial attractiveness") on different expressions can not be covered by this easy answer.

The key issue rests on what type of underlying mechanism would be responsible for the influence from attractiveness on the expressions. Are there significant differences for human brain to interpret the different expressions with the reference to attractiveness?

For instance, attractiveness and smile expression seems to interact each other by activating the OFC cortex which involves representing stimulus-reward value (O'Doherty et al., 2003). Some negative expressions such as angry, fear, disgust, however, may not be associated with the rewarding-related perception. Thus, we have the question whether the attractiveness will still influence the perception of negative expressions. By existing theories, however, it seems little help to account for these issues. These issues are important because they help to address the behavior pattern and perception bias of the human in the case of presenting or interpreting the expression in the social communication. Furthermore, these issues will provide the potential clue from behavioral perspective to understand how the attractiveness perception and emotion perception interact in the neurological level.

5.1.2 Research methodology

Logically, we reason that the attractiveness would influence the expression dimension in two ways. 1) From the view of an expression receiver, the expression perception is possibly influenced by the attractiveness via the halo effect, which refer to a cognitive bias that the perception of a particular trait is influenced by the perception of the former traits in a sequence of interpretations (Thorndike, 1920; Lucker, Beane, and Helmreich, 1981; Wade, Loyden, Renninger, and Tobey, 2003). If the halo effect occurs in the expression perception, an identical physical expression configuration in an attractive face will produce a stronger impression strength than that in an unattractive face. 2) From the view of an expression sender, it is also possible for the attractiveness to influence the expressive habituation of the expression sender in the person's development of social skills. Some potential lines to support this possibility can be found in the previous behavior studies. For instance, the development of social skills appears to be influenced by the attractiveness due to the self-fulfilling effect. The attractiveness is reported to positively enhance nonverbal encoding accuracy but negatively weaken nonverbal decoding abilities (Sabatelli and Bubin, 1986). Similarly, another study (Larrance and Zuckerman, 1981) has suggested that the attractiveness and vocal likeability increases sending accuracy of facial and vocal cues of pleasant affects, indicating a superiority in a controllable skill of attractive persons.

In term of these two possible possibilities we discussed above, we aim to examine the influence from the attractiveness on expression perception or expressive habituation, with the special regard given to the smile and angry expressions in this research. The reason to choose smile and angry as the delegate is that they are explicit indicators to positive or negative emotions of human as two opposites in the expression categories (e.g. Feleky, 1924) and they have different influences on expression impression.

The expression intensity (Schlosberg, 1952; Frijda and Philipzoon, 1963) and expression naturalness (Frijda and Philipzoon, 1963) will serve to evaluate the expression impression. We expect that the difference of these two expression dimensions between the unattractive group and the attractive group would provide to assess the influence of the attractiveness on the expression. One key difficulty here was how to isolate the influence from expressive habituation of a sender with the influence from expression perception of a receiver. We introduced a novel experimental paradigm to cope with interrelated chaos as following. In the first experiment, attractiveness, the expression intensity, and expression naturalness are rated on smile, blank, and angry expression images of a total of 60 image target persons. Here, we do not explicitly control the physical configuration of the expression for target persons, which allow the perceived expression impression to be influenced by both the expressive habituations and attractiveness bias. In the second control experiment, we excluded the influence from the expressive habituation by controlling a degree of the physical expression configuration. The fifteen top unattractive persons and fifteen top attractive persons are selected from the original

Fig. 5.1 Example of stimuli used in the experiment 1. a) Three expressions of one image target person used in the magnitude estimation rating session, the attractiveness, the expression intensity and the expression naturalness of each image were rated, respectively. b) Two faces of one trial in the session of the Thurstone's method of paired comparisons, in which the subject was asked to make a two-alternative-forced choice to determine which image person is more attractive.

target face set in the experiment 1 to construct a set of artificial expression stimuli, in which every target person was set to the same physical expression configuration using a computer morphing template. Thus, if there is still the significant difference of the impression strength between two groups, this difference can only be attributed to the perception of the expression receiver. Consequently, we can make a distinction between the influence of the attractiveness on the expression perception and the influence of the attractiveness on the expressive habituation in comparison of the results between experiment 1 and experiment 2.

5.2 General Method

5.2.1 Subjects

A total of 20 subjects (11 Japanese and 9 Chinese, 3 female; age = 25.0 ± 3.8 years) in Kochi University of Technology in Japan consented to participate in the two experiments of this study. All subjects are naïve to the purpose of experiments and have normal or corrected-to-normal vision. All 20 subjects attended the magnitude estimation sessions of experiment 1 and 15 subjects attended the sessions of Thurstone's method of paired-comparison in experiment 1. 10 subjects attended the experiment 2. The statistical test do not indicate the gender difference among subjects, thus, the data will be merged for all subjects in the further analysis.

5.2.2 Apparatus

Face images were presented on 19 inch LCD screen (DELL Monitor, Model 1905.FP) controlled by the computer (DELL $Xeon^{TM}$ 2.8G HZ and NVIDIA Quadro FX 1400). The vertical refresh rate was 85 Hz and the spatial resolution was 1024*768 pixels. Subjects was instructed to view the monitor from the distance of 50cm, the visual stimuli were shown in the center of screen and subtended a visual angle of approximately 12 degree (horizontally) by 15 degree (vertically) in this distance. All experiments were run by Matlab platform with Cogent 2000 Psychophysics Toolbox extensions (http://www.vislab.ucl.ac.uk/cogent.php).

5.2.3 Procedure

Before the experiment, the subjects had the following instruction to comprehend the expression intensity and expression naturalness; "May you recognize the expression cue from this image? Please select the corresponding expression options. If you feel the high emotional strength from this image, use high score on "expression intensity", otherwise, use low score on "expression intensity". Is facial muscle movement consistent with the corresponding emotion to be expressed? If consistent, use high score in "expression naturalness", otherwise, use low score."

The attractiveness was not further interpreted because it was worried that the subject's own criterion for the attractiveness would be distorted by our instruction.

There are two sessions in one experiment, with each subject individually tested.

We use a magnitude estimation method in the first session to rate the attractiveness, the expression intensity and the expression naturalness. For each image, the subject was instructed to firstly judge the expression type and then rate the corresponding three dimensions (See Fig. 5.1a). The subject could select the expression type from six options (smile, angry, sad, fear, disgust and blank expression), in which ”sad”, ”disgust”, and ”fear” were distractors. The magnitude estimation was from 1 to 9, with 1 representing low strength and 9 representing high strength. A pilot result showed that subjects tended to use a very limited range of scale for rating, which would impoverish the rating capacity of the magnitude estimation. Thus ,we further instructed subject to divided score range into three sub-categories, i.e., 1 to 3 for low strength, 4 to 6 for normal strength, and 7 to 9 for high strength. The subject was asked to firstly choose the sub-category and then to determine the rating score according to the impression of the target person.

In the second session, we use Thurstone's method of paired-comparison (See Fig. 5.1b) to further verify accuracy of the attractiveness rating result by the magnitude estimation method. The blank expression images of twelve image persons were selected from the original 60 persons, with each possible combination of every two persons as one trial, resulting in a total of 66 trials ($12 * 11/2 = 66$). In each trial, subjects were simultaneously shown two facial images and were asked to judge which is more attractive. The selected image person received one point per subject and 165 points (1 * 15 subjects * 11 combinations) were the maximum point.

The 20 students learned the task through the oral instruction (9 Chinese subjects) or written instructions (11 Japanese students) and a short practice session of 8 trials before the experiment.

A total of 180 facial images (60 image persons * 3 expressions) were subsequently presented on the center of the screen, with the fixed turn (smile, blank face and angry face). The reason to use this sequence rather than random order is to exclude the possible influence from the expression adaptation (Webster, Kaping, Mizokami, and Duhamel, 2004), in which an exposure to certain expression (for example, viewing smile) will significantly bias the perception to opposite direction (for example, tending to perceive the subsequent image as angry). The blank face in the midst between smile and angry will reduce this adaptation effect to the great extent.

