Master Thesis

The effect of spatial frequency on faster detection of emotional expressions in visual search

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Thesis, 27.5 ECTS

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August 22, 2022

Abstract

Facial expressions are adaptive social and communicative tools. In some early investigations of expression detection, both anger superiority effect and happiness superiority effect were reported. Several attempts were made to resolve the contradictory reports of emotion superiority effects in visual search and a well-supported explanation is that preferential detection of emotion can be attributed to simple visual features of faces. The current research focused on the spatial frequency (SF) of facial expressions to test if the reported inconsistencies are related to SF differences between the expressions. To do so, emotional faces were manipulated at the level of SF content by replacing original Fourier magnitude spectrum and four kinds of faces containing new SF information were created as stimuli. An online visual search task was conducted to examine preferential emotion detection. The results revealed the anger superiority effect for faces containing only main SF features that separate emotional expressions, faces with average magnitude spectra per expression category, or faces with 1/f noise frequency. However, ASE did not reveal when main SF features that separate emotional expressions were removed from faces. Such findings suggest that SF content can produce the emotion superiority effect when it can provide emotion-related important information in the detection of emotion.

Keywords: Emotional expressions, emotion detection, visual search, anger superiority effect, spatial frequency

Introduction

Humans convey information through emotions in the process of interpersonal communication. In fact, facial expressions display many important visual signals, such as the indication of emotional state and interpersonal intent (Darwin, 1896), which in fact provides survival value in the interaction between human and their immediate environment. This survival value plays an important role in helping humans appraise environmental information and infer interpersonal behaviors so as to make effective adaption (Knutson, 1996; Erickson & Schulkin, 2003; Fox, 2002). Due to the significance of emotions in the evolutionary perspective, humans have developed a selective attention mechanism that enables fast detection of expressions (Eimer & Holmes, 2007; Palermo & Rhodes, 2007), while the amount of attention towards expressions is dissimilar for different emotions.

The study of universals in emotional expression has proposed a canon of six basic emotions with a specific facial prototype expression: anger, happiness, fear, disgust, surprise and sadness, which was met with the general consensus through a range of supportive evidence among various research (Ekman, 1972; Ekman, 1993; Ekman & Friesen, 1986; Dalgleish & Power, 2000). Early research that explored the survival value of emotional communication and interpretation studied the effect of angry facial expressions on the allocation of attention. The results showed the anger superiority effect (ASE), also known as “the face in the crowd effect”. It states that anger faces are detected faster than happy faces in a crowd of neutral ones (Hansen & Hansen, 1988). This effect is supported by a large number of subsequent studies reporting similar results for both schematic and real faces (e.g., Fox & Damjanovic, 2006; Frischen, Eastwood, & Smilek, 2008; Pinkham et al., 2010; Ceccarini & Caudek, 2013). According to Öhman and others (e.g., Öhman, Lundqvist, & Esteves, 2001; Fox et al., 2000; Horstmann & Bauland, 2006), the idea of threat-advantage was a convincing explanation for the anger advantage in visual search. Specifically, the threat-advantage hypothesis argued humans favorably oriented their attention toward threats and threatening angry faces grab more attention than neutral or other emotional expressions. As compelling support of this theory, threat-related attentional bias has been demonstrated repeatedly in neurophysiological findings and studies of clinical anxiety (Fox, Russo, Bowles, & Dutton, 2001; Fox, 2002; Armony & Dolan, 2002; Morris, Friston, et al., 1998).

Quite some other research, however, has reported an apparently opposite finding: happy facial expressions other than angry faces are easier to "pop out" from crowds (e.g., Becker et al., 2011; Juth et al., 2005; Pool et al., 2016; Calvo and Nummenmaa, 2008). That is, a happiness superiority effect (HSE) was shown to be as robust as anger superiority effect. It might be attributed to happiness expressions showing a more visible sign of communication that makes it more visually distinguishable in the process of evolution (Becker et al., 2011). Moreover, happy facial expressions were thought to be strong positive feedback responding to alliances and collaborations which attract more automatic attention orienting (Calvo & Nummenmaa, 2008).

