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Happy Face Superiority Effect in Change Detection Paradigm

Domagoj Švegar, Igor Kardum

Department of Psychology, Faculty of Humanities and Social Sciences, University of Rijeka, Croatia

Marko Polič

Department of Psychology, Faculty of Arts, University of Ljubljana, Slovenia

Abstract

The aim of the present study was to investigate which affective component guides cognitive processing of emotional facial expressions. According to the threat hypothesis, processing of angry faces is prioritized by the human cognitive system, because rapid detection of threat has a large adaptive value. The negativity hypothesis presumes that distressing emotional experiences of other people attract attention, regardless of whether they represent danger or not. The emotionality hypothesis proposes that positive emotional facial expressions can capture attention as effective as negative ones, while the happy face superiority hypothesis predicts that happy faces are prioritized. In the present study, which was conducted on 24 participants, change detection paradigm was used, because that procedure enables insight into the later stage of information processing. The results obtained show that happy facial expressions are heavily prioritized by the human cognitive system. In explanation of these results, that clearly support the happy face superiority hypothesis, we propose that angry expressions are initially prioritized by our cognitive system, because we benefit from early detection of potential threat in the environment, but in later cognitive processing, happy expressions are given the priority, because smiling is a valuable mechanism for forming and maintaining cooperative relationships. Besides the theoretical relevance, the present study is also valuable methodologically, because we demonstrated that change detection paradigm can be efficiently used for the research of emotional facial expressions processing.

Keywords: emotional expression, happy face, change detection paradigm, evolution of smiling

Introduction

The capability to recognize the emotional state of other people is one of the most important objectives of human perception. Since perceived emotional states govern the undertaking of action, they are an important factor for social behavior, and also for the entire human cognition: from decision making and problem solving

✉ Domagoj Švegar, Department of Psychology, Faculty of Humanities and Social Sciences, University of Rijeka, 51000 Rijeka, Sveučilišna avenija 4, Croatia. E-mail: *dsvegar@gmail.com.*

to intelligence. The face reveals an ocean of social signals, and among other channels, face is the most dominant medium for transmitting emotional information (Knapp, 1978; Noller, 1985).

Since rapid response to a presence of a potential threat in the environment is an obvious evolutional advantage, a rapid detection of the facial expression of anger clearly has a large adaptive value. A fast detection of facial threat is therefore assumed to be prioritized by our cognitive system and in the field of recognition of facial expressions that premise is known as *the threat hypothesis* (Calvo, Avero, & Lundqvist, 2006; Fox et al., 2000). On the other hand, according to *the negativity hypothesis*, a distressing emotional experience of a person attracts attention, regardless of whether it represents danger or not. Therefore, angry faces do not capture attention because they represent danger, but because they show negative affect. Thus, the negativity hypothesis presumes that a sad face should be detected equally well as an angry one in a crowd of faces (Calvo et al., 2006). Finally, Martin, Williams, and Clark (1991) argue that positive emotional expressions can capture attention as effective as negative ones, and that standpoint is called *the emotionality hypothesis*. According to the emotionality hypothesis, special attention is paid to all emotional events (Calvo et al., 2006; Fox et al., 2000).

In order to discover which one of these three hypotheses is valid, numerous studies based on various methodological approaches, that are specific for research in cognitive processing of emotional facial expressions, were conducted. Great majority of these attempts can be divided into three categories: visual search tasks, dot probe tasks and eye movement monitoring. *Visual search task* is a psychophysical method in which participants are required to search through an array of facial expressions. Usually in one half of the trials one target face expresses a specific emotion, while the rest of the faces (distracters) exhibit another emotion. In the other half of the trials, all facial expressions are identical. Participants' task is to answer whether one facial expression differs from the rest of them or not. Reaction times are then measured and analyzed (Frischen, Eastwood, & Smilek, 2008). *Dot probe task* is a paradigm commonly used to assess selective attention, especially to threatening stimuli. The task begins with a presentation of a fixation mark in the center of the display. After the fixation mark, two stimuli (one threatening and one non-threatening) appear simultaneously, one in the left, and one in the right visual field. When they are withdrawn, a target dot is presented in a location previously occupied by one of the two stimuli. Participants' task is to indicate the location of the dot. The logic is simple: reactions are expected to be faster if the dot is presented in a region of visual display where attention gaze rests. If the dot is presented at the location previously occupied by a threatening stimulus (such as a threatening face, fearful face, gun), reaction time is usually quicker compared to trials in which the dot is presented in the location earlier occupied by a neutral stimulus (Armony & Dolan, 2002; Beaver, Mogg, & Bradley, 2005; Broadbent & Broadbent, 1988; Fox, 1993, 2002; Hunt, Keogh, & French, 2006; MacLeod & Mathews, 1988; Mogg & Bradley, 1999). *Eye movement monitoring* procedure, on the other hand, provides a continuous index of attention, so it is often used in studies of visual perception and spatial attention (Gitelman, Parrish, LaBar, & Mesulam, 2000; Rohner, 2002), in which patterns of eye movements are used to examine the direction of attention. The rationale of the eye fixation measurement is quite simple: fixations reflect the direction of attention, while gaze duration indicates the amount of attention devoted to the identification of stimuli (Calvo et al., 2006; Frischen et al., 2008). Eye movement monitoring is often combined with visual search task paradigm (Bradley, Mogg, & Millar, 2000; Calvo et al., 2006; Reynolds, Eastwood, Partanen, Frischen, & Smilek, 2009).