5.3 Experiment 1

5.3.1 Stimuli

According to the experimental goal, it was extremely critical in these two experiments to keep reasonable distribution of attractiveness strength when selecting image target persons. A lack of distribution of the attractiveness strength will always lead to the failure to examine the possible influence of the attractiveness because the influence of the attractiveness should be masked by other facial dimensions. We used two steps to control the strength of the attractiveness, Firstly, one author(MS) and two subjects together selected 100 relatively unattractive female image persons and 100 relatively attractive female persons from the total of 445 females image persons on the CAS_PEAL Face Database (http://www.jdl.ac.cn/peal/project_description.htm). The second step is to select 30 unattractive images and 30 attractive persons randomly from the collection of 100 unattractive persons and 100 attractive persons, respectively. The manipulation here, however, was not used to define the unattractive group and the attractive group as classification. The total of 60 image persons were put together for

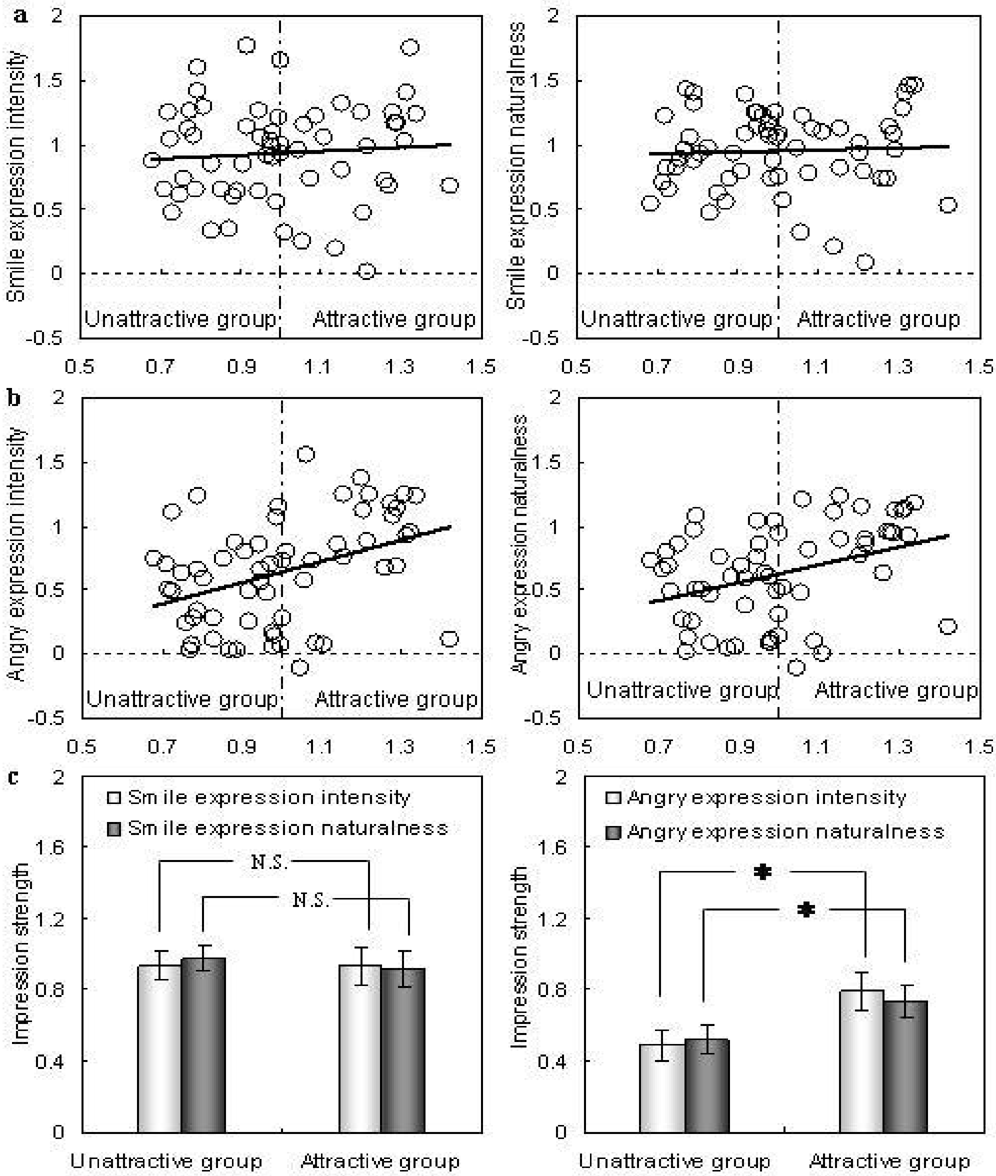

Fig. 5.2 The result of experiment 1. The expression intensity (left panels) or the expression naturalness (right panels) of the smile expression (a) or the angry expression (b) as the function of the attractiveness, with the vertical dotted line indicating the group distinction according to the attractiveness strength. Solid lines denote the least-square linear regression. (c) The mean and S.E.M of the expression intensity or the expression naturalness for the unattractive group and the attractive group in smile faces (left panel) and angry faces (right panel), with the error bar denoting S.E.M., asterisks (*) indicating significant tests and N.S. indicating no significant test.

further attractiveness rating by 20 subjects.

Each image person has smile, blank and angry expressions, resulting in a total of 180 facial images used in the experiments. We cropped the all images to the uniform size of 370*500 pixels, in those most of the neck and the clothing area was excluded but hair was included. The background of the image was set to gray. One example of used image person was shown in the Fig. 5.1a.

5.3.2 Data Analysis

A preliminary analysis revealed no significant differences between Japanese subjects and Chinese subjects (p=.82). Thus, their data were merged for subsequent analyses.

An attractiveness score, as an independent rating value, was directly used in the further data analysis. The responses of expression intensity and expression naturalness were associated with judgment and the rating value was translated as following way. 1) The rating value was directly used if the subject correctly judged the expression. 2) The values of the expression intensity and the expression naturalness were assigned to 0 regardless of original rating values if the smile or angry was judged as "blank expression". 3) The values of the expression intensity and the expression naturalness were assigned to -1 despite of original rating values, if an expression was misjudged. We did not remove the wrong judge response in the further analysis because these data indicated the expression of unnatural configuration and/or of a low physical intensity, which is a reflection of the expressive habituation of the expression sender to some extent.

In order to exclude the possibility that the data would be dominated and shifted by responses from subjects who rated relatively high scores as the variation of psychological rating baseline, we firstly perform the data normalization on the original data, every rating score of all image persons including all of smile, blank and angry expressions were divided by the average on the corresponding dimension for one subject ($x_i = x_i/\{(sum_{k=1}^{n} X_i)/N\}$).

The expression intensity and the expression naturalness were separately normalized. Zero and minus one of the wrong response were not included the normalization manipulation. Because zero and minus one are not the real rating value of human response and not related to rating baseline of subjects, we directly used the zero and divided minus one by the nine (the maximum of the magnitude scale) as the normalized value.

Then, the mean and S.E.M. of the attractiveness, the expression intensity and the expression naturalness for each image person were calculated by averaging the normalized rating scores among all 20 subjects.

A two-Way ANOVA (The SPSS 13.0 statistical software (www.SPSS.com)) was performed with the expression intensity and the expression naturalness as the dependent variables, respectively. An attractiveness level (the unattractive group or the attractive group) and an expression type (angry or smile) were used as fixed factors. Significance level was set at P $<$ 0.05. If there is the significant interaction of the attractiveness level $\times$ the expression type, the smile and angry will be separately analyzed by the one-way ANOVA in this case, because the attractiveness level $\times$ expression type interaction indicates the attractiveness would pose the different influence on smile or angry.

5.3.3 Results

The accuracy of the attractiveness rating was evaluated by determining the similarity between the values obtained by the magnitude estimation method and Thurstone's method of paired-comparisons. We computed the Pearson product-moment correlation coefficients for the values measured on the blank expression face, the correlations were highly significant ($r = 0.923, p < 0.000$), suggesting that magnitude estimation values closely approximating the values obtained by Thurstone's method of paired-comparisons.

The results from 20 subjects rating the expression intensity and the expression naturalness of 60 image persons are shown in the Fig. 5.2, We plotted normalized rating values of the expression intensity or the expression naturalness as the function of the attractiveness strength as shown in the Fig. 5.2a and Fig. 5.2b., in those each circle denotes the expression intensity or the expression naturalness of the one image person. Because some subjects' 0 or -1 were not included in the normalization, the entire average of the data including both smile and angry was below one. Also, the average of the data for smile is higher than the average for angry because smiling faces got higher values than angry faces,

We divided all image target persons into the unattractive group and the attractive group in terms of the rating attractiveness, with each group including 30 target persons. The distinction of the attractiveness strength between these two groups is significant. ($F_{1,59} = 120.310, p < 0.000$).