It is thus clear that some expressions are detected faster and more accurately than others, however, current results of the search advantage of emotional faces are, as noted above, also inconsistent across studies. Given such inconsistent reports, a comprehensive review of previous studies undertaken by Frischen et.el (2008). They examined the methodological considerations of visual search tasks, showing that set size, distractor background and top-down search strategies significantly influenced the search performance. For instance, the number of face stimulus models could probably account for the disparities regarding the superior superiority of angry versus happy faces. By comparison of experiments with large model samples (28 and 60 models) (Juth et al. 2005; Calvo & Nummenmaa, 2008) and small model samples (Hansen & Hansen, 1988; Purcell et al., 1996; Fox & Damjanovic, 2006; Horstmann & Bauland, 2006), the result implied that ASE might be restricted to small selective subsets of facial stimuli. A possible explanation is that the high variability in the ways of expressing anger (e.g. frowning, visible teeth, closed lips, see Kohler et al., 2004) increases the difficulty of recognizing them accurately in contrast with happy faces which are generally characterized by a distinct feature like a smile (Calvo & Nummenmaa, 2008). According to this explanation, only a limited set of angry model samples adds to the uniformity of the angry expressions so that ASE has been found. In a word, set size, distractor background and top-down search strategies must be controlled to make sound assessments with regard to detection of emotional expressions in the search process. Other researchers examined limitations related to the stimuli used in previous studies. One of limitations was concerned with visual saliency of different stimuli. Search efficiency for various emotional expressions could be largely determined by visual saliency of emotional faces. Supporting evidence has shown that visual saliency influences initial attention orienting to scenes and pictures (e.g., Torralb et el., 2006; Parkhurst et al., 2002; Underwood et.el, 2006; Navalpakkam & Itti, 2005). On this account, happy faces with a higher visual saliency compared with other emotional faces are more likely to get attention orienting which contributes to shortening the detection time, hence HSE (Calvo & Nummenmaa, 2008; Calvo & Nummenmaa, 2011). On top of that, Becker et al (2011) reviewed the literature on the ASE and pointed out that the results were cofounded with low-level visual features, such as lines and colors, in consideration of the majority of existing research using schematic line drawings of expressions for stimuli. Although schematic faces were supposed to control perceptual variance and avoid potential confounds such as individual variability, the prominent visual features of schematic stimuli in fact introduce additional confounds (i.e. low-level visual features). Therefore, according to the conclusion of Becker et al, low-level perceptual features drove superior detection effect other than content of the expression.

The possible explanations of contradictory findings on superior detection described above indicate that simple visual features of emotional faces might ultimately be responsible for the detection advantages for certain emotional expressions. This conclusion is in line with findings from other research displaying the connection between facial components and emotion superiority effects. In Horstmann and his colleagues' study (Horstmann, Lipp & Becker, 2012), the emotional target of the most effective search depended on the visibility of teeth. Specifically, as long as the mouth was open and the teeth were visible, a superiority effect appeared no matter what the expression was. Calvo and Nummenmaa (2011) also found that the higher salient of the mouth region in happy face in comparison with non-happy distracters, the faster detection was. Likewise, the critical function of the eye region in promoting identification was also confirmed in ASE (Fox & Damjanovic, 2006; Nothdurft, 1993; Peters et al., 2005; Horstmann & Bauland, 2006).

