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DETEKCIJA SPREMEMB EMOCIONALNIH IZRAZOV OBRAZA

CHANGE DETECTION OF FACIAL EMOTIONAL EXPRESSIONS

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The face is
~~The eyes are~~ the window to the soul.

In Ljubljana, 12 March 2010

Domagoj Švegar

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1 INTRODUCTION

People rely on various verbal and non-verbal channels to communicate. While non-verbal behavior includes facial expressions, body posture, gestures, vocalization, gaze and proximal behavior (Argyle, 1988), the verbal communication channel is language. Whereas language scarcely transmits important social messages, processes of monitoring and interpreting non-verbal signals are regarded to be the essence of human interpersonal behavior (Strongman 1996).

From an evolutionary perspective, the capability to recognize the emotional state of other people is one of the most important purposes in human perception, because perceived and expressed emotional states govern undertaking of action, and can even be critical for survival. Perceived emotions are an important factor not only for social behavior, but also for the entire human cognition: from decision-making and problem solving to intelligence.

In everyday interaction, we continuously monitor and interpret emotional expressions of other people. The face reveals an ocean of social signals and is the dominant medium for transmitting emotional information (Noller, 1985; Knapp, 1978). Facial identity and emotional expression of the face are even processed via two separate pathways (Bruce & Young, 1986).

Since the ancient 1870-s, starting with Darwin (1872), face has been is the core of research on the human communication of emotion.

1.1 Threat, negativity or emotionality?

Since rapid response to a presence of potential threat in the environment is an obvious evolutional advantage, rapid detection of facial expression of anger clearly has large adaptive value. Fast detection of facial threat is thus assumed to be prioritised by our cognitive system (in order to initiate immediate action), and in the field of recognition of facial expressions, that hypothesis is known as *the threat hypothesis* (Fox, Russo, Bowles & Dutton, 2000; Calvo, Avero & Lundqvist, 2006).

On the other hand, according to *the negativity hypothesis*, 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 (Calvo et al., 2006).

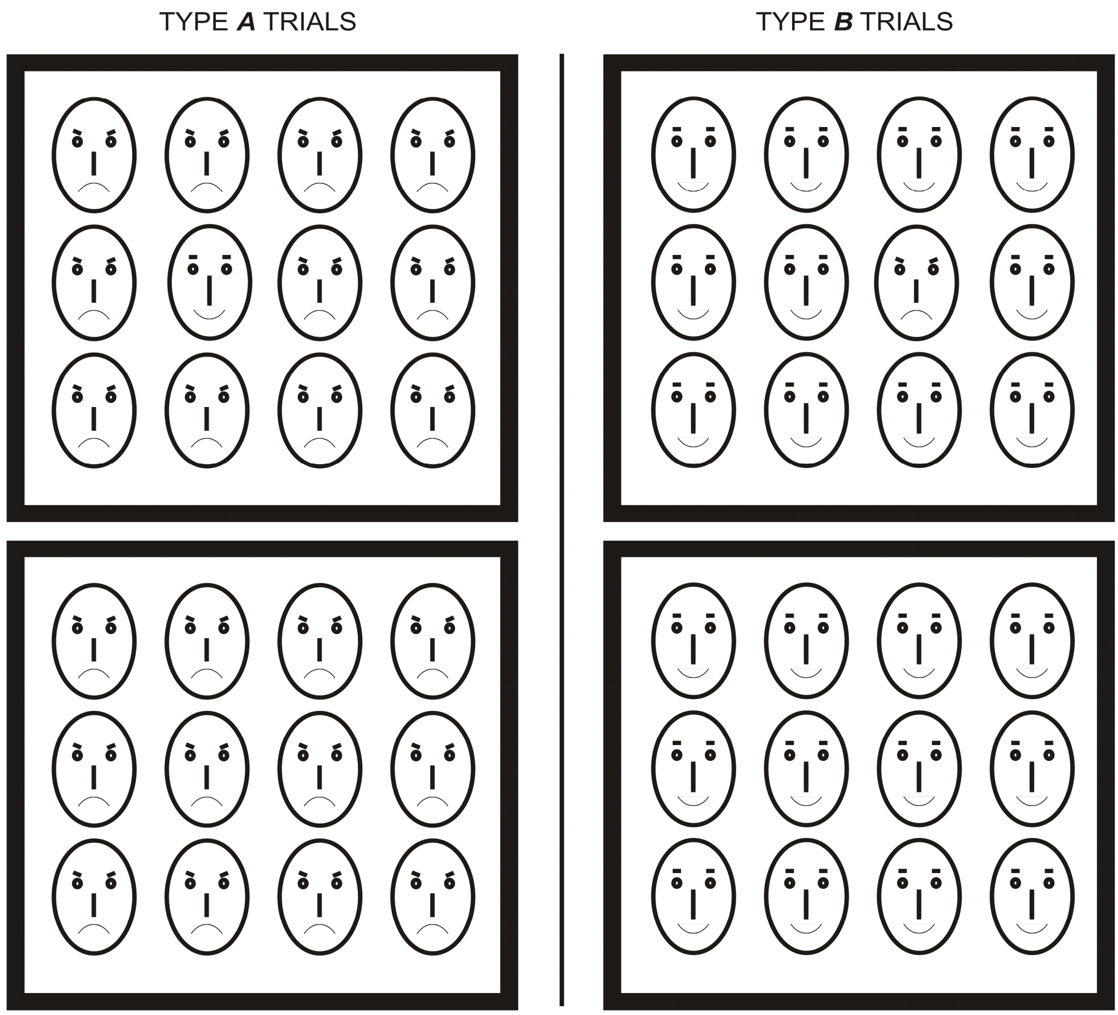
Finally, Martin et al. (1991) argue that positive emotional expressions can capture attention as effective as negative emotional expressions, and that standpoint is called *the emotionality hypothesis.* According to the emotionality hypothesis, special attention is paid to all emotional events (Fox et al., 2000; Calvo et al., 2006).