The expression type indicated the statistically-significant main effect on the expression intensity and the expression naturalness. The perceived expression intensity and the expression naturalness of smile is much stronger than those of the angry (See Fig. 5.2c). This difference can be attributed to the different capability of human to pose smile or angry. Because smile is the most commonly used expression to facilitate social interaction, every person can present smile expression more naturally and impressively than angry.

Attractiveness level indicated a slightly-significant main effect on the expression intensity ($F_{1,59} = 4.429, p < 0.037$), but no significant main effect on expression naturalness ($F_{1,59} = 1.573, p = 0.212$). However, we observed the significant interaction of the attractiveness level × expression type on both the expression intensity

($F_{1,59} = 4.733, p < 0.032$) and the expression naturalness ($F_{1,59} = 5.013, p < 0.027$). It suggests that the perceived expression intensity and the expression naturalness are influenced by the attractiveness in different way according to the expression type. Thus, we separately examine the influence from the attractiveness on the smile or angry in the further analysis.

For the smile expression, an one-way ANOVA reveals no significant influence from the attractiveness on the expression intensity ($F_{59} = 0.003, p = 0.960$), with the perceived expression intensity of the attractive group approximately identical to that of the unattractive group. Similarly, there is also no significant influence from the attractiveness on the expression naturalness ($F_{59} = 0.579, p = 0.450$). These two observations indicate no obvious perceptual bias effect between the unattractive group and the attractive group (see Fig. 5.2a).

Interestingly, however, we observed the opposite result for the angry expression. There is a significant influence from the attractiveness on the angry expression intensity ($F_{59} = 8.934, p < 0.004$), the perceived expression intensity of the attractive group is much stronger than that of the unattractive group. Also, the perceived expression naturalness of the attractive group is stronger than that of the unattractive group ($F_{59} = 5.247, p < 0.026$). It suggests that the attractiveness can somehow enhance the perceived impression strength of the angry expression (See Fig. 5.2b).

The overview of the data analysis (Expression intensity, Expression naturalness, and Attractiveness) is presented in Table 5.1.

5.4 Experiment 2

The result of experiment1 suggests that the attractiveness influences the impression strength of angry but not of smile. However, the underlying reason for this observation

Table 5.1 Mean rating and standard deviation of the expression intensity and the expression naturalness measured with the stimuli of the uncontrolled expression configuration

	Attractiveness strength	expression types			
		Smile		Angry	
		EI [*1]	EN[*2]	EI	EN
UG [*3]	0.84 ± 0.02	0.94 ± 0.06	0.98 ± 0.05	0.49 ± 0.06	0.52 ± 0.06
AG [*4]	1.16 ± 0.02	0.94 ± 0.08	0.92 ± 0.06	0.79 ± 0.08	0.74 ± 0.07
ST [*5]	$F = 120.31$, $p < 0.000$	$F = 0.003$, $p = 0.960$	$F = 0.579$, $p = 0.450$	$F = 8.934$, $p < 0.004$	$F = 5.247$, $p < 0.026$

[1] EI: Expression intensity

[2] EN: Expression naturalness

[3] UG: Unattractive group

[4] AG: Attractive group

[5] ST: Statistical test of an ANOVA between the unattractive group and the attractive group

is still ambiguous. Thus, we perform an additional experiment to exclude the influence from the expressive habituation of different image persons, using the expressions made by a computer morphing technology.

5.4.1 Stimuli

We generate morphing expressions by applying the identical expression template on blank expression faces selected from the original photo set used in the experiment 1. Faces of fifteen top unattractive persons and fifteen top attractive persons were chosen to ensure the sufficient distinction of the attractiveness strength. For each face, we gen-

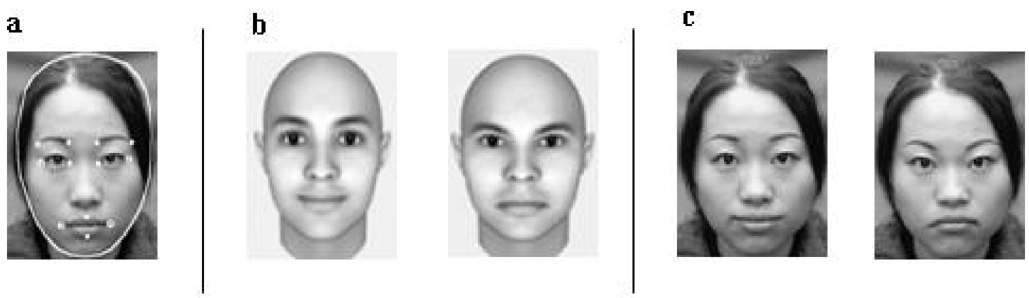

Fig. 5.3 The illustration of the method to construct the artificial expression. a) The original blank expression face, with the white point and curve indicating the morphing mark and morphing facial contour, respectively. b) The expression template of smile and angry. c) The final morphing result constructed by (a) and (b).

erate morphing smile and angry expressions by corresponding morphing template, using FaceFilter Studio 2.0 (http://www.reallusion.com/facefilter/, Reallusion Inc.) (See Fig. 5.3).

One may argue that it is not necessary to produce the identical physical expression intensity or expression naturalness for different faces even with the identical expression template, because the impression of morphing expression will not only be influenced by the morphing expression template but also by the original face configuration. However, we have two reasons to believe that this difference of the facial configuration would not significant distort the result. Firstly, for the blank expression face, the expression template will play a much more important role on shaping expression impression than the face configuration. More importantly, the influence from the different facial configuration will simultaneously occur in the unattractiveness group and in the attractive group, which can be mutually compensated in the between-group comparison.

Additionally, several previous studies suggested that attractive faces are closer to the average face than unattractive faces (Langlois and Roggman, 1990). If the morphing software could only work well on certain face configurations those were close to the