So far, the contribution of different facial regions to visual search of emotional faces is encouraging an assumption that human emotion detection probably relies merely on the perceptual analysis of visual features. Aimed at this point, inversion face effect (Yin, 1969) and composite face task (Young, Hellawell, & Hay, 1987) have been used to interfere processing of emotion detection to verify this perspective. There is an amount of evidence in the facial expression recognition literature showing that faster detection of a certain emotional expression was not removed when faces were reverted (Horstmann & Bauland, 2006; Lipp, 2009; Öhman et el., 2001), which proves that facial expression is identified based on emotion-related visual features because inversion is assumed to disrupt holistic expression of emotion. However, Fox and Damjanovic (2006) and Fox et al. (2000) reported the disappearance of ASE due to inverted faces. The composite task (Calder et el., 2000) undermined the recognition of facial expressions as well. In order to clarify these contradictory results, Savage and Lipp (2015) designed a series of visual search tasks following the recommendations by Becker et al. (2011) to investigate the effect of face orientation on superior detection of emotions. On review of inconsistencies in experimental procedures of previous studies, Savage and Lipp varied array sizes, presentation times and trial types used in the experiments and the results across all experiments revealed that both anger and happiness superiority effects in the upright and inverted faces utilizing varied methods and stimuli. All these findings suggest that purely perceptual grounds on the basis of emotion-related features of face is more likely to play a crucial role in detection of emotional expressions in visual search.

After the intensive inspection of literature regarding detection advantages of emotional expressions in visual search, it is able to conclude that characteristic components of facial expressions may account for the inconsistently reported emotion superiority effect as a result of feature-based processing of facial expressions. The studies presented thus far demonstrated that the facial region and visual saliency of facial features contribute significantly to expression identification (see Calvo & Nummenmaa, 2008 & 2011; Calvo et el., 2013; Horstmann, Lipp & Becker, 2012; Fox & Damjanovic, 2006; Horstmann & Bauland, 2006). However, the relation between emotional-related features and superiority effect varied in different experiments. For example, Fox et el. (2002) and Öhman et al. (2001) pinpointed that eyebrows in schematic faces could effectively drive the superior detection of angry faces, while happy faces with eyebrows were detected faster than angry faces with eyebrows in a visual task using real faces (Becker et al., 2011). More importantly, we are still not sure what low-level feature information is critical for expression detection, and how perceptual mechanisms contribute to expression processing. To address these issues, the field of computer vision provides a more specific and underlying perspective based on spatial frequency.

Spatial frequency (SF), as one of the low-level features, represents various periodic luminance variations across space, which plays an important role in image identification. Hou and Zhang (2007) made use of a computational modeling method to detect visual saliency of images through a spectral residual approach. Similarly, Achanta et el. (2009) developed a method for salient region detection that mainly operates using low-frequency content in the image. Overall, SF information in images has been shown to be critical for face perception, as well as for emotion perception (Goffau & Rossion, 2006; Mermillod, 2009; Kumar & Srinivasan, 2011), while different SF channels have different influences. There is now substantial evidence to suggest that subcortical pathways (including the amygdala, pulvinar, and superior colliculus), thought to be associated with the processing of emotional faces, are critically sensitive to coarse visual information extracted from low SF (LSF) (Vuilleumier et al., 2003; LeDoux, 2012; Tamietto & Gelder, 2010). In other words, LSF content triggers the recognition of threat-relevant or fearful faces. By contrast, high SF (HSF) provides more effective information for the analysis of face local details (Vuilleumier et al., 2003; Goffaux & Rossion, 2006). Stuit et al. (2021) revealed the predictive value of SF and Histograms of Oriented Gradients (HOG) features for initial eye movement between two expressions in a data-driven manner by decoding the low-level image features of emotional expressions. It was shown that SF as a low-level feature other than the emotional content served as a better indicator for understanding how perceptual process affects facial expression detection. Given the striking sensitivity of SF, there is reason to believe that manipulating on SF content of facial images gives us a proper approach to influencing participants' perceptual analysis of stimuli properties of expressions.

This current study aims to examine if the ASE can be attributed to emotion-related features by manipulating SF content of facial images in the visual search paradigm. Savage and Lipp (2015) examined inconsistent experimental procedures in the prior visual search tasks and thus designed a train of modified experiments. It is reasonable to follow one of their visual search tasks in the current study. If the ASE or HSE comes and goes depending on the controlled SF content in the experiment, it shows that SF underlies emotional face processing. On the one hand, it gives another compelling evidence that the pattern of preferential detection of emotional expression in visual search relies on low-level perceptual features of emotional faces. On the other hand, it is of service to elucidate inconsistently reported discrepancies in the emotional superiority effect.