Which of these three hypotheses is true? Although prior research has not provided a definite answer, plenty empirical evidence exist for the threat hypothesis.

According to the hypothesis that face processing is oriented towards detection of threat, faces are preattentively processed for features of threat (Hansen & Hansen, 1988). If that assumption is correct, then an angry face in a crowd of benign or neutral faces should be detected more easily then a happy or a benign face in a crowd of angry faces. Exactly that was experimentally confirmed in visual search tasks, by Hansen & Hansen (1988), who found that an angry face among happy distractors is detected faster then a happy face among angry distractors (Figure 1). That finding suggests that the majority of attentional processing was allocated to angry faces. Specifically, angry faces were shown to capture attention more effectively then happy faces.

In several other studies, mechanisms which navigate face processing were found to be maximally efficient at locating facial signals of potential threat (Sackett, 1966; Schwartz et al., 1985; Serrano, Iglesias & Loeches, 1992). Analogously, an angry face in a crowd of happy faces results with highly accessable memorial representation, and also, detection and identification of an angry face changing into happy face is hypothesized to be rather efficient (Henson & Henson, 1988).

Figure 1. Visual search task (example of four trials). In some trials, participants are required to answer if all faces are angry, or one of them is happy (Type *A* trials), while in other (Type *B* trials) they have to respond if all faces are happy, or one of them is angry. Using similar procedure, Henson & Henson, 1988) found that an angry face among happy distractor is located faster then a happy face among angry distractors.