In various studies using visual search tasks, dot probe paradigm, eye movement monitoring and other paradigms, it was demonstrated that angry facial expressions are prioritized by our cognitive system. An angry face in a crowd of happy faces is detected faster than a happy face in a crowd of angry faces (Hansen & Hansen, 1988; Horstmann & Bauland, 2006). Additionally, an angry face in a crowd of neutral faces is detected faster than a happy face in a crowd of neutral faces (Calvo et al., 2006; Fox et al., 2000) or a sad face in a crowd of neutral faces (Calvo et al., 2006). Response to a probe stimulus in dot probe tasks is faster if the probe is presented at the location previously occupied by a masked angry face (Mogg & Bradley, 1999). Furthermore, search slopes are slower for angry faces compared to happy faces, which means that the introduction of additional distracter faces does not result in significant prolongation of search time required to detect an angry face, while detection of a happy face is decelerated if the crowd of distracter faces is increased (Fox et al., 2000). Similarly, dwell time is longer for angry relative to happy crowds: visual search through a crowd of angry faces is slow compared to a search through a crowd of happy faces, because each angry facial stimulus tends to hold visual attention and therefore slows down the shift of attention to another stimulus, which consequently decelerates search speed (Fox et al., 2000). Finally, compared to other emotional or neutral faces, angry faces are most likely to be processed preattentionally in parafoveal vision (Calvo et al., 2006). All these conclusions present strong evidence that the detection of angry faces is facilitated as it should be expected according to the threat hypothesis. Angry faces are detected more efficiently than other emotional or neutral faces and that implies that face processing is oriented towards detecting a threat. At the same time, most of these findings are not contradictory with the negativity hypothesis, while some other findings directly suggest that negatively valenced facial expressions are detected more efficiently compared to positive ones (Eastwood, Smilek, & Merikle, 2001; Hahn & Gronlund, 2007; Horstmann, 2007). Other previous findings fit well into the framework of the emotionality hypothesis. For example, in the condition of increased exposure time, the detection of the absence of a discrepant face does not require a larger amount of time for angry relative to happy crowds (Fox et al., 2000). Furthermore, all emotional faces receive first eye-fixation more often than neutral faces (Calvo et al., 2006) and moreover, all emotional faces are more likely to be re-fixated than neutral faces, which reveals late attentional engagement on emotional faces (Calvo et al., 2006).

Accordingly, search performance is better for emotional faces among neutral distracters compared to neutral targets among emotional distracters (Williams, Moss, Bradshaw, & Mattingley, 2005). This is also consistent with the emotionality hypothesis.

However, besides the three mentioned hypotheses, there are also a few interesting findings revealing the happy face superiority effect. In several such studies it was found that happy facial expressions are recognized faster than other facial expressions. In some of them, pictures of facial expressions were presented to participants, whose task was to categorize these pictures according to the emotional state (or emotional valence) they are displaying. Reaction time needed for the correct recognition was measured for each emotional expression. In the rest of these experiments, exposition time was varied in order to determine thresholds for the recognition of different emotional facial expressions. In some of such experiments, emotional facial expressions were masked. Accuracy of responding was also analyzed in all these experiments. The results of these studies revealed that the facial expression of happiness is recognized faster and/or more correctly than the expressions of: anger (Calvo & Lundqvist, 2008; Goren & Wilson, 2006; Harrison, Corelczenko, & Cook, 1990; Hugdahl, Iversen, & Johnsen, 1993; Milders, Sahraie, & Logan, 2008; Montagne, Kessels, De Haan, & Perrett, 2007; Palermo & Coltheart, 2004), disgust (Calvo & Lundqvist, 2008; Leppänen & Hietanen, 2004; Montagne et al., 2007; Palermo & Coltheart, 2004), fear (Calvo & Lundqvist, 2008; Goren & Wilson, 2006; Milders et al., 2008; Montagne et al., 2007; Palermo & Coltheart, 2004), sadness (Calvo & Lundqvist, 2008; Crews & Harrison, 1994; Feyereisen, Malet, & Martin, 1986; Goren & Wilson, 2006; Montagne et al., 2007; Palermo & Coltheart, 2004; Stanners, Byrd, & Gabriel, 1985), surprise (Calvo & Lundqvist, 2008; Montagne et al., 2007; Palermo & Coltheart, 2004) and neutral expression (Esteves & Öhman, 1993; Hugdahl et al., 1993; Leppänen & Hietanen, 2004; Milders et al., 2008; Palermo & Coltheart, 2004). In other, cross-cultural studies, recognition scores were also the highest for happy facial expressions (Ekman, 1982; Ekman & Friesen, 1976; Russell, 1994).