Method

Participants

A total of 41 (23 females, M = 24.29 years, SD = 1.63 years) participants participated in this study, 9 of whom (6 males, M = 24.33 years, SD = 1.22 years) were part of the a pilot version of the experiment. All participants are undergraduate students from universities who were invited online via social media. All participants provided informed consent before taking to doing the experiment. In addition, all participants had indicated normal or corrected to normal vision, no history of visually triggered epilepsy and no color blindness.

Apparatus

The experiment was designed by the Gorilla Experiment Builder and ran online. Participants performed the experiment on their own PC and responded using the left and right shift keys of the computer keyboard. All stimuli and text were presented during the experiment. The full experiment took around 20 minutes to complete. There was no specific requirement for operating system and performance of PC or environment other than that participants were asked to find a quiet place to do the task and muted all sounds of electronics during the experiment to avoid distraction.

Stimuli

The stimuli for this experiment consisted of 17 photographs of facial expressions of male Caucasian faces with a frontal gaze from the NimStim database (Tottenham et al., 2009). The images were divided into two separate image-sets for the practice and formal trials, each including 9 neutral, 8 happy and 8 angry faces. For the practice, posers 21, 23, 26, 27, 28, 29, 31, 33 in poses CA, AN_O and HA_O and poser 35 in only pose CA were chosen, the same as those in Savage's experiment (2015). While posers 20, 22, 24, 25, 30, 32, 34, 37 in poses CA, AN_O and HA_O and poser 21 in pose CA were used for formal trials. All images were presented in greyscale.

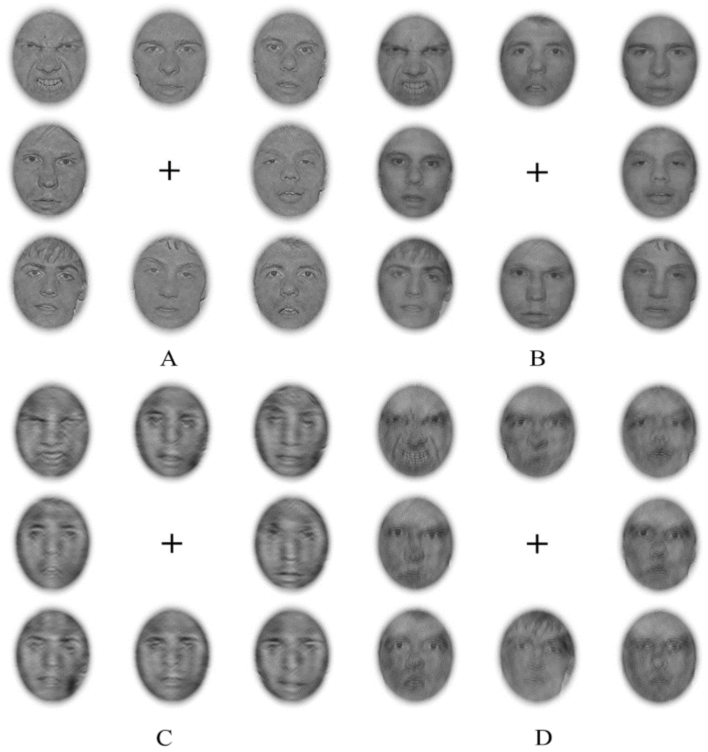
The spatial frequency content of image was manipulated in one of four methods described below. In order to manipulate the spatial frequency content, all happy, angry and calm expressions of the NimStim face set, including the specific male faces note above, were first used by the Protosc toolbox (Stuit et al., 2020) to train models for decoding expressions. Protosc is an open-source, MATLAB-based toolbox that runs an analysis to extract the relevant features of a group of images in various feature spaces by which the categories the images belong to can be objectively and quantitatively defined. First, Protosc detected the face area using Viola-Jones object detection framework (Viola & Jones, 2001) and a 35% increase to the surrounding face area was added to the face images as defined by the face detection algorithm. Next, all images were converted to grayscale and resized to 240 by 240 pixels. A mask was then created to limit face to an oval aperture with smooth edge while leaving irrelevant background unedited in the process of making adjustments. For the mask, all areas of the face in the vertical direction were intact but only 75% portion of facial area in the horizontal direction were preserved. Next, Protosc toolbox was used to convert all facial information of the images into Fourier magnitude spectrum via fast Fourier transform. Phase feature was ignored because magnitude information was enough to decode the emotional content. After decoding Fourier magnitude features of images, top 50% of the features based on the estimated feature weight assigned by Protosc were selected and output as a reference map in which significantly relevant features and non-relevant features were included altogether. Manipulation models were then created after all preparations. Note that all manipulation models built on the whole image set of poses HA, AN and CA obtained from NimStim database, instead of images of required posers.