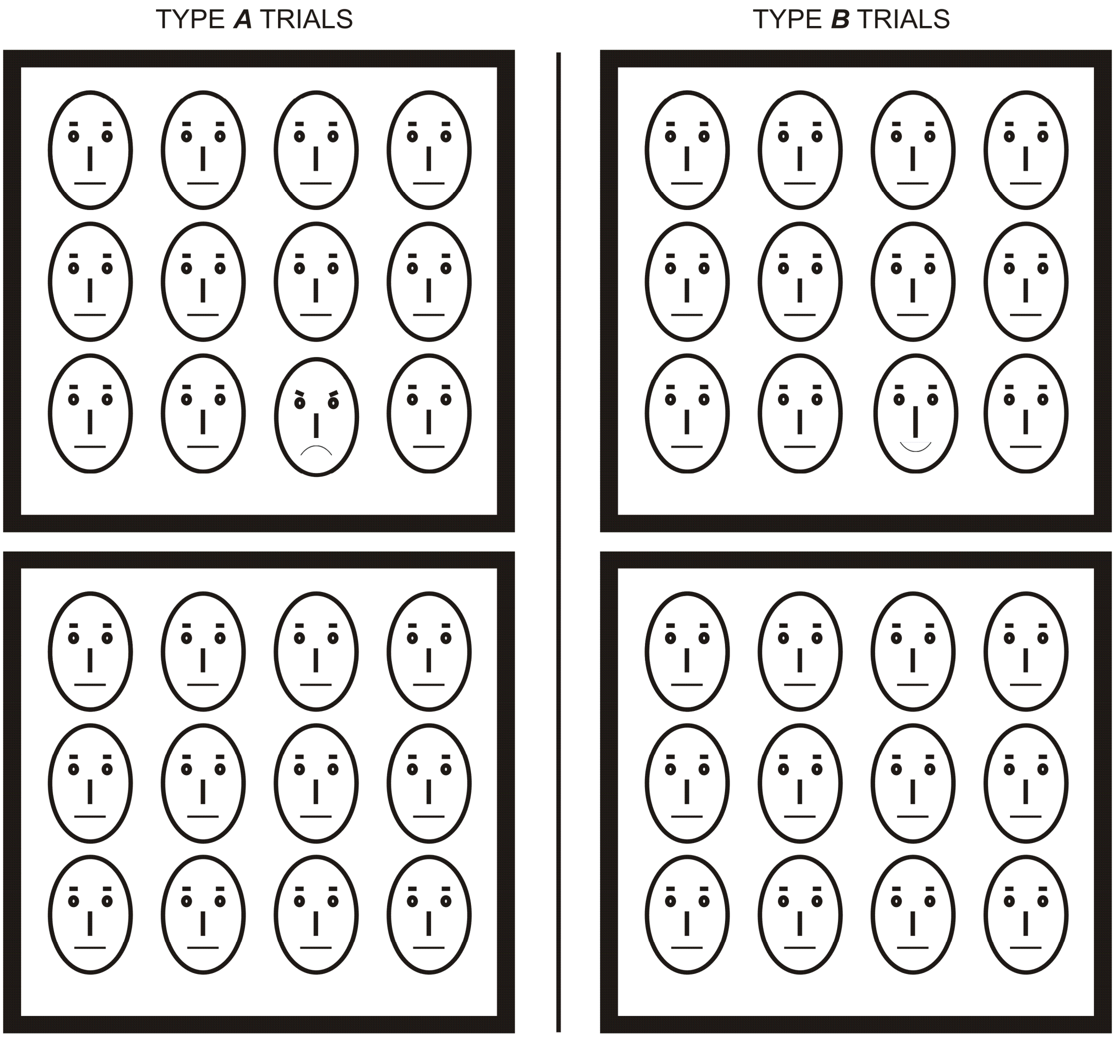


Several neurobiological and psychophysiological studies also converge with the threat hypothesis, and corroborate the belief that angry facial expressions are processed automatically (e.g. Esteves, Dimberg & Öhman, 1994a; Esteves, Parra, Dimberg & Öhman, 1994b). Since sensory thalamus is directly connected to amygdala (LeDoux, 1996), it is not surprising that fear-relevant or threatening stimuli such as angry faces or snakes can cause defensive response even before these stimuli are identified as threatening, because amygdale is a crucial structure involved in the analysis of fear (Adolphs, Tranel, Damasio & Damasio, 1994).

Although all the results mentioned above support the threat hypothesis, numerous noteworthy contrary evidences also exist. For example, Purcell et al. (1996) hypothesized that inadvertent visual cues, which were present in Hansen & Hansen's (1988) stimuli, might have lead to inaccurate conclusions. Specifically, conspicuous dark spots occurred only on angry faces during conversion of pictures from grey-scale into black-and-white. It was possible that participants relied on these spots to discriminate angry expressions. In order to solve that question, they replicated Hansen & Hansen's (1988) study, using grey scale version of their original stimuli. In such a replication search asymmetry was not obtained. Purcell et al. (1996) found no evidence for the «pop-out» of angry faces, and suggested that the effect observed in Hansen & Hansen's (1988) study was just a consequence of a contrast artefact. As a consequence, instead of photographs, schematised drawings of facial expressions became more popular in search-asymmetry studies (Hortsmann & Bauland, 2006).

Fox et al. (2000) argue that a better test would be to present angry or happy faces among neutral distractors. Such visual search tasks would be a better method to indicate whether angry faces indeed hold attention and whether they are indeed detected more rapidly (Fox et al., 2000), because combining two emotional expressions confounds the effects of distractors and targets (Eastwood, Smilek & Merikle, 2001). Therefore, Fox et al. (2000) conducted several visual search task experiments similar to Hansen & Hansen's (1988). They presented happy faces surrounded by neutral or angry crowd, and angry faces surrounded by neutral or happy crowd (Figure 2). In the 3 remaining experimental conditions, all faces were the same (all neutral / all happy / all angry). According to the threat hypothesis, a discrepant angry face surrounded by neutral crowd should be detected faster than a discrepant happy face surrounded by neutral crowd. The threat hypothesis also predicts that angry faces will demand longer dwell time than happy faces or neutral faces. That means that participants would take longer time to detect that there is no discrepant face in displays consisting only of angry faces, in comparison to displays consisting only of happy faces or only of neutral faces. This is presumed because angry faces are expected to hold visual attention, and if that is true, visual search through a crowd of angry faces would have to be slowed down (e.g. White, 1995, reported such effect).

Figure 2. Example of an improved variant of visual search task procedure. Target face is presented among neutral distractors. Participants are required to answer if all faces are neutral, ore one of them is angry (in Type *A* trials) or happy (in Type *B* trials). Fox et al. (2000) used similar procedure.