Leppänen and Hietanen (2004) clearly demonstrated that the observed advantages of happy faces in recognition speed studies could not be attributed to low-level physical differences between happy and other facial expressions.

In similar recognition studies, Hess, Blairy, and Kleck (1997) and Palermo and Coltheart (2004) varied the intensity of emotional expressions. Hess et al. (1997) investigated the relation between the physical intensity and recognition accuracy, while Palermo and Coltheart (2004) examined the correlation between the intensity of emotional expressions and the time needed for their recognition. The recognition accuracy of all emotional expressions, except happy, was found to increase linearly as intensity ratings increased. Only the recognition of happy expressions was not affected by the intensity of happy facial expressions – even low intensity happy faces were recognized with nearly 100% accuracy (Hess et al., 1997). Data regarding reaction times follow a similar pattern as the accuracy of recognition data: the intensity of emotional expressions is in high negative correlation with time needed for correct recognition of facial emotions. However, the correlation is not significant for happy facial expressions, which are recognized equally fast regardless of the intensity (Palermo & Coltheart, 2004).

In addition, Goren and Wilson (2006) discovered that peripheral recognition of emotional expressions is impaired compared to foveal recognition. However, this finding is not valid only for happy facial expressions. In other words, even when gaze is not directed toward happy faces, they are recognized successfully. In line with the findings of Goren and Wilson (2006), Mack and Rock (1998) discovered that happy faces are recognized even when they are presented unexpectedly among a mass of other stimuli. While other facial expressions remained unnoticed, happy faces were recognized in a similar manner as a person's own name in a "cocktail party phenomenon" (Mack & Rock, 1998).

As presented so far, the previous research conducted in order to evaluate the threat, the negativity, the emotionality and the happy face superiority hypotheses, gave some support to all of them, especially to the threat hypothesis. However, it seems that confirmation of a particular hypothesis partly depends on the type of experimental method. For example, the threat hypothesis was most frequently confirmed when using visual search and dot probe tasks, the happy face superiority effect in the studies using speed recognition tasks and the emotionality hypothesis when using eye movement monitoring paradigm. While all these methods principally assess earlier stages of cognitive processing of visual information, the later stages are considerably less explored.

Therefore, in the present study, the new methodology of facial expressions cognitive processing was introduced – *the change detection paradigm*. In contrast to conventional methods for the research of emotional expressions processing, change detection paradigm provides insight into later processing of information (such as e.g. working memory) that occurs between several hundred and several thousand ms after the stimuli are presented. The core of the procedure is mutual to all its variations – it comprises two or more displays which can differ in some segments. These displays are successively presented to participants, and their task is to answer if they are identical or not. The accuracy of responding and reaction times are then measured and analyzed (Rensink, 2002). The change detection paradigm was so far specific for other areas of experimental research, such as working memory (Alvarez & Cavanagh, 2004; Pashler, 1988; Phillips, 1974; Vogel, Woodman, & Luck, 2001; Wheeler & Treisman, 2002), attention (Rensink, O'Regan, & Clark, 1997; Simons & Levin, 1998), vision (Hollingworth, 2006; Mitroff, Simons, & Levin, 2004; Varakin & Levin, 2006) and consciousness (Rensink, 2004; Simons, Nevarez, & Boot, 2005). The present research is one of the first attempts to apply the change detection paradigm in the research of human emotional expressions.

Therefore, the problem of this study was to explore which affective component facilitates detection of facial emotional expressions, using change detection paradigm.

According to the threat hypothesis, the highest proportion of correct answers and the fastest reaction times are expected to occur in trials in which test stimulus (regardless of its emotional expression) is presented at a location initially occupied by an angry face. According to the emotionality hypothesis, the lowest proportion of correct answers and the slowest reaction times are expected to occur in trials in which test stimulus is presented at a location initially occupied by a neutral face. If the negativity hypothesis is true, the proportion of correct answers should be higher and the reaction times faster in trials in which test stimulus is presented at a location initially occupied by an angry, sad, disgusted or frightened face, then in trials in which test stimulus is presented at a location initially occupied by happy or neutral face. Finally, the happy face superiority effect will be confirmed if highest proportion of correct answers and fastest reaction times are obtained in trials in which test stimulus is presented at a location initially occupied by a happy face.