The object of all manipulations was Fourier magnitude spectrum. For the first two manipulations, the purpose was to remove SF differences in the face domain. Therefor, 1/f noise was chosen for the first manipulation. 1/f noise is a frequency spectrum for which the noise power is inversely proportional to the frequency (Ward & Greenwood, 2007). Within the 1/f condition, SF difference are absent and cannot affect emotion detection. Therefore, replacing the original magnitude spectra of each image with 1/f is able to remove any SF difference of all images. To do this, the Fourier magnitude spectrum of images were inverted. The second manipulation was to replace original magnitude spectrum of images per category with average spectra of overall images belonging to the same emotion. By means of this, individual SF differences among all same facial expressions were eliminated. The mean spectrum of each expression was calculated respectively in advance.

As to the last two manipulations, the difference between them was the presence of relevant features associated with emotional expressions found via Protosc. By means of keeping or removing relevant features, we can compare the detection performance of participants between the presence and absence of relevant features so as to verify that participants primarily use emotional-related SF features to discriminate different expressions. In these manipulations, SF differences were also removed by using overall average magnitude spectra of each expression instead of original magnitude spectra. To retain the main features only, the relevant features in the reference map were selected and replaced with individual average spectra. In a like manner, the non-relevant features in the reference map were selected and replaced with individual average spectra for the reconstruction of faces without main features.

Finally, all faces were reconstructed using their individual their phases. Figure 1 presents examples of four manipulation.

Fig 1. Image examples of four manipulation



(A) Image replacing amplitude spectra with 1/f noise.

(B) Image replacing amplitude spectra with average amplitude spectra of overall images belonging to its category.

(C) Images with only significantly relevant features found by Protosc preserved.

(D) Images with only significantly relevant features found by Protosc removed.

Procedure

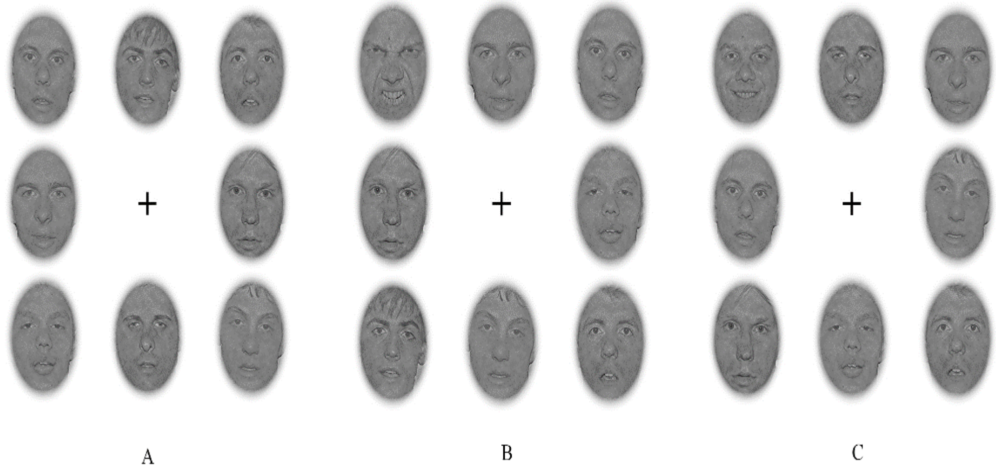
The procedure of the current experiment was based on the visual search task paradigm in experiment one from Savage and Lipp (2015). Instruction concerning the procedure of the experiment were displayed onscreen prior to the experiment. Before the experiment started, participants were required to calibrate the size of stimuli in visual angle. Throughout the experiment, participants were asked to determine whether all the faces presented expressed the same emotions or if there was any different expression among. Responses were collected via the left and right arrow keys of the computer keyboard. The right arrow key was labeled as “different;” and the left arrow key was labeled as “same”. Reminders were given at the bottom of each screen to tell participants how to operate.