Within their study, Fox et al. (2000) had the opportunity to directly test the emotionality hypothesis, according to which positive emotional expressions can capture attention as effective as negative emotional expressions (Martin et al., 1991). They could compare dwell time for angry faces, happy faces and neutral faces. If displays consisting only of happy faces or only of angry faces require more time for correct responding than displays consisting only of neutral faces, that would be consistent with the emotionality hypothesis. Also, according to that hypothesis, there should be no larger differences in dwell time between displays consisting only of happy in comparison to displays consisting only of angry faces. However, due to certain obscurities regarding displays containing only neutral faces (some prior research had shown that displays containing only neutral faces are extremely easily processed if stimuli are schematic), Fox et al. (2000) were cautious and decided not to make any conclusions about the emotionality hypothesis.

Results of Fox et al.'s (2000) experiment have shown that detection of the absence of a discrepant face takes more time for angry relative to happy crowds. That finding is in conformity with Hansen & Hansen's (1988) findings and corroborates the threat hypothesis. Regarding the displays containing a discrepant face, detection of an angry face in neutral crowd was faster then detection of a happy face in neutral crowd. That finding also gives evidence for the threat hypothesis. According to the emotionality hypothesis, no difference should be expected between conditions of happy faces in neutral crowds and angry faces in neutral crowds, so that assumption was disproved.

However, Fox et al. (2000) were concerned about the relatively high amount of errors in that experiment, so therefore they decided to run a replication with a longer presentation time. Results have shown that the increase of exposure time led to accurate responding. In contrast to the previous experiment, detection of the absence of a discrepant face required approximately the same amount of time for both angry and happy crowds. Therefore, in that experiment, detection of anger did not have priority over detection of happiness, and that finding is in accordance with the emotionality hypothesis. The other finding from the previous experiment, that detecting of an angry face in neutral crowd was faster then detecting of a happy face in neutral crowd, was replicated.

In another experiment, Fox et al. (2000) investigated if the detection of angry faces is automatic. They hypothesized that detection of angry faces could be so efficient that it could occur even preattentively. To investigate that question, Fox et al. (2000) measured search slopes. Search slope is a value computed by dividing the overall increase in reaction time by the number of extra distractors added to the display. Automatic detection of a stimulus is indicated if a search slope is smaller then 10 ms per item (Fox et al., 2000). To check whether detection of angry faces is automatic, Fox et al. (2000) varied the set size, and found that detection of discrepant angry target was less affected by the number of distractors compared to detection of discrepant happy target. However, since search time for discrepant angry faces was 17 ms per item, it could not be concluded that detection of angry target face is fully automatic, as Hansen & Hansen (1988), White (1995) or Suzuki & Cavanagh (1992) claim. Thus, a debate about the nature of processing angry faces remained unsolved – it is possible that search for angry expressions is controlled, as Nothdurft (1993) or Purcell et al. (1996) claim. However, that finding (concerning search slopes) is still in accordance with findings from previous Fox et al.'s (2000) experiments that detection of angry faces is more efficient than detection of happy faces.

In conclusion, Fox et al. (2000) report that these three experiments, together with two control experiments that were conducted within the same study, present clear evidence that angry faces are detected more efficiently than happy faces.

Besides Fox et al. (2000), Hansen & Hansen (1994), Eastwood et al. (2001), Öhman et al. (2001), Tipples et al. (2002) and Hortsmann & Bauland (2006) also followed Hansen & Hansen's (1988) pioneering experiments and reached similar conclusion in their studies.