Method

Participants

Twenty-four students (age range 20-26) from The University of Rijeka, Croatia, participated in the experiment, after they had given informed consent. Ethical approval for the study was provided by the Ethics Committee of the Faculty of Humanities and Social Sciences. The number of male and female participants was equal, and all of them reported to have normal or corrected to normal visual acuity.

Instruments and Stimuli

Stimuli were displayed on a 17-inch monitor with resolution of 1024 x 768 pixels. Stimuli presentation and data collection were controlled by a PC-computer. Responses were collected via keyboard. The Averaged Karolinska Directed Emotional Faces (AKDEF) database (Lundqvist & Litton, 1998) and Calvo & Lundqvist's (2008) adaptation of facial stimuli from The Karolinska Directed Emotional Faces (KDEF) database (Lundqvist, Flykt, & Öhman, 1998) were used for the construction of stimuli material. Four sets of stimuli were prepared, each of which contained seven pictures of emotional facial expressions: afraid, angry, disgusted, happy, neutral, sad and surprised. Calvo and Lundqvist's (2008) norming data was considered during the selection of the stimuli: only expressions that were correctly identified with 90% or higher accuracy were included in the present study. In order to keep idiosyncratic facial features constant, each stimuli set contained different expressions of the same face, so the only variable aspect of stimuli within each set was the emotional expression. During the setup of final stimuli material, color was removed from Calvo and Lundqvist's (2008) adaptation of KDEF stimuli, while the AKDEF stimuli were left intact, since they are already grey-scaled in original version. Grey-scale images were used in order to ensure attribution of experimental effects exclusively to emotional expressions rather than to low-level perceptual properties of stimuli. Specifically, Purcell, Stewart, and Skow (1996) demonstrated that cognitive processing in Hansen and Hansen's (1988) experiments was guided by contrast differences, rather than facial expressions. In order to avoid such and other effects of perceptual properties and to obtain pure effects of emotional expressions, either grey-scale images or schematic faces are used.

An argument contra schematic stimuli is the fact that they are excessively artificial and stereotyped (Frischen et al., 2008), and may introduce certain perceptual factors. For example, in smiling faces, curvature of mouth is in an excessive congruence with the curvature of circular facial contour. Simultaneously, in frowning faces these curvatures are in an exaggerated incongruence. Therefore, when all advantages and disadvantages are considered, the problem of influence of low-level perceptual factors is more present and more announced in studies using schematic stimuli than in studies using real face photographs (Horstmann & Bauland, 2006), so the minimization of the problem of the influence of such factors, was in the present study assured by the use of grey-scale images of models' facial expressions.

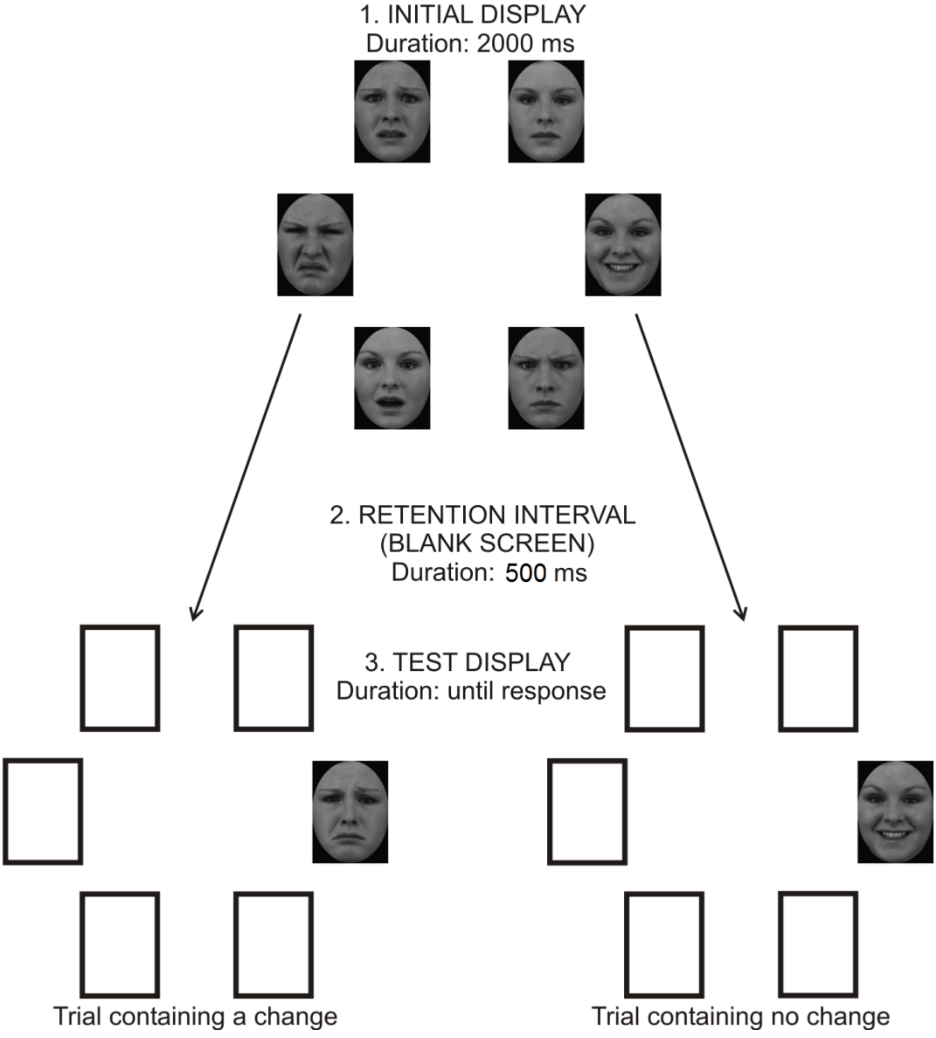
Another methodological issue, regarding the selection of stimuli, was the dilemma between the use of static or dynamic displays. Complexity of display in change detection paradigm varies from simple static objects, such as drawings or schematic stimuli, to video clips or even real life interactions. While deciding about the complexity of the display for the present study, the following trade-off was taken into consideration: complexity of display negatively correlates with experimental control, and is positively connected with external validity. In order to assign more importance to internal experimental validity, static displays were used, because dynamic displays would generate a serious obstacle for obtaining high internal validity. Thus, in order to increase the possibility of generalization of experimental results to everyday human functioning, and in order to minimize the influence of low-level perceptual factors, photographs were used instead of dynamic displays and schematic stimuli or drawings.