The experiment consisted of four blocks using an array of nine faces, one block for each manipulation condition. Each block comprised 16 practice trials, 32 target-present trials and 32 target-absent trials. Practice trials were always presented first and there was a break both before and after practice until participants chose to continue. Target trials consisted of one target emotional face (angry or happy) presented among other 7 neutral faces from different posers. Non-target trials correspondingly were 8 neutral faces. All faces were presented on the screen in a 3 × 3 grid on a white background and each grid position was filled by a face except for the central position. The central position was occupied by a black cross. The 32 target trials in each block included 8 trials for each target emotion (happy and angry) at a specific position of the array, which was matched with 32 non-target trials for the same block. Furthermore, the intertrial interval was 500 milliseconds two, during which the black fixation cross in the middle of the screen was presented all the time. Figure 2 shows the search arrays of target trials and non-target trials used in the experiment.

A pilot was conducted before the formal experiment. There were two differences between pilot and main experiment. In the pilot, the same posers were used in both the practice and experiment trials and the number of practice trials was 10 per manipulation condition compared to 16 per manipulation condition of actual experiment. It might introduce practice effect and the target trials and non-target trials were not balanced. Another difference was that the stimuli were presented for a maximum of 3000 milliseconds or until the participant made a response. A few participants reported that the time limit was too strict to make any response. Based on these issues, the formal experiment changed the procedure design in these two places: the time limit of each trial was removed and practice trials selected different posers from formal trials.

In order to control the posers and positions of faces and the length of the experiment, four versions of visual research task were devised, one of which was randomly assigned to each participant in the experiment. Each version has four blocks and 64 trials per block. The only difference among four versions was the combination of posers and the positions of their faces in the array. For each poser to appear once in any position in the gird, there were 64 combinations of each expression. Every combination of both happiness expression and angry expression was presented two times across all versions for the same condition, while each combination of neutral expressions was presented four times. Moreover, for 16 trials of each emotion condition, the same poser was displayed twice but the positions of two occurrences of his face were only at opposite ends of the diagonal or bisector of the 3×3 grid. That is, the trial orders were balanced so that every poser appeared two times in the same position of search array for target trials per condition across all four versions and no combination was repeated within one version. The selection of all combinations for each block was set up in advance but presented in a pseudo-random sequence. For each of four conditions, the pseudo-random sequences of combinations were identical. The practice trials were balanced in a like manner.

Fig 2. 3 × 3 face grid used in the experimetn



(A) 3 × 3 grid of non-target trial, all 9 positions were occupied by neutral faces

(B) 3 × 3 grid of target trial, one angry face among 7 neutral distractor, angry face appeared at random postion

(C) 3 × 3 grid of target trial, one happy face among 7 neutral distractor, happy face appeared at random postion