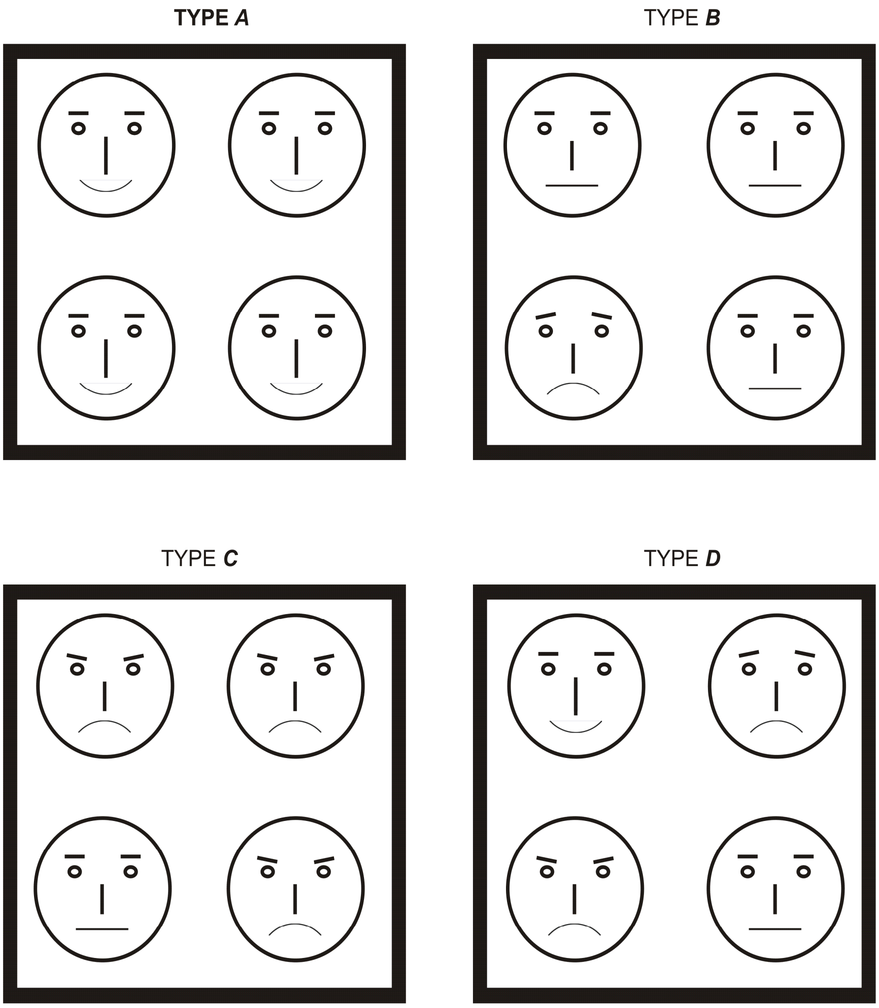
Calvo, Alvero & Lundquist (2006) decided to extend these findings. Their goal was to investigate whether angry faces are detected faster because they are looked at earlier, or because they are identified more efficiently. Another objective of their study was to investigate whether angry faces are detected faster because of their specific threatening attributes, because they evoke negative affect, or because of their general emotional context – in other words, Calvo et al. (2006) examinated which affective component (threat, emotionality or negativity) is the most important for facilitated detection of angry faces.

According to Posner & Peterson (1990), the visual attention system consists of two main components: initial orienting (shifting of attention towards a stimulus in a context) and maintenance of attention. In conformity with Calvo et al.'s (2006) attentional orienting hypothesis, detection af angry faces is facilitated due to the shifting mechanism – as soon as such faces are presented in a display, they are more likely to attract attention. If that is true, then gaze should be directed to angry faces earlier then towards non-angry faces. In contrast, Calvo et al.'s (2006) processing efficiency hypothesis presumes that once attention is directed towards it, the detection of an angry face requires little attentional resources. This implies that angry faces are not looked at earlier than other faces, but when looked at, they are identified more easily then other faces.

To test the threat hypothesis against the negativity hypothesis, facilitation of anger detection has to be compared with facilitation of negative affect (sadness) detection. The threat (and the negativity) hypothesis can be discriminated from the emotionality hypothesis by comparing detection of angry faces (and sad faces respectively) with detection of happy faces. If detection is facilitated for both sad and angry faces, but not for happy faces, that would support the negativity hypothesis, whereas facilitated detection of only angry faces would be in conformity with the threat hypothesis. An advantage of angry, happy and sad faces over neutral faces, would be an argument for the emotionality hypothesis.

In order to evaluate the initial orienting vs. processing efficiency hypothesis, and threat vs. emotionality vs. negativity hypothesis, Calvo et al. (2006) used the eye-movement monitoring paradigm combined with visual search tasks. In visual search tasks, they presented angry, happy, sad and neutral faces at four display locations (Figure 3).

Figure 3. Another improvement of the original Henson & Henson's (1988) method. Calvo et al. (2006) used four types of displays. They used displays containing all identical faces (Type *A*), one discrepant emotional face in a context of neutral faces (Type *B*), one discrepant neutral face in a context of emotional faces (Type *C*) and displays consisting of four different faces (Type *D*). Displays consisting of four different faces (Type *D*) are also particularly suitable for eye-movement monitoring paradigm.



Stimulus display type was manipulated on four levels:

a) displays consisting of the same faces,
b) one discrepant emotional face in a context of neutral faces,
c) one discrepant neutral face in a context of emotional faces (either angry, happy or sad),
d) displays consisting of four different faces (angry, happy, sad and neutral).

Vision field was also varied: stimuli were presented peripherally, parafoveally and foveally.

Analyses have shown that a discrepant angry face in a neutral crowd is detected faster then a discrepant sad or happy face in the same crowd. That is in conformity with the central finding of several studies (e.g. Fox et al., 2000, Eastwood et al., 2001, Öhman et al., 2001, Tipples et al., 2002) that detection of angry faces is facilitated. Regarding the reason of facilitated detection of angry faces, it was found that neither angry nor sad nor happy faces were looked at earlier than neutral faces, and also there were no such differences among the three emotional faces. In other words, participants did not fixate angry faces earlier, but they did detect them faster anyway. That finding can obviously not be explained by the initial orienting hypothesis.