Procedure

The experiment was divided into four experimental sessions, each of which was composed of 252 experimental trials, and lasted for approximately 30 minutes. Therefore, every participant went through a total of 1008 trials, plus 32 practice trials (eight per session), which were excluded from analyses. In order to ease such a difficult activity, participants took 7-days break between every experimental session. All participants went through the experiment in a laboratory under the same conditions. Noise was minimized, and illumination as well as air temperature was held constant. Participants sat with their eyes at a distance of 100 cm from the monitor.

Every trial began with the fixation mark, presented in the center of the screen, in duration of 250 ms, which was followed by the presentation of the initial stimuli display that always subtended 13.29° x 12.27° of visual angle. The initial display consisted of six different facial expressions, each of which always occupied 3.38° x 2.58° of visual angle. To generate initial stimuli display, six pictures were randomly pulled from a set of seven emotional pictures, with the restriction that two or more identical expressions could never be present at the same display. These facial expressions were randomly located at six spatial positions, circularly arranged in relation to the center of the screen (Figure 1).

Figure 1. *Example of a Trial Containing a Change and a Trial Containing no Change*



After 2000 ms-lasting presentation of the initial display, blank screen was presented for 500 ms, and after that the test display appeared. Single test displays were used in this experiment, which means that only one facial expression was presented per test display, and it was placed on one of the six locations previously occupied in the initial display. The test face appeared the same number of times at each location (168 times per location), with several restrictions. In half of all trials (all trials containing no change), facial expression of the test face was identical as the expression of the face previously occupying its location in the initial display within the same trial, while in the other half of all trials (all trials containing a change), the facial expression presented at test display was the expression which was not presented at all at the initial display (Figure 1). Also, every facial expression was presented the equal number of times as a test expression at any location. Thus, each of the seven expressions was presented 144 times in test display, 24 times at each of six possible locations. Also, when only initial displays are considered, each facial expression occupied the location of the test display in an equal number of trials (N=144). In 72 trials, the facial expression occupying the location of the test display in the initial display remained unchanged during the retention interval, and was again presented in the same spot in the test display. In the other 72 trials it changed during the retention interval, exactly 12 times into each of the 6 remaining expressions.