Results

Preprocessing

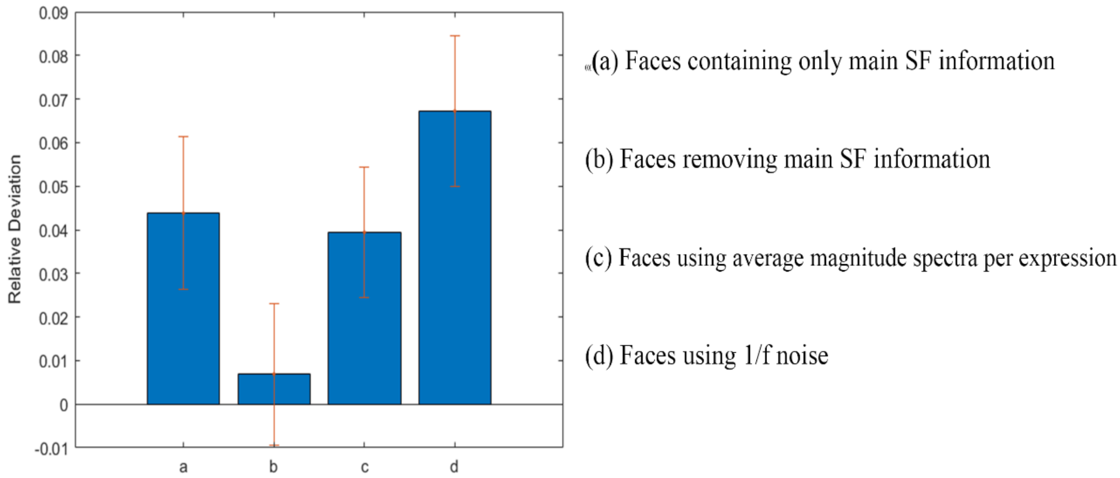
Incorrect responses, response times less than 100 milliseconds and response times of more than 3000 milliseconds were defined as errors. All data classified as errors were removed in the process of analysis. Participants with less than 60% correct were excluded as well.

The medians other than means of response times were used to do the statistic test on account of failed normality test. Subsequent analysis of difference in response time between four conditions was performed using non-parametric Friedman test. To test the significance of the emotion superiority effect which might emerge in each condition, Wilcoxon signed-rank test was conducted to provide an exhaustive analysis.

Formal experiment

Valid data from a total of 30 subjects were extracted and engaged in the analysis for the formal experiment after exclusion of two subjects whose correct response rate was below 60%. Figure 3 below shows the mean of the relative deviation in response time between detection of happy target and angry target for each condition. As shown in the figure, the relative deviation of faces containing only main SF information is around 0.0438, the relative deviation of faces removing main SF information is around 0.0069, the relative deviation of faces using average spectra per category is around 0.0394 and the relative deviation of faces using 1/f noise is around 0.0672. The results of Friedman test suggest that the difference in relative deviation of response time was small, not statistically significant, $\chi 2$ (3, N = 120) = 5.48, p = .1398. In addition, the results of Wilcoxon signed-rank test on the emotion superiority effect of each manipulation condition are displayed in the Figure 4 as well. Except for the faces removing main SF information (p $\approx$ 0.9754), the ASE was statistically significant for the other three conditions: p value of faces containing only main SF information is around 0.0218, p value of faces using average spectra per category is around 0.0124 and p value of faces using 1/f noise is around 0.00017.

Fig 3. Summary of means of the relative deviation between target detection time for happy target and angry target per condition. Error bars represent standard errors.



Discussion

The purpose of the current study was to investigate if preferential detection of emotional expressions in visual search is related to the spatial frequency (SF) content of the images. By seeking the relevance of SF to emotion superiority effect, we can gives some evidence for anger superiority effect (ASE) or happiness superiority effect (HSE), or both depending on the low-level visual features of expression target. It contributes to understanding the inconsistent results regarding superior detection of emotional faces in the past decades.

In the experiment, the author examined the emotion superiority effect under four different SF content. The results show that except for the faces removing main SF information, ASE was significantly revealed for other three conditions. Additionally, the results indicate that there is no significant difference in the performance of visual search task between manipulation conditions. That is, none of the manipulations of SF content contributes to facial expression detection in a significantly different way among all four manipulation conditions. In total, faster detection of angry expressions than happy expressions was consistently found when expressions containing only main SF information, or using average magnitude spectra per category or 1/f noise, while it did not appear in the condition of expressions removing main SF information.