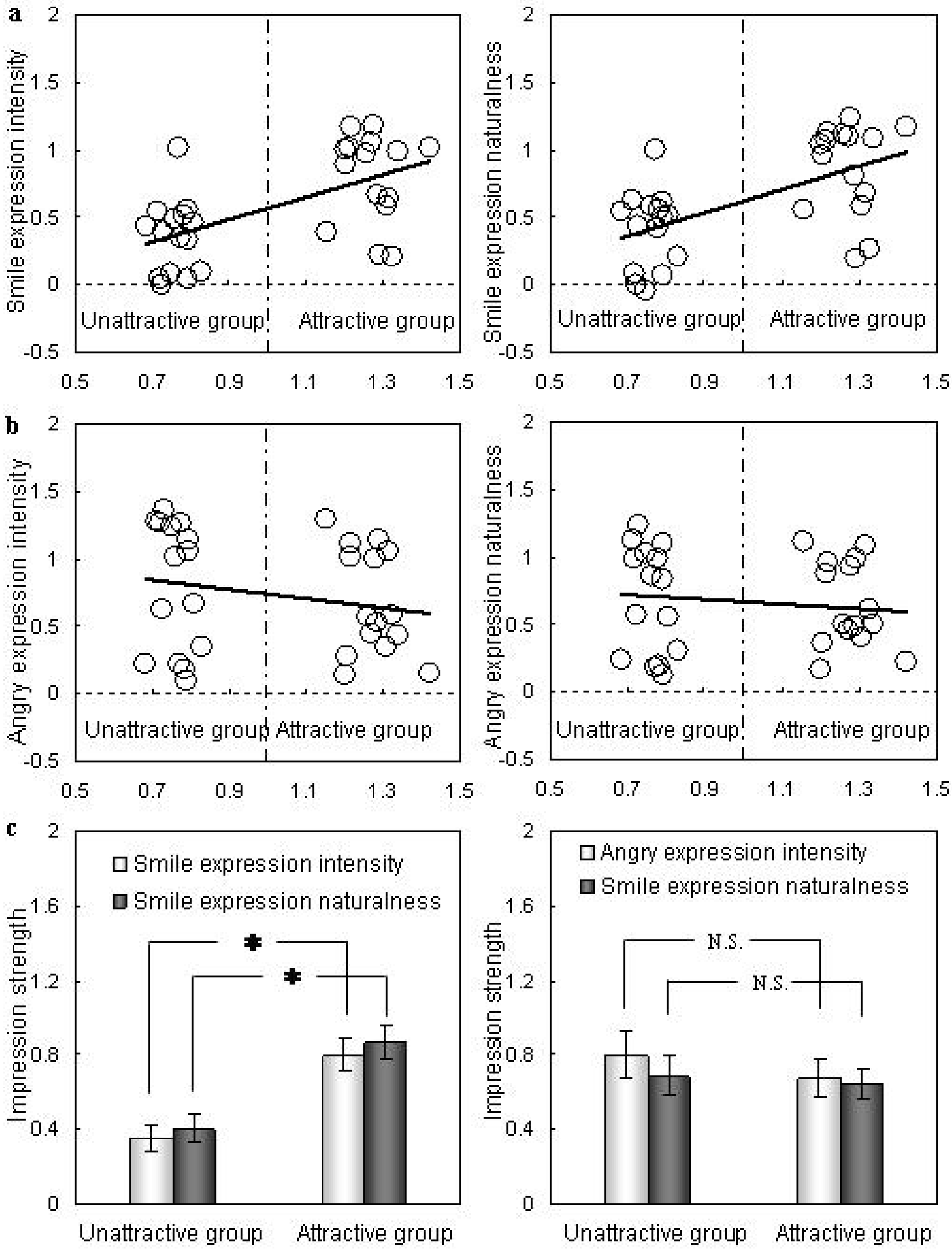

Fig. 5.4 The results of experiment 2 as in Fig. 5.2.

Fig. 5.5 The illustration for the relationship between physical expression configurations and perceived expression impression (see text for details).

averaged face, we would have evaluated the different influence on two groups induced by the imperfect morphing technology. If the case, the physical expression impression of two groups was not necessarily the same, because of the different morphing effect for the attractive group and the unattractive group. In order to exclude this possibility, we instructed eight subjects to rate the "artificialness" of the morphing effect for all morphing expression used in the experiments as a control experiment. We found that the "artificialness" of the unattractive group do not significantly differ from that of the attractive group in both morphing smile expression ($F_{29} = 2.982, p < 0.095$) and morphing angry expression (($F_{29} = 2.971, p < 0.096$)). It suggested that the morphing software could generate the approximately identical expression physical expression impression between two groups.

5.4.2 Result

The result from 10 subjects rating the expression intensity and naturalness of morphing expressions of 30 image persons are shown in the Fig. 5.4. We plotted the normalized rating values of the expression intensity or the expression naturalness as the function of the attractiveness strength as shown in the Fig. 5.4a and Fig. 5.4b.

In contrast with the observation of the experiment 1 that the impression strength of smile was stronger than that of angry, we did not observe the significant main effect of expression type on the expression intensity ($F_{1,29} = 2.611, p = 0.112$) or the expression naturalness ($F_{1,29} = 0.115, p = 0.735$). It suggests that there is no significant difference of the impression strength between smile and angry when physical expression configuration was controlled. Additionally, there is an significant expression type $\times$ attractiveness level interaction on the expression intensity ($F_{1,29} = 8.610, p < 0.005$) and on the expression naturalness($F_{1,29} = 8.379, P < 0.005$), those are due to the fact that the expression intensity of smile in the unattractiveness group is significant lower than the other three measurements.

As indicated in the experiment 1, The human seems to interpret the smile and angry in different strategy in terms of the physical attractiveness, thus, we separately analyzed the effect of the facial physical attractiveness on smile or angry. For smile expression, a one-way ANOVA revealed a significant influence from the attractiveness on the expression intensity ($F_{29} = 16.180, P < 0.000$) and the expression naturalness($F_{29} = 16.210, P < 0.000$). Both the expression intensity and the expression naturalness of smile in the attractive group are significantly stronger than those of the unattractive group. It suggests a positive correlation between the attractiveness and the impression strength of smile. (See Fig. 5.4a, c). In contrast, the impression strength of the angry expression appears to be regardless of the attractiveness, we do not observe the significant influence from the attractiveness on the expression intensity ($F_{29} = 0.631, p = 0.434$) or the expression naturalness ($F_{29} = 0.112, p = 0.740$) of the angry expression. The perceived expression intensity or the expression naturalness of the attractive group approximates the corresponding dimensions of the unattractive group. (See Fig. 5.4b, c).

The overview of the data analysis (the expression intensity, the expression naturalness and the attractiveness) is presented in Table 5.2.

Table 5.2 Mean rating and standard deviation of the expression intensity and the expression naturalness measured with the stimuli of the controlled expression configuration[1]

	Attractiveness strength	expression types			
		Smile		Angry	
		EI	EN	EI	EN
UG	0.76 ± 0.01	0.36 ± 0.07	0.41 ± 0.07	0.80 ± 0.12	0.69 ± 0.10
AG	1.27 ± 0.02	0.80 ± 0.08	0.86 ± 0.09	0.67 ± 0.10	0.64 ± 0.08
ST	$F = 636.812$, $p < 0.000$	$F = 16.180$, $p < 0.000$	$F = 16.210$, $p < 0.000$	$F = 0.631$, $p = 0.434$	$F = 0.112$, $p = 0.740$

[1] The abbreviation of table 5.2 is the same in Table 5.1

5.5 General Discussion

5.5.1 Summary of key observations

The results of two experiments reported here appear to be contradictory. The first experiment using the stimuli of uncontrolled expression configuration demonstrated that

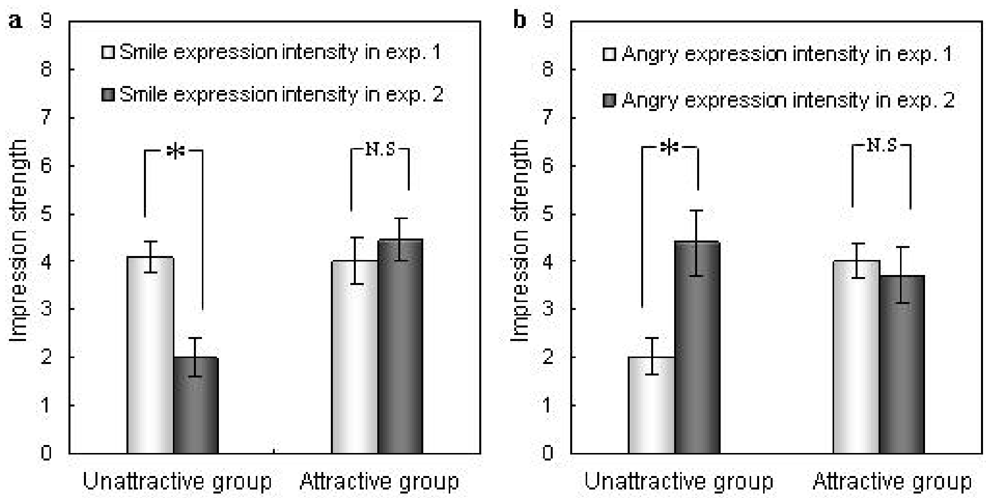

Fig. 5.6 The comparison of expression intensity for smile (a) and angry (b) between experiment 1 and experiment 2.

the perceived expression intensity and expression naturalness of angry in the attractive group are much stronger than that in the unattractive group. However, this difference disappears with the stimuli of smile expression. In contrast, the second experiment using the stimuli of controlled expression configuration suggested that the perceived expression intensity and expression naturalness of smile expression in the attractive group is significantly stronger than that in the unattractive group, however the impression strength of angry in the attractive group approximates the unattractive group. Which type of mechanism is responsible for this discrepancy between these two experiments?

In order to reconcile this discrepancy, it is essential to firstly clarify the relationship between the physical expression configuration and the perceived expression impression. Previous studies have revealed that the perceived expression intensity is primarily determined by the physical expression intensity, and that the change of perceived intensity is primarily linear with the physical intensity of the expression (Hess, Blairy, and Kleck, 1997). The perceived expression intensity is also influenced by the other subtle and complicated factors such as attractiveness and sociality of the context (Buck, 1994; Jakobs, Manstead, and Fischer, 2001). Because of the method we used, the influence from the sociality of the context was excluded in our experiments. Thus, we reason that the perceived expression intensity is only determined by the physical expression intensity and attractiveness bias in the current experimental context, as shown in the Fig. 5.5.