On the other hand, several other results obtained also support the processing efficiency hypothesis: in condition when all presented faces were different, there were fewer fixations on angry faces than on neutral faces before the response. Also, in the condition when there was one discrepant face in the display, the frequency of fixations before the response was lower for angry faces than for sad or happy faces. In case of short presentation intervals (150 ms), detection accuracy was higher for angry than for sad or happy faces, but in case when a longer fixation on the display was possible (250), detection accuracy was similar for all emotional faces.

Therefore, it can be concluded that all these findings support the processing efficiency hypothesis, and that is consistant with several other studies using various different paradigms. For example, Fox, Russo, Bowles & Dutton (2001) used a cueing paradigm to explore how sudden onset of emotional faces attracts attention and found that sudden onset of angry faces did not attract attention more then the onset of other faces. Bradley, Mogg & Millar (2000) used a dot probe paradigm combined with eye-movement monitoring. They presented pairs of faces differing in expressions, and found no differences in initial eye movements as a function of facial expression: participants did not look at threatening stimulus first[1].

[1] Only anxious patients more frequently moved their eyes towards threatening stimuli first.

Within the same study, Calvo et al. (2006) tested threat vs. emotionality vs. negativity hypothesis. Several findings were consistent with the threat and with the emotionality hypothesis, while the negativity hypothesis received no support. Higher detection accuracy for angry faces than for sad, happy or neutral faces in the condition of short presentation intervals (150 ms), is consistant with the threat hypothesis. Frequency of fixations before the response was the lowest for angry faces, which is also in conformity with the threat hypothesis. Other findings are congruent with the emotionality hypothesis. Late engagement as a function of emotionality was found: all emotional faces were more likely to be refixated than neutral faces. Also, the first fixation before the response was more often directed towards emotional faces than towards neutral faces. Therefore, Calvo et al. (2006) concluded that general emotionality affects initial attentional orienting and late engagement, while threat affects speed in detecting discrepant face. They also inferred that angry faces are more likely to be processed preattentionally in parafoveal vision. In other words, they are especially likely to be perceived to certain extent, even when they are outside the focus of spatial attention.

Williams, Bradshaw & Mattingley (2005) conducted series of experiments using visual search paradigm to investigate whether faces displaying emotional expressions have an advantage in attracting attention over neutral faces. They also examined if threatening facial expressions are more efficient at capturing attention than nonthreatening expressions.

To investigate whether positive and negative facial expressions capture attention, Williams et al. (2005) evaluated the efficiency of visual search for happiness and sadness in the first two experiments of their study. They found that happy faces among neutral distractors are detected faster than neutral faces among happy distractors. Similarly, participants were faster to detect a sad face surrounded by neutral distractors than vice versa. These findings suggest that sad and happy faces attract attention more effective than neutral faces, which is in conformity with the emotionality hypothesis.

In their final experiment, Williams et al. (2005) directly compared search times for threatening (fearful and angry) and nonthreatening (sad and happy) facial expressions.

In all of these four conditions, distractor facial expressions were neutral. Contrary to expectations, search times were approximately same for threatening and nonthreatening faces. Happy and angry faces were located faster than sad and fearful faces. Even though fearful faces are generally considered to indicate potential threat (Williams et al., 2005), they were not detected faster than sad or happy faces.

In interpretation of these surprising results, Williams et al. (2005) referred to Öhman & Mineka (2001), who suggested that angry facial expressions attract attention because they are processed by mechanisms that have evolved to alert us of danger, and according to that theory angry and fearful facial expressions should attract attention more effectively compared to nonthreatening stimuli. Although at first glance Williams et al.'s (2005) findings are not consistent with Öhman & Mineka's (2001) proposal, Williams et al. (2005) offered an alternative interpretation. They hypothesized that an angry face and a fearful face do not express equivalent types of threat. On the contrary, an angry face transmits potential danger signals from that particular individual, while a fearful face signalizes that potential threat is somewhere else in the environment. Thereafter, focal attention is allocated to an angry face because it is the source of danger, but rather than allocating attention to a fearful face, it is directed elsewhere to locate the threat (Williams et al., 2005).

Although all the studies mentioned above addressed the «threat vs. negativity vs. emotionality» question, it remained unanswered. One of the central aims of the present study is to contribute to the solution of that puzzle, by investigating which affective component (threat, emotionality or negativity) facilitates detection of facial emotions. Special attention will be devoted to Williams et al.'s (2005) hypothesis that fearful faces reflect spatial attention in order to perceive the source of their fear, which is located elswhere in the environment. Approbation of that speculation would be a strong pro argument for evolutional threat hypothesis.

1.2 Fear and surprise – independent facial expressions or not?

Are there cross-cultural differences in expressing and recognizing facial expressions of emotions? According to the oldest theories, no. Prominent early researchers claimed that emotions are innate and independent of culture (Darwin, 1872), and the first extensive experimental studies corroborated that concept.