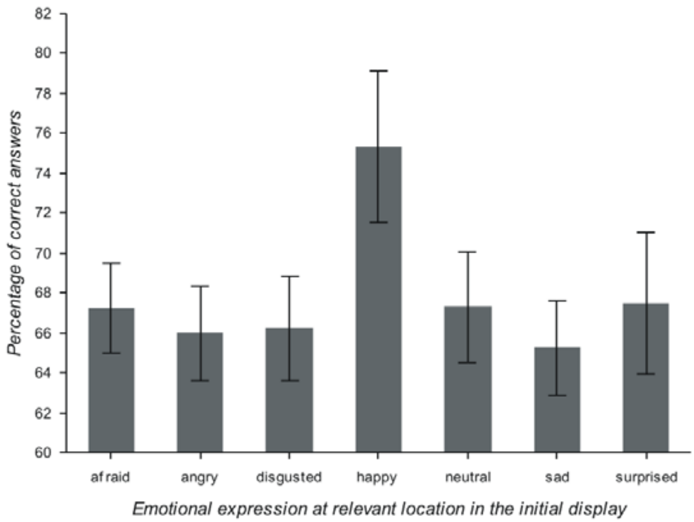
After the presentation of the test display, participants were instructed to hit the "1" key if a change occurred during the retention interval (if the emotion in the test display differs from the emotion occupying the same location in the initial display), or to hit the "0" key if a change did not occur (if the emotion on the test display was identical to emotion occupying the same location in the initial display). They were emphasized to aim for accuracy, not speed. In trials in which they were uncertain if a change had occurred or not, they were told to respond by chance. Feedback followed immediately after each reaction of participants. If the response was correct, the word "correct" appeared in blue color at the center of display, and if their answer was wrong, then the word "incorrect" was presented in red color. The experiment was conducted in a self-paced manner. After the presentation of feedback, which lasted for 500 ms participants had to press the "space bar" in order to start a new trial.

Results

In order to analyze participants' performance, percentages of correct answers were analyzed as a function of emotional expression that occupies relevant location in the initial display. The term relevant location refers to a location in the initial display which is the same as the location of the emotional stimulus in the test display within the same trial. Reaction times were also processed, as a supplementary measure, also as a function of emotional expression that occupies relevant location in the initial display. For the purpose of eliminating the impact of extreme results, median reaction times were computed for every participant across each experimental condition. Only these median values were used in subsequent statistical analyses of reaction times. In conformity with the findings of other experiments investigating effects of gender on processing of facial expressions (Calvo & Lundqvist, 2008; Palermo & Coltheart, 2004), gender of participants had no effect on performance, regardless of criterion variables. It had no impact either on accuracy of responding or reaction times. Furthermore, gender did not interact significantly with other independent variables. Since patterns of results were similar for male and female participants, in order to avoid unnecessary complexity, results are not going to be reported separately for men and women. The effects of model gender were not analyzed, because external validity of obtained conclusions would be poor, since four sets of stimuli were used.

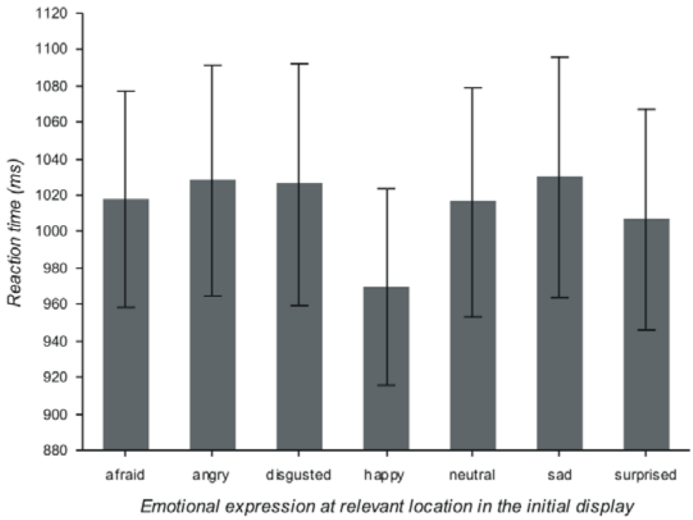
Analysis of accuracy as a function of emotional expression that occupies relevant location in the initial display, conducted on all trials, was of central interest for the present study. In order to analyze obtained percentages of correct answers, one-way repeated measures ANOVA was conducted, and it revealed that the main effect of emotional expression occupying relevant location in the initial display was significant ($F(6,138)=8.57$, $p<.001$, partial $\eta^2=.27$). Tukey HSD post-hoc test revealed that, compared to any of corresponding six conditions, the percentage of correct answers was significantly higher in the condition of happy facial expression occupying relevant location in the initial display. Amongst the remaining six conditions there were no significant differences (Figure 2).

Figure 2. *Percentage of Correct Answers as a Function of Emotional Expression that Occupies Relevant Location in the Initial Display*



In the second ANOVA, reaction time was set as dependent variable. The main effect of emotional expression occupying relevant location in the initial display was again significant ($F(6,138)=8.51$, $p<.001$, partial $\eta^2=.27$). Tukey HSD post-hoc test showed that participants responded the fastest in the condition of happy facial expression occupying relevant location in the initial display. Reaction time in that condition was significantly shorter compared to any of the other six corresponding conditions, among which none of the differences was statistically significant (Figure 3).

Figure 3. *Reaction Time as a Function of Emotional Expression that Occupies Relevant Location in the Initial Display*



To obtain a more detailed insight into cognitive processing, performance was also analyzed separately for trials that contain a change and trials that do not contain a change, because different patterns of results can emerge in these two conditions. Performance was also analyzed as a function of emotional expression in the test display for the same reason – to gain a more detailed insight into cognitive processes (such as the strategy of memorizing, criterion of responding, comparison of test expression to memorized items from the initial display, etc.). Since all these results follow the same pattern in confluence with the happy face superiority effect, for the sake of brevity they are not presented in detail.