As demonstrated before, because the identical morphing expressions excluded the influence of expressive habituations or skills, we firstly characterize the influence of the attractiveness on the expression perception based on the result of experiment 2, and then we will explore the possible explanations for discrepancy between two experiments.

5.5.2 Possible explanations for smile expression

In terms of the observation of experiment 2, we concluded that attractiveness would significantly bias smile perception and increase the perceived expression intensity and the expression naturalness of smile. It suggests that the existence of the halo effect in the smile perception. However, why this attractiveness bias could not be observed in the uncontrolled natural expressions? From the relationship in the Fig. 5.5, It is expected that the physical expression intensity or the expression naturalness in the unattractive group is stronger than that in the attractive group. This physical expression difference dominates the attractiveness bias and thus leads to the result that the final perception bias could not be observed.

This hypothesis can be supported by paired-comparison of the initial rating values for each subject between experiment 1 and experiment 2 in the unattractive group and the attractive group, respectively. For the unattractive group, we observed the significant increase of the expression intensity from the controlled expression stimuli in the experiment 2 to the uncontrolled stimuli in the experiment 1 ($t_{14} = 3.878, p = 0.002$), The attractive group does not show the similar increase ($t_{14} = 0.568, p = 0.579$) (See Fig. 5.6a). Because the physical intensity between the attractive group and the unattractive group in the experiment 2 is identical, the observation that the increase only occurs in the unattractive group reflects an increase of the physical intensity for the uncontrolled expression in the unattractive group in contrast with the attractive group.

However, why does unattractive persons will show the stronger expression intensity than attractive persons? It seems to be associated with the issue how facial physical attractiveness shapes the development of social skill. We propose the compensation hypothesis as follows; by realization of the powerful role of the attractiveness in social interaction and instinctive comprehension that the smile expression could enhance the perceived attractiveness, the unattractive persons tend to present the smile expression stronger in the communication than the attractive persons to compensate the attractiveness bias, which is more like a benefiting selection in the sociality context. Actually, the subtle clue for this kind of explanation can be found in the previous study examining strength of halo effect (Lucker et al., 1981), Their result suggests the halo effect is much more limited than what peoples think or previously implied, The mask of halo effect appears to be a inevitable result induced by strategical difference of compensation behavior between the unattractive persons and the attractive persons.

One more possible explanation is that attractive female persons are not willing to use furious muscle movement which distorts the female static facial attractiveness.

5.5.3 The possible explanation for angry expression

In contrast with the significant bias of the attractiveness on the smile perception, the attractiveness does not significantly influence the angry expression perception according to the result of the experiment 2. The reason why the attractiveness influences the smile perception but not the angry perception can be associated with the positive reinforcement effect (Michael, 2005). Both the attractiveness and the smile expression induce the relatively positive visual impression, and lead to the mutual enhancement in the perceived expression intensity. However, the positive visual impression of the facial attractiveness could not enhance the perception of negative expression such as angry.

We further ask why the impression strength of angry in the attractive group is significantly stronger than that of the unattractive group in the experiment 1, if the physical attractiveness does not influence the angry perception. Similarly in the smile expression, we compared the angry intensity between experiment 1 and experiment 2 for the unattractive group and the attractive group. A significant decrease of the expression intensity from the controlled expression stimuli in the experiment 2 to uncontrolled stimuli in the experiment 1 is observed in the unattractive group ($t_{14} = 3,227, p = 0.006$) , but not in the attractive group ($t_(44) = 0.453, p = 0.657$) (See Fig. 5.6b). It suggests that persons in the unattractive group would present angry in lower intensity than persons in the attractive group.

This observation, to some extent, can also be interpreted by compensation hypothesis we proposed above, angry expression poses a negative impression in the most occasion of social interaction, thus, unattractive target persons tend to present the angry expression with the lower intensity to avoid the negative bias induced by unattractiveness being further strengthen, which can be considered as the conversed compensation based on benefiting selection.

On the other hand, we focus on the determinants of anger generation which describe the process of becoming angry, the previous studies (Roseman, 2004) suggest that a major determinant of anger generation is control potential which refer to human's ability to control the situation. If control potential were low, aggressive angry behaviors would likely be a futile waste of energy and could provoke disastrous retaliation from more powerful others. Because of attractiveness advantage in the social interaction, it is possible for attractive female persons to obtain the stronger controlling potential, thus leading that attractive persons tend to show stronger expression intensity. This could be another explanation for our observation.

So far we can not make a definite choice between two explanations. Actually, these two explanations are not absolutely competitive. It is possible that both of them can contribute to the observed difference of expressive habituation between unattractive persons and attractive persons. We expect more intensive evidences to emerge for understanding this difference of behavior pattern modulated by facial attractiveness in the future research.

5.6 Conclusion

To conclude, we have demonstrated the facial physical attractiveness can influence the smile expression perception but not the angry perception, which potentially indicating a perceptual distinction between positive and negative emotional affection with the reference to the facial physical attractiveness. In terms of this observation, we further show the different expressive habituation between unattractive persons and attractive persons, i.e., unattractive person appears to adopt the positive compensation strategy to balance negative bias induced by unattractiveness in the social communication. Our result provides the further insight for understanding the expression perception mechanism and expressive habituation modulated by facial physical attractiveness.

It should also be possible to adopt our paradigm to investigate the relationship between expression with other facial dimensions, by separating the expressive habituation and expression perception of stimuli, we may obtains the power to independent dissect the mutual-interacted facial dimensions.

Chapter 6

Conclusions and future inquiries

6.1 General conclusion

Human face is not only a common visual stimulus in everyday life but also an important message to recognize a personal identity and an emotional state in human social communication. Thus, it has been a long history for researchers in physiological, psychological and psychophysical fields to investigate the mechanism about how the brain recognizes the faces. In this dissertation, i firstly introduced the bruce functional model and haxby neural model for the face recognitions, these two models are the general framework for the current face-related studies. Then, we point out the following three issues in the face recognition studies, wich has not be covered by the two models and previous literatures. These three issues is important to obtain the better understanding the recognition strategy and function model for the Human Face recognition system

- The relationship between low-level visual system and high-level face system.
- The relationship between face identity recognition systen and expression recognition system.
- The influence from the facial physical attractiveness on the smile and angry expressions

In the Chapter 2, we introduced the physiological mechanism and the time scales about the visual adaptation, these two issues involves the fundamental knowledges for the experimental design in the chapter 3 and chapter 4.

The chapter 3 focuses on the relationship between the low-level visual system and a high-level face-responsive system using a visual adaptation experimental paradigm. This issue is crucial to understand a neural coding and transmission mechanism theoretically in different neural level. We performed two experiments to investigate the adaptation propagations along two neural routes are investigated, respectively. One is from color system to face identity system (Experiment 1) and the other is from figure recognition system to face identity system (Experiment 2). In the experiment 1, aftereffects were measured within the real face while adapted by one of a real face or a color chip. Difference in an aftereffect size was used to evaluate the gaining from the low-level color perception system to the face identity system. In the experiment 2, I examined whether the high-level figure adaptation can contribute to the identity system. I adapted subjects by one of a real face or a face profile without any inter facial components, and measured aftereffects in the real faces. Similarly, the aftereffect difference was to estimate the contribution between these two systems.

The experiment results revealed two major findings from the experiments:

- The adaptation to color and figure can contribute to the high-level facial identity aftereffect. I observed the significant aftereffect difference in the face adapting condition ($t_{44} = 7.01, p < 0.0001$), in the color chip adapting condition ($t_{44} = 3.155, p < 0.003$) and in the figure adapting condition ($t_{44} = 3.4, p < 0.001$). It indicates that adaptation effects can propagate from neural systems in the lower visual areas to a distributed face recognition system and from figure systems to the face recognition system.

- Although both of adaptations by isolated facial dimensions (skin color or facial profile figure) and by whole faces generate significant facial identity aftereffect, the aftereffect size of latter is much stronger than that of isolated facial dimensions. The aftereffect size on the face adapting condition was much stronger than that in the color chip adapting condition ($t_{44} = 7.477, p < 0.0001$) in the experiment 1 and the figure adapting condition in the experiment 2 ($t_{44} = 5.595, p < 0.0001$).