It makes sense that faces containing only main SF information brought forth evident ASE in the experiment. The main SF information were Fourier magnitude features selected by the Protosc feature selection procedure that were highly relevant to facial expression. They are thought to be shortcuts for quick detection of emotion. According to the result, the presence of main SF features revealed the fast detection of angry faces, which exactly supports the critical role of these SF features in the detection of facial expressions. Correspondently, the absence of main features disrupted the fast detection of angry faces. However, it is contradictory that ASE was not gone in the case of using faces with 1/f noise since 1/f noise removed all SF differences between relevant SF features and non-relevant SF features from each face. In theory, if ome specific SF content plays a critical role in the precise detection of expressions, then the due detection effect is supposed to consistently disappear when differences between SF content are missing. With regard to inconsistent results against this assumption, one possible explanation is that the processing of SF information in visual perception may adhere to a diagnostic recognition framework (Ruiz-Soler & Beltran, 2006). The diagnostic recognition framework proposed that the role of SF in face perception varies depending on the interaction between the demands of the task and the information in the image. When trying to solve the visual perception task, humans would select the most diagnostic SF content from among the SF information available in the stimuli based on the task requirements. According to the framework, all SF information contained in an image contributes to recognition of face in some way and configural information as a result of the combination of SF was important. In the current experiment faces images using 1/f noise kept all relevant and non-relevant SF information though SF differences between them were eliminated. Due to the change of the amount of SF information provided on the expressions, participants selected diagnostic SF content in different optimal bandwidth range. Moreover, the lack of some information affected the processing of configuration information and led to a biased result. As we can see in the figure 3, the relative deviation of faces using 1/f noise is larger than that of faces containing only main SF features. It suggests that non-relevant SF information also play a role in emotion detection. Therefore, the condition of 1/f noise still revealed ASE in the experiment. The exposed ASE in the condition of faces using average magnitude spectra per expression can be explained by the diagnostic recognition framework too because of more intact SF information. Through explanation provided by the diagnostic recognition framework, we may clarify the inconsistent ASE between conditions and conclude that SF content is greatly important in the fast detection of particular facial expressions.

However, there is no significant difference between four different SF contents used in the experiment in general. This finding conflicts with results discussed above. It is hard to explain and thus the conclusion about the relation between SF and emotion superiority effect has to be made with caution. Not that the sensitivity of faces to SF is related to many factors: spatial filtering (Näsänen, 1999; Costen et el., 1996), contrast reverse (Gaspar et al., 2008) and orientation (Yu, Chai, & Chung, 2011). Phase information is also required to keep the appearance of faces (Tadmo & Tolhurst, 1993). Retained details of facial region, filtering, and orientation of spectrum may interfere with the sensitivity to SF altogether resulting in contrast energy not being below the threshold at which expressions could be barely detection by participants. Hence, we may not be able to detect significant differences between different SF manipulation conditions in terms of statistical. Furthermore, given the not-so-large sample and the flaws associated with online experiments, such as the lack of control over the setting in which participants gave their responses and the low engagement of participants (Konstan et el., 2005; Teitcher et al., 2015; Jones, House & Gao, 2015), the data might be contaminated by experimental errors. Consequently, it is not assured to conclude that different SF contents have different influences on the processing of visual stimuli in the current experiment just according to available results.

In conclusion, the experiment reports the anger superiority effect except when main SF features that separate emotional expressions were removed from faces. Although for faces in which differences between main and subsidiary were eliminated did not show the same absence of ASE, the results still suggest SF information plays a big part in the detection of facial features since the author think that the role of all SF content varies on the basis of information provided by the faces and comprehensive information is very important for emotion processing. However, this conclusion is weakened by another finding in the experiment that there is no significant difference between four conditions by Friedman test. The sample size and limitations of online experiment might be reasons behind this result. Therefore, while the contribution of SF features to detection of facial expressions is still admitted, it cannot be denied that this conclusion may be unreliable in consideration of incompatible results .

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