One of the most notable living scientists representing the universality view is Paul Ekman. Inspired by Darwin's research, he believes that six prototypical emotions (anger, disgust, fear, happiness, sadness and surprise) are expressed and recognized universally, irrespective of culture (Ekman, 1982).

Although some of the relatively recent theories discard the extreme universality perspective, and approve the relevance of cultural specificity (e.g. Markus & Kitayama, 1991; Mesquita & Frijda, 1992; Russell, 1994; Fiske, Kitayama, Markus & Nisbett, 1998; Shiori, Someya, Helmeste & Tang, 1999), many studies are in accordance with this Ekman's view: people from various cultures are reported to uniformly understand, experience, recognize and express facial expressions of emotion (e.g. Ekman, Sorenson & Friesen, 1969; Ekman & Friesen, 1971; Izard, 1971; Borod & Caron, 1980; Matsumoto & Ekman, 1989).

The strongest empirical arguments pro genetically determined and universal nature of facial expressions were provided by Ekman & Friesen (1971) and Ekman, Friesen & Ellsworth (1972). Members of preliterate «stone-age» New Guinean tribe, who participated in their study, were presented with photographs of American students. Even though the natives were never exposed to any segment of the Western civilization, they managed to accurately judge facial expressions.

Another group of natives were told an emotional story and asked to express the concerning emotion on their face. They produced the same expressions as participants from other cultures.

In several similar experiments, Ekman and his associates compared results of different cultures estimating emotional expressions of various models also differing in culture, and found strong evidence for universality of six prototypical emotional facial expressions (anger, disgust, fear, happiness, sadness and surprise) practically across the entire humankind: United States, New Guinea, Japan, Chile, Argentina and Brazil (Ekman, 2003).

Nevertheless, there were two exceptions from these results. New Guineans could not discriminate between facial expressions of fear and surprise. When they were asked to express basic emotions, they again confused the same two emotions with each other (Ekman & Friesen, 1971; Ekman et al., 1972).

In one of the most recent studies, which was composed of two experiments, Calvo & Lundqvist (2008) examined identification of all 6 basic facial emotional expressions (together with neutral expression) under different display-duration conditions. In order to examine identification thresholds, they presented each face under free-viewing condition, and also for 25, 50, 100, 250 and 500 ms. They always presented only one face per display, and told the participants to identify the facial expression. Their task was to respond as soon as possible by pressing one of seven keys, each of which corresponded to one facial expression. Analyses have shown that happy and neutral expressions were identified faster and more accurate than all other expressions (identification threshold was especially low for happy facial expression), while identification of fearful expressions was the slowest and the least accurate. Accuracy and reaction time for identification of angry, sad, disgusted and surprised expressions differed only slightly between themselves. Detection of all these four expressions was faster and more accurate when compared to detection of fearful expressions, and slower and less accurate when compared to neutral or happy expression. Calvo & Lundqvist (2008) then analyzed errors of misperception among expressions, and found that anger was misinterpreted as disgust (and vice versa), sadness was misinterpreted as fear or disgust and surprise was misinterpreted as fear (and vice versa). Other types of errors made by participants were not significant. Only two misinterpretations occurred in more than 10% of trials: the misclassification of surprised faces as fearful and vice versa.

A similar study was conducted a few years earlier by Palermo & Coltheart (2004). The major difference between their and Calvo & Lundqvist's (2008) study, was the stimuli database: while Calvo & Lundqvist (2008) used Karolinska Directed Emotional Faces (KDEF) database, which was developed by Lundqvist, Flykt & Öhman (1988), Palermo & Coltheart (2004) obtained their stimuli from Ekman & Friesen's (1976) Pictures of Facial Affect (PFA), and from databases of Gur, Sara, Hagendoorn, Marom, Hughett, Macy, et al. (2002), Mazurski & Bond (1993), Tottenham, Borscheid, Ellertsen, Marcus & Nelson (2002), and Watson (2001). Conclusions of these two studies are consistent. Palermo & Coltheart (2004) found that happiness is recognized most rapidly, most accurately, and that it is very rarely (in less then 1% of trials) confused with other expressions, while fear was recognized more slowly and less accurately than any other expression.

The finding that happy faces are recognized more quickly and more accurately than any other expression was reported in several prior research (e.g. Feyereisen, Malet & Martin, 1986; Leppänen, Tenhunen & Hietanen, 2003; Maxwell & Davidson, 2004; Juth, Lundqvist, Karlsson & Öhman, 2005).

Analyses of types of errors in Palermo & Coltheart’s (2004) study revealed that participants had most problems with discriminating fearful from surprised faces: in 31.1% of trials, fearful faces were misinterpreted as surprised. Fearful faces were also often confused with surprised faces in other studies (Adolphs, 2002; Rapcsak, Galper, Comer, Reminger, Nielsen, Kaszniak et al., 2000; Huang, Tang, Helmeste, Shioiri & Someya, 2001). Russell (1994) also reports a deficit in the identification of fearful faces.