These findings implicitly supported the hypothesized holistic neural representation previously proposed in the previous literatures. In conditions of adaptations to the isolated facial dimensions such as color and figure, only the perception system directly related to these visual properties was adapted. Then, the adaptation contributions would be propagated to the high-level face neural representation system to produce aftereffects in the test stage. In contrast, when I used the whole face as the adapting stimuli, besides these isolated visual properties were adapted, the high-level holistic facial neural representation would also be adapted and thus produced the much stronger aftereffect.

The chapter 4 investigated the mutual influences between facial identity system and expression system. The relationship between identity system and expression system is a long term controversy. In order to reconcile this discrepancy, I systematically investigated this issue by inducing the facial identity and expression adaptation paradigm. I performed three experiments in this study.

In the first experiment, I examined whether identity invariance would influence the size of expression aftereffect. The expression aftereffect was measured in a congruent condition (adapting face and test face are same person) and in an incongruent condition (adapting face and test face are different person), respectively. The difference between these two conditions was used to evaluate the influence from the identity system on the expression system.

In the second experiment, I further examined the influence from the expression variance on the identity aftereffect. Faces of image persons in smiling, blank, and angry expressions were used in the experiment. I measured the aftereffect sizes in four different conditions. Also, the difference between every two conditions was used to evaluate the influence from the expression system on the identity system.

In the third experiment, in order to examine whether there is an identity independent expression aftereffect, it is the key issue to define the type of functional dependency between the expression system and the identity system. I repeated the incongruent condition in the experiment 1 by using the similar faces and WIKE faces (weakening identity while keeping expression cue) as the adapting stimuli. The observation that the similar face would generate the larger aftereffect than dissimilar face should oppose to the existence of the identity-independent neural representation, whereas the observation that similar persons would also generate the equal aftereffect should support the existence of the hypothesized identity-independent aftereffect. As far as WIKE faces are concerned, the observation that the WIKE face would generate much less aftereffect than normal face should oppose to the existence of the identity-independent neural representation. Conversely, if the WIKE face would generate approximately equal aftereffect as that of normal face, the existence of hypothesized identity-independent neural representation should be supported.

There are three major observations in this study.

- The identity variance significantly influences the expression aftereffect while expression variance does not significantly influence the identity aftereffect. Thus, it suggests that an asymmetric interference pattern on the high level aftereffect between the facial identity and the expression.

- The significant decrease for the expression aftereffect in the congruent condition can not simply be attributed to the expression configuration difference between adapting faces and test faces. Thus it confirms the hypothesized identity-expression aftereffect.
- The residual expression aftereffect in the incongruent adapting condition is not only modulated by the identity similarity between the adapting person and the test face, but also is reduced by the face stimuli with a recognizable expression but with a weaken identity. This fact provides no evidence for the existence of identity-independent expression aftereffect.

These findings potentially indicate the asymmetric relation between the neural representation of the facial identity system and the expression system. As far as biological status of the facial identity and the expression is concerned, identity might provide a reference with respect to the more transient changes such as expressions or nonverbal speech (Schweinberger1999). Therefore, the identity system seems to be more "primary" compared to the expression system. It is possible that the computation of expression recognition rests with the information conveyed by the facial identity system. Thus, it induces this one-way dependent relationship between the identity perception and the expression perception.

The chapter 5 investigated the influence from the facial attractiveness on the smile and angry expression. Previous studies show that smile expression can significantly enhance the perceived facial attractiveness. However, it is known little about how the facial physical attractiveness conversely influences expression dimension. We performed the two experiments to investigate this issue as following. In the first experiment, the expression intensity, the expression naturalness, and the facial attractiveness are rated on smile, blank and angry expressions of a total of 60 image target persons. Here, I did not explicitly control the physical configuration of the expression for target persons, although it would allow the perceived expression impression to be influenced by both the expressive habituations and the attractiveness bias.

In the second control experiment, 15 top attractive persons and 15 top unattractive persons were selected from the original target face set in the experiment 1 to construct a set of artificial expression stimuli, in which an identical physical expression configuration for each target person was obtained using an identical computer morphing template. Thus, if there would be still the significant difference of the impression strength between two groups, this difference can only be attributed to the perception of the expression receivers.

There are three major observations in this study.

- In the first experiment, with the stimuli of the uncontrolled expression configuration, the perceived expression intensity and the expression naturalness of the angry expression in the attractive group are much stronger than that in the unattractive group. However, this difference disappears with the stimuli of the smile expression.
- In the second experiment, with the stimuli of the controlled expression configuration, we found that the perceived expression intensity and the expression naturalness of the smile expression in the attractive group is significant stronger than those in the unattractive group, and that the perceived expression intensity and the expression naturalness of the angry expression in the attractive group is approximately identical to those in the unattractive group.

In terms of these two observations, i proposed one compensation hypothesis that the unattractive target persons tend to present the smile expression with a higher intensity or angry expression with a lower intensity to avoid the negative bias induced by the unattractiveness being further strengthened. It can be considered as one certain compensation strategy based on benefiting selection.

6.2 Future Inquiries

This dissertation focuses on the recognition strategy and function modeling for the human face-responsive neural system. However, there are several future inquiries that can be pursued to extend the current work. For example, we has found the influence from the low-level color and figure visual system on the high-level face system. In the future work, it should be interesting to investigate the generation of high-level face aftereffect, i.e. whether high-level face aftereffect is just a combination for adapting effect propagations from the low-level systems or it also involved the adaptation to the high-level face neural representation.

This dissertation examines the relationship between the identity recognition and expression recognition and proposed the hierarchical model. The future work also includes investigations on the relationship between other facial changeable parts such as facial speech, gaze perception and facial identity.

This dissertation investigated the influence from the attractiveness on the smile and angry expression and proposed the compensation hypothesis modulated by attractiveness in the social communication. In the future, we seek to understand the influence of the physical attractiveness on the other expressions such as the fear, disgust, surprise, which will help to clarify the different functional dependence of the expression perception on physical facial attractiveness. The final inquiry may be associated with the compensation hypothesis we proposed. Although it is encouraging to find the potential clue of this possible compensation mechanism in current study, it is important for future research to provide more extensive and intensive evidences to consolidate this hypothesis.

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References

Abbott, L. F., Varela, J. A., Sen, K., Nelson, S. B., 1997. Synaptic depression and cortical gain control. Science 275 (6), 220–224.

Afraz, S. R., Cavanagh, P., 2007. Retinotopy of the face aftereffec. Vision Research 48, 42–54.

Asch, S. E., Zukier, M., 1984. Thinking about persons. Journal of Personality and Social Psychology 46, 1230–1240.

Ashida, H., Osaka, N., 1995. Motion aftereffect with flickering test stimuli depends on adapting speed. Vision Research 35, 1825–1833.

Baudouin, J. Y., Martin, F., Tiberghien, G., Verlut, I., Frank, N., 2002. Selective attention to facial emotion and identity in schizophrenia. Neuropsychologia 40, 503–511.

Berscheid, E., Walster, E., 1974. Physical attractiveness, Advances in experimental social psychology. New York: Academic Press.

Blair, R. J. R., Morris, J. S., Frith, C. D., Perrett, D. I., Dolan, J. R., 1999. Dissociable neural responses to facial expressions of sadness and anger. Brain 122, 883–893.

Blake, R., Fox, R., 1974. Adaptation to invisible gratings and the site of binocular rivalry suppression. Nature 249, 488–490.

Blakemore, C., Sutton, P., 1969. Size adaptation: A new aftereffect. Science 166, 245–247.

Breiter, H. C., Etcoff, N., J., W. P., Kennedy, W. A., Rauch, S. L., Buckner, R. L., et al., 1996. Response and habituation of the human amygdala during visual processing of facial expression. Neuron 17, 875–887.

Bruce, V., 1986. Influences of familiarity on the processing of faces. Perception 15, 387–397.

Bruce, V., Young, A., 1986. Understanding face recognition. Br. J. Psychol 77, 305–327.

Bruyer, R., et al., 1983. A case of prosopagnosia with some preserved covert remembrance of of familiar faces. Brain Cognition 2, 257–284.

Buck, R., 1994. Social and emotional functions in facial expression and communication: The readout hypothesis. Biological Psychology 38, 95–115.