Thus, all the analyses revealed the superiority effect of happy faces in cognitive processing: performance was the most accurate (Figure 2) and the fastest

(Figure 3) for trials containing happy expressions at the relevant location in the initial display, which means that happy facial expressions are prioritized by our cognitive system.

Discussion

The experiment was designed primarily to explore which affective component facilitates detection of facial emotional expressions, using change detection paradigm. According to the threat hypothesis, accuracy was expected to be the highest in trials in which an angry face is presented at the relevant location in the initial display. However, analyses have shown that performance was no better in these trials relative to any other types of trials. Performance was even significantly worse for these trials compared to trials in which a happy face is presented at the relevant location in the initial display. If the negativity hypothesis is valid then a higher accuracy is expected to occur in trials in which test stimulus is presented at a location initially occupied by an angry, sad, disgusted or frightened face, compared to trials in which test stimulus is presented at a location initially occupied by a neutral face and especially by a happy face. The observed pattern of results is diametrical in its entirety. The accuracy for trials in which an angry, disgusted, frightened or a sad face occupy the relevant location in the initial display is significantly lower compared to trials in which the relevant location is occupied by a happy face. The analyses of reaction times are in conformity with the analyses of accuracy. Reactions were the fastest in trials where the relevant location in the initial display was occupied by a happy face. According to the emotionality hypothesis, the lowest proportion of correct answers was expected in the condition of neutral facial expression occupying the relevant location in the initial display. The results obtained do not support that hypothesis, because none of the emotional facial expressions (with the exception of happy) had an advantage over neutral expression in cognitive processing – neither when the accuracy of responding was examined, nor when the speed of responding was analyzed. Moreover, no differences were expected between emotional expressions. The advantage of happy expression over angry, frightened, sad, disgusted and surprised also does not fit into the emotionality hypothesis.

The findings obtained are consistent and imply that happy facial expressions are prioritized by our cognitive system: performance was the best and the fastest for trials containing happy expressions at the relevant location in the initial display. However, the results of the present study are not directly comparable with results of the previous studies because unlike former experiments, which were designed to measure the effects of facial expressions on perception or attention, our study was designed to measure a slightly higher level of cognitive processing, such as visual working memory.

Before providing an explanation for the happy face superiority effect observed in the present experiment, special attention must be given to methodological issues.

In this context one important question is what guides cognitive processing: emotional component of facial expressions or their low-level perceptual properties? Besides the application of grey-scale images, which ensure that facial expressions guide cognitive processing in the present study, there is another convincing evidence contra hypothesis that perceptual properties of stimuli affect cognitive processing. That argument arises from experiments in which photographs of facial expressions are inverted, because by the inversion of stimuli it can be tested if low-level perceptual properties of stimuli or emotional expressions affect participants' performance. The logic behind that is simple: if the results are identical for upright and inverted displays, then all experimental effects are the consequence of low-level physical properties, and in the opposite, the effects are the result of emotional expressions. Using such procedures, Eastwood et al. (2001), Fox et al. (2000) and Williams et al. (2005) demonstrated that emotional expressions, rather than low-level physical properties, guide cognitive processing.

Another creative experiment, conducted by Gerritsen, Frischen, Blake, Smilek, and Eastwood (2008) confirms the crucial importance of emotional component rather than low-level perceptual properties. They demonstrated that even emotional valences of facial stimuli guide cognitive processing, and thereby showed that the impact of perceptual characteristics of stimuli on cognitive processing is minimal. Before conducting a series of visual search tasks, Gerritsen et al. (2008) assigned emotional meaning to some stimuli and conditioned participants to associate hostile and peaceful etiquettes to two different target faces, which were both neutral and perceptually identical. Visual search for a target face among neutral faces was more efficient for "hostile" compared to "peaceful" face, just as it would be expected if instead of "hostile" an angry face was used, and if instead of "peaceful" a happy face was used. In addition, experiments using emotional words instead of emotional faces revealed that positively toned words are categorized faster compared to negatively toned ones (Feyereisen et al., 1986; Osgood & Hoosain, 1983; Stenberg, Wiking, & Dahl, 1998). These results suggest that emotional meaning affects cognitive processing. The same results simultaneously contradict (although not directly) the hypothesis that emphasizes the importance of low-level physical features, instead of emotional expressions.

All these findings strongly suggest that emotional meaning of facial expressions has a much more important contribution to cognitive processing, then low-level physical perceptual components do, and that conclusion is valid for the stimuli used in the present study.

Generally, the results of the present study are in conformity with the findings of speed recognition studies.