Calder, A. J., Young, A. W., 2005. Understanding the recognition of facial identity and facial expression. Nature Rev. Neuroscience 6 (8), 641–651.

Catherine, J., 2007. The composite face effect in six-year-old children: Evidence of adult-like holistic face processing. Visual Cognition 15, 564 – 577.

Chander, D., Chichilnisky, E. J., 2001. Adaptation to temporal contrast in primate and salamander retina. Journal of Neuroscience 21, 9904–9916.

Clifford, C., 2002. Perceptual adaptation: Motion parallels orientation. Trends in Cognitive Sciences 6, 136–143.

Clifford, C., Webster, M., Stanley, G. B., et al., 2007. Visual adaptation: Neural, psychological and computational aspects. Vision Research 47, 3125–3131.

Craik, K. J. W., 1938. The effect of adaptation on differential brightness discrimination. Journal of Phsiology 92, 406–421.

Dakin, S. C., Bex, P. J., 2002. Summation of concentric orientation structure: seeing the glass or the window? Vision Research 42, 2013–2020.

deCharms, R. C., Zador, A., 2000. Neural representation and the cortical code. Annual Review of Neuroscience 23, 614–647.

Dion, K. K., Berscheid, E., Walster, E., 1972. What is beautiful is what is good. Journal of Personality and Social Psychology 24, 285–290.

Dragoi, V., Sharma, J., M., S., 2000. Adaptation-induced plasticity of orientation tuning in adult visual cortex. Neuron 28, 287–298.

Efran, M., Patterson, E., 1974. Voters vote beautiful: the effect of physical appearance on a national debate. Canadian Journal of Behavior Science 6, 352–356.

Ellis, A., Young, A., Flude, B. M., 1990. Repetition priming and face processing: Priming occurs within the system that responds to the identity of a face. Quarterly Journal of Experimental Psychology: Human Experimental Psychology 42, 495–512.

Endo, N., Endo, M., Kirita, T., Maruyama, K., 1992. The effects of expression on face recognition. Tohoku Psychol. Folia 52, 37–44.

Engell, A. D., Haxby, J. V., 2007. Facial expression and gaze-direction in human superior temporal sulcus. Neuropsychologia 45 (14), 3234–3241.

Feleky, A. M., 1924. Feelings and emotions. New York: Pioneer.

Felleman, D. J., Van, E. D. C., 1991. Distributed hierarchical processing in the primate cerebral cortex. Cerebral Cortex 1, 1–47.

Fox, C. J., Barton, J. J., 2007. What is adapted in face adaptation? the neural representations of expression in the human visual system. Brain Research 1127 (1), 80–89.

Fox, C. J., Oruc, I., Barton, J. J., 2008. It doesn't matter how you feel. the facial identity aftereffect is invariant to changes in facial expression. Journal of Vision 8 (3), 1–13.

Freyd, J. J., 1983. Representing the dynamics of a static form. Memory Cognition 11, 342–346.

Frijda, N. H., Philipzoon, E., 1963. Dimensions of recognition of facial expression. Journal of Abnormal and Social Psychology 66, 45–51.

Ganel, T., Goshen-Gottstein, Y., 2004. Effects of familarity on the perceptual integrality of the identity and expression of faces: The parallel-route hypothesis revisited. Journal of Experimental psychology: Human perception and Performance 30 (3), 583–597.

George, N., Dolan, R. J., Fink, G. R., Baylis, G. C., Russell, C., Driver, J., 1999. Contrast polarity and face recognition in the human fusiform gyrus. Nature Neuroscience

2 (6), 574–580.

Georgopoulous, A., 1986. Neuronal polulation coding of movement direction. Science 233, 1416–1419.

Glass, L., 1969. Moiré effect from random dots. Nature 223, 578–580.

Gorno-Tempini, M. L., Pradelli, S., Serafini, M., Pagnoni, G., Baraldi, P., Porro, C., et al., 2001. Explicit and incidental facial expression processing: An fmri study. Neuroimage 14, 465–473.

Griffin, A. M., Langlois, J. H., 2006. Stereotype directionality and attractiveness stereotyping: Is beauty good or is ugly bad? Social Cognition 24 (2), 187C206.

Gross, C., 2002. Genealogy of the "grandmother cell. Neuroscientist 8, 512–518.

Hasselmo, M. E., Rolls, E. T., Baylis, G. C., 1989. The role of expression and identity in face-selective response of neurons in the temporal visual cortex of the monkey. Behav.Brain Res. 32, 203–218.

Haxby, J. e. a., 1999. The effect of face inversion on activity in human neural systems for face and object perception. Neuron 22, 189–199.

Haxby, J. V., Hoffman, E. A., Gobbini, M. I., 2000. The distributed human neural system for face perception. Trends Cogn. Sci. 4, 223–233.

He, S., MacLeod, D. I., 2001. Orientation-selective adaptation and tilt aftereffect from invisible patterns. Nature 411, 473–476.

Hershenson, M., 1989. Duration, time constant, and decay of the linear motion aftereffect as a function of inspection duration. Percept Psychophys 45, 251–257.

Hess, U., Blairy, S., Kleck, R. E., 1997. The intensity of emotional facial expressions and decoding accuracy. Journal of Nonverbal Behavior 21 (4), 241–257.

Hoffman, E. A., Haxby, J. V., 2000. Distinct representations of eye gaze and identity in the distributed human neural system for face perception. Nature Neuroscience 3, 80–84.

Hsu, S. M., Young, A. W., 2004. Adaptation effects in facial expression recognition. Visual Cognition 11, 871–899.

Humphreys, G., Donnelly, N., Riddoch, M. J., 1993. Expression is computed separately from facial identity, and it is computed separately for moving and static faces: Neuropsychological evidence. Neuropsychologia 31, 173–181.

Jakobs, E., Manstead, A. S., Fischer, A. H., 2001. Social context effects on facial activity in a negative emotional setting. Emotion 1 (1), 51–69.

Johnston, R. A., Kanazawa, M., Kato, T., Oda, M., 1997. Exploring the Structure of Multidimensional Face-space: The Effects of Age and Gender. Vol. 4.

Kanwisher, N., McDermott, J., Chun, M., 1997. The fusiform face area: a module in human extrastriate cortex specialized for face perception. The Journal of Neuroscience 17, 4302–4311.

Knappmeyer, B., Thornton, I. M., Etcoff, N., Bülthoff, H. H., 2002. Facial motion and the perception of facial attractiveness. In: Second Annual Meeting of the Vision Science Society. Sarasota, Florida.

Kohn, A., 2007. Visual adaptation: Physiology, mechanisms, and functional benefits. Journal of Neurophysiology 97, 3155–3164.

Kohn, A., Movshon, J. A., 2003. Neuronal adaptation to visual motion in area mt of the macaque. Neuron 39, 681–691.

Krekelberg, B., Boynton, G. M., Wezel, R. J. V., 2006. Adaptation: from single cells to bold signals. Trends in Neuroscience 29, 250–256.

L., J., Rhodes, G., Busey, T., 2006. View-specific coding of face shape. Psychological Science 17 (6), 501–505.

Langlois, J. H., Roggman, L. A., 1990. Attractive faces are only average. Psychological Science 1 (2), 115–121.

Larrance, D. T., Zuckerman, M., 1981. Facial attractiveness and vocal likeability as determinants of nonverbal sending skills. Journal of Personality 49 (4), 349–362.

Lehmkuhle, S. W., Fox, R., 2004. Effects of binocular rivalry suppression on the motion aftereffect. Vision Research 15, 855–859.

Leopold, D. A., Gillian, R., Kai-markus, M., Linda, J., 2005. The dynamics of visual adaptation to faces. Proceedings of the royal society 272, 897–904.

Leopold, D. A., O'Toole, A. J., Vetter, T., Blanz, V., 2001. Prototype-referenced shape encoding revealed by high-level aftereffects. Nature Neuroscience 4, 89–94.

Levinson, E., Sekuler, R., 1976. Adaptation alters perceived direction of motion. Vision Research 16, 779–781.

Livingstone, M. S., Hubel, D. H., 1988. Segregation of form, color, movement and depth: anatomy, physiology and perception. Science 240, 740–749.

Lucker, G. W., Beane, W. E., Helmreich, R. L., 1981. The strength of the halo effect in physical attractiveness research. Journal of Psychology 107 (1), 69–75.

Magnussen, S., Johnsen, T., 1986. Temporal aspects of spatial adaptation. a study of the tilt aftereffect. Vision Research 26, 661–672.

Martinez, A. M., Benavente, R., 1998. The ar face database. CVC Technical Report 24.

McCarthy, G., Puce, A., Gore, J. C., Allison, T., 1997. Face-specific processing in the human fusiform gyrus. Journal of Cognitive Neuroscience 9 (5), 605–610.

Mehu, M., Little, A. C., Dunbar, R. I. M., 2008. Sex differences in the effect of smiling on social judgments: an evolutionary approach. Journal of Social, Evolutionary, and Cultural Psychology 2 (3), 103–121.

Michael, J., 2005. Positive and negative reinforcement, a distinction that is no longer necessary; or a better way to talk about bad things. Journal of Orgnizational Behavior Management 24, 207–222.

Miller, A. G., 1970. Role of physical attractiveness in impression formation. Psychonomic Science 19, 241–243.

Moradi, F., Koch, C., Shimojo, S., 2005. Face adaptation depends on seeing the face. Neuron 45 (1), 169–175.

Morris, J. S., Frith, C. D., Perrett, D. I., Rowland, D., Young, A. W., Calder, A. J., et al., 1996. A differential neural response in the human amygdala to fearful and happy facial expressions. Nature 383, 812–815.

Morrison, E., Gralewski, L., Campbell, N., Penton-Voak, I. S., 2007. Facial movement varies by sex and is related to attractiveness. Evolution and Human Behavior 28 (3), 186–192.

O'Doherty, J., Winston, J., Critley, H., Perett, D., Burt, D. M., Dolan, R. J., 2003. Beauty in a smile: the role of medial orbitofrontal cortex in facial attractiveness. Neuropsychologia 41 (2), 147–155.

Ohla, K., Busch, N. A., Dahlemc, M. A., Herrmannb, C. S., 2005. Circles are different: The perception of glass patterns modulates early event-related potentials. Vision Research 54 (20), 2668–2676.

Phillips, M. L., Young, A. W., Senior, C., Brammer, M., Andrew, C., Calder, A. J., et al., 1997. A specific neutral substrate for perceiving facial expressions of disgust. Nature 389, 495–498.

Puce, A., Allison, T., B. S., Gore, J. C., McCarthy, G., 1998. Temporal cortex activation in humans viewing eye and mouth movements. The Journal of Neuroscience 18 (6), 2188–2199.

Rajimehr, R., 2004a. Unconscious orientation processing. Neuron 41, 663–673.

Rajimehr, R., 2004b. Unconscious orientation processing. Neuron 41, 663–673.

Rhodes, G., Jeffery, L., Watson, T. L., Clifford, C. W. G., Nakayama, K., 2003. Fitting the mind to the world: face adaptation and attractiveness aftereffects. Psychological Science 14 (6), 558–556.

Rose, D., 1996. Some reflections on (or by?) grandmother cells. Perception 25, 881–886.

Roseman, I. J., 2004. Appraisal, rather than unpleasantness or muscle movements, are the primary determinants of specific emotions. Emotion 4 (2), 145–150.

Rossion, B., chiltz, C., Robaye, L., Pirenne, D., Crommelinck, M., 2004. How does the brain discriminate familiar and unfamiliar faces? a pet study of face categorical perception. Journal of Cognitive Neuroscience 13, 1019–1034.

Rozin, P., Royzman, B. E., 2001. Negativity bias, negativity dominance, and contagion. Personality and Social Psychology Review 5 (4), 296–320.

Sabatelli, R. M., Bubin, M., 1986. Nonverbal expressiveness and physical attractiveness as mediators of interpersonal perceptions. Journal of nonverbal behavior 10 (2), 120–133.

Sato, W., Yoshikawa, S., 2008. Dynamic facial expressions of emotion induce representational momentum. Cognitive, Affective, Behavioral Neuroscience 8, 25–31.

Schlosberg, H., 1952. The description of facial expressions in terms of two dimensions. Journal of Experimental Psychology 44, 229–237.

Schweinberger, S. R., Burton, A. M., Kelly, S. W., 1999. Asymmetric dependencies in perceiving identity and emotion: experiments with morphed faces. Perception and Psychophysics 61, 1102–1115.

Schweinberger, S. R., Soukup, G. R., 1998. Asymmetric relationships among perceptions of facial identity, emotion, and facial speech. Journal of Experimental Psychology: Human Perception and Performance 24 (6), 1748–1765.

Sergent, J., Ohta, S., Macdonald, B., 1992. Functional neuroanatomy of face and object processing. Brain 115 (1), 15–36.

Sharp, P. E., 2002. The neural basis of navigation: Evidence from single cell recording. Kluwer Academic Publishers, Norwell, Massachusetts.

Sprengelmeyer, R., Rausch, M., Eysel, U. T., Przuntek, H., 1998. Neural structures associated with recognition of facial expressions of basic emotions. Proc. R. Soc.

Lond. B Biol. Sci. 265, 1927–1931.

Sugase, Y., Yamane, S. Y., Ueno, S., Kawano, K., 1999. Global and fine information coded by single neurons in the temporal visual cortex. Nature 400, 869–873.

Suzuki, S., 2001. Attention-dependent brief adaptation to contour orientation: a high level aftereffect for convexity. Vision Research 41, 3883–3902.

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

Tanaka, J. W., Sengco, J. A., 1997. Features and their configuration in face recognition. Memory and Cognition 25, 583–592.

Thorndike, E. L., 1920. A consistent error in psychological rating. Journal of Applied Psychology 4 (1), 25–29.

Thornhill, R., Furlow, F. B., 1998. Stress and human reproductive behavior: Attractiveness, womens sexual development, post-partum depression, and babys cry. Advances in the Study of Behavior. New York: Academic Press.

Ungerleider, L. G., Haxby, J. V., 1994. 'what'and 'where'in the human brain. Current Opinion in Neurobiology 4, 157–165.

Wade, T. J., Loyden, J., Renninger, L., Tobey, L., 2003. Weight halo effects: individual differences in personality evaluations as a function of weight? Personality an Individual Differences 34 (2), 263–268.

Watkins, L. M., Johnston, L., 2000. Screening job applicants: The impact of physical attractiveness and application quality. International Journal of Selection and Assessment 8, 76–84.

Webster, M., Kaping, D., Mizokami, Y., Duhamel, P., 2004. Adaptation to natural facial categories. Nature 428 (6982), 557–561.

Wilson, J. A., Switkes, E., Valois, R. L. D., 2004. Glass pattern studies of local and global processing of contrast variations. Vision Research 44, 2629–2641.

Winston, J. S., Henson, R. N. A., Fine-Goulden, M. R., Dolan, R. J., 2004. Fmri adaptation reveals dissociable neural representations of identity and expression in face perception. Journal of Neurophysiology 92, 1830–1839.

Wright, C. I., Fischer, H., Whalen, P. J., McInerney, S. C., Shin, L. M., Rauch, S. L., 2001. Differential prefrontal cortex and amygdala habituation to repeatedly presented emotional stimuli. Neuroreport 12, 379–383.

Xu, H., Dayan, P., Lipkin, R. M., Qian, N., 2008. Adaptation across the cortical hierarchy: Low-level curve adaptation affects high-level facial-expressions. The Journal of neuroscience 28 (13), 3374–3383.

Yamashita, J. A., Hardy, J. L., Webster, M. A., 2005. Stimulus selectivity of figural aftereffects for faces. Journal of experimental psychology 31 (3), 420–437.

Young, A. W., Hellawell, D., Hay, D. C., 1987. Configurational information in face perception. Trends in Cognitive Science 16, 747–759.

Young, A. W., McWeeny, K. H., Hay, D. C., Ellis, A. W., 1986. Matching familiar and unfamiliar faces on identity and expression. Psychology Research 48, 63–68.

Young, A. W., Newcombe, F., de Haan, E. H. F., Small, M., Hay, D. C., 1993. Face perception after brain injury: selective impairments affecting identity and expression. Brain 116, 941–959.

young, M., 1992. Sparse population coding of faces in the infertemporal cortex. Science 256, 1327–1331.

Zhao, L., Chubb, C., 2001. The size-tuning of the face-distortion aftereffect. Vision Research 41 (23), 2979–2994.