Although in other paradigms the happy face superiority was almost never observed (with some exceptions, such as Juth, Lundqvist, Karlsson, & Öhman, 2005, who applied visual search tasks, or Leppänen, Tenhunen, & Hietanen, 2003, who used choice reaction time paradigm), nearly all recognition experiments point to the same conclusion that happy facial expressions are prioritized by our cognitive system. However, happy face superiority effects in cognitive processing have received surprisingly little attention. Authors who discovered these effects were focused on other research problems, so they did not concentrate on providing theoretical explanations for unexpected happy face superiority effects they had observed.

Pure happy face superiority effect, which was obtained in the present study, fits well into the evolutionary framework. In non-human primates, silent bared-teeth display is a signal of non-hostile intentions, and human smiling is a modern form of silent bared-teeth display (Mehu, Grammer, & Dunbar, 2007). Specifically, human smile can be considered as a behavior emancipated from silent bared-teeth display, which is crucial for creating social relationships in humans (Mehu et al., 2007). According to Owren and Bacharowski (2001), smiling is much more uniquely human expressive behavior than are signals of negative affect. While negative facial expressions are derived from features that were present in the common ancestor of modern chimpanzees and humans, key changes in smiling evidently occurred after these two lines had diverged. Genuine spontaneous smiling evolved as a reliable indicator of a positive emotional state, and such a mechanism allowed early hominids to form and maintain stable and reciprocal cooperative relationships, for mutual benefit. In explanation, if an individual smiles, a receiver of such a signal knows that the other individual is experiencing positive emotions in his presence (Owren & Bacharowski, 2001). If the sender consistently experiences and signals positive emotions to a particular individual, the receiver is more likely to experience cooperative treatment, and can use such signals as means of predicting potentially advantageous outcome. Moreover, the higher the consistency and quantity of spontaneous smiles over time, the more the receiver can afford to show cooperative behavior to the sender. Consequently, if some individuals smile honestly, using both zygomatic and orbicularis oculi muscles, but others do not, receivers will benefit by soliciting cooperative behavior from those individuals who exhibit positive emotions toward them by smiling to them (Owren & Bacharowski, 2001).

Besides signaling the readiness to cooperate through facial expressions, when people smile, they advertise their attractiveness and health to other people (Mehu et al., 2007). Smiling in the context of advertising attractiveness and health is characteristic especially for women, who often use deception in order to enhance their physical appearance (Buss, 1992). Smiling is also efficient in changing the observer's attitude towards the sender, it increases trust among strangers (Scharlemann, Eckel, Kacelnik, & Wilson, 2001), and even has positive effects on the attribution of leniency to criminals (LaFrance & Hecht, 1995). In addition, people who smile are considered to be more generous, competitive, agreeable and extraverted (Mehu, Little, & Dunbar, 2008). Finally, smiling is used in a flexible adaptive way – besides advertising attractiveness, health, generosity and other positive characteristics, together with reflecting people's motivation to cooperate, smiling induces positive emotions in the observers at the same time (Mehu et al., 2007; Surakka & Heitanen, 1998).

Therefore, smiling is a behavior adaptive for the sender and for the receiver, which consequently has positive effects, especially on social relationships (Mehu et al., 2007; Scharlemann et al., 2001), in accordance with the behavioral ecology approach (Fridlund, 1994). For all these reasons, it is very logical that smiling faces should receive priority in cognitive processing, because observers clearly benefit from detecting, recognizing and memorizing the location of a happy face in a crowd. In this way, our evolutionary fitness is optimized.

The threat hypothesis received the most empirical support from prior research, which was based on methodology that enables insight into earliest phase of cognitive processing. However, when we consider the conclusions of previous research and the findings of the present experiment, we propose that as soon as emotional facial stimuli reach our retina, angry expressions are prioritized by our cognitive system, because we benefit from early detection of potential threat in the environment. After the attention was initially captured by angry expressions, happy facial expressions are given the priority in later cognitive processing, because smiling as a signal of positive affect is a valuable mechanism for forming and maintaining cooperative relationships. Besides the theoretical relevance of these findings, the present study is also valuable from the methodological point of view, because in this experiment we demonstrated that change detection paradigm can be efficiently used for the research of cognitive mechanisms that are in charge of processing emotional facial expressions.

Prospective research should be directed towards the examination of the external validity of the findings of the present study. Instead of static stimuli, dynamic ones should be used in subsequent experiments. Also, variables such as set size, type of stimuli, retention interval should be varied. The proportion of positive and negative expressions per set of stimuli should also be manipulated with, because sets of stimuli contained more negative than positive expressions in the present study. Moreover, further studies should be conducted in order to examine the effects of emotional state and personality traits of participants on the cognitive processing of emotional facial expressions, since, because of a small sample size, we were unable to examine these effects.

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