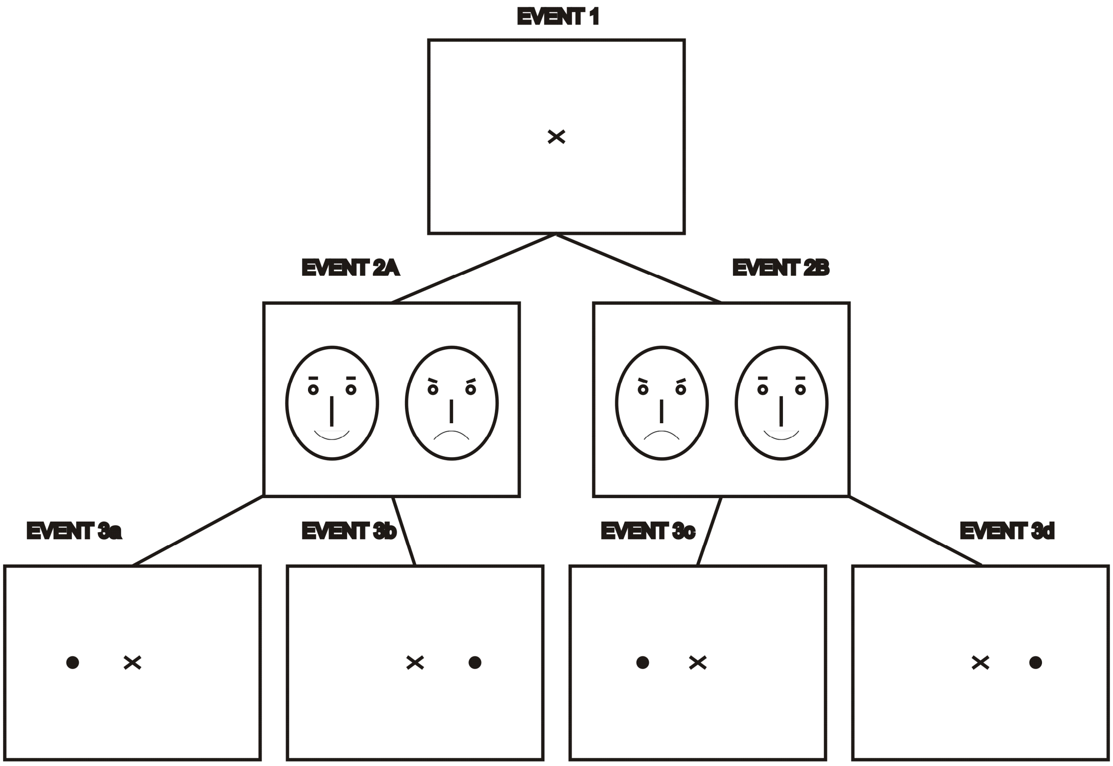
Although Palermo & Coltheart (2004) and Calvo & Lundqvist (2008) failed to realize that, their mutual finding that facial expressions of fear and surprise are often replaced one for other, in fact triggers the reopening of dilemma dating from the early 1970s, which is going to be set up as one of the problems of the present study: are there six prototypical facial expressions as Ekman claims, or there are only five of them, because fear and surprise can be considered as the same expression?

1.3 Overview of methods for investigating the effects of facial emotional expressions on attention

As it can be concluded from the studies presented so far, visual search task is the most popular paradigm in the research of attentional capture (Figures 1, 2, 3). In this psychophysical method 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 (distractors) exhibit another emotion. In the other half of the trials, all facial expression are identical. Participants have 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). In the first type of analyses, only trials containing a discrepant face are evaluated. The logic is simple: search asymmetries are analyzed and reaction time is in negative correlation with attentional capture efficiency. In the second type of analyses, only trials with all identical facial expressions are considered, and dwell time is then analyzed. Dwell time is a measure of speed that participants reach while searching for a discrepant face through a crowd of identical facial expressions. Dwell time correlates positively with attentional capture intensity of a specific emotional expression: visual search through a crowd of facial expressions that capture attention effectively is slow because each such facial stimulus tends to hold visual attention and therefore slows down the attentional shift to another stimulus, and consequently decelerates search speed (e.g. Fox et al., 2000).

Another common procedure within the visual search paradigm is varying a set size and measuring search efficacy via search slopes. Search slope is the relationship between search time and the number of distractors (e.g. Wolfe, 1998). If introduction of additional stimuli does not result with significant prolongation of search time, the target is then thought to capture attention (e.g. Williams et al., 2005). Complete insensitivity of search time to the number of distractors indicates automatic capture of attention by a target (Treisman & Souther, 1985). Naturally, such logic is valid only for trials containing a discrepant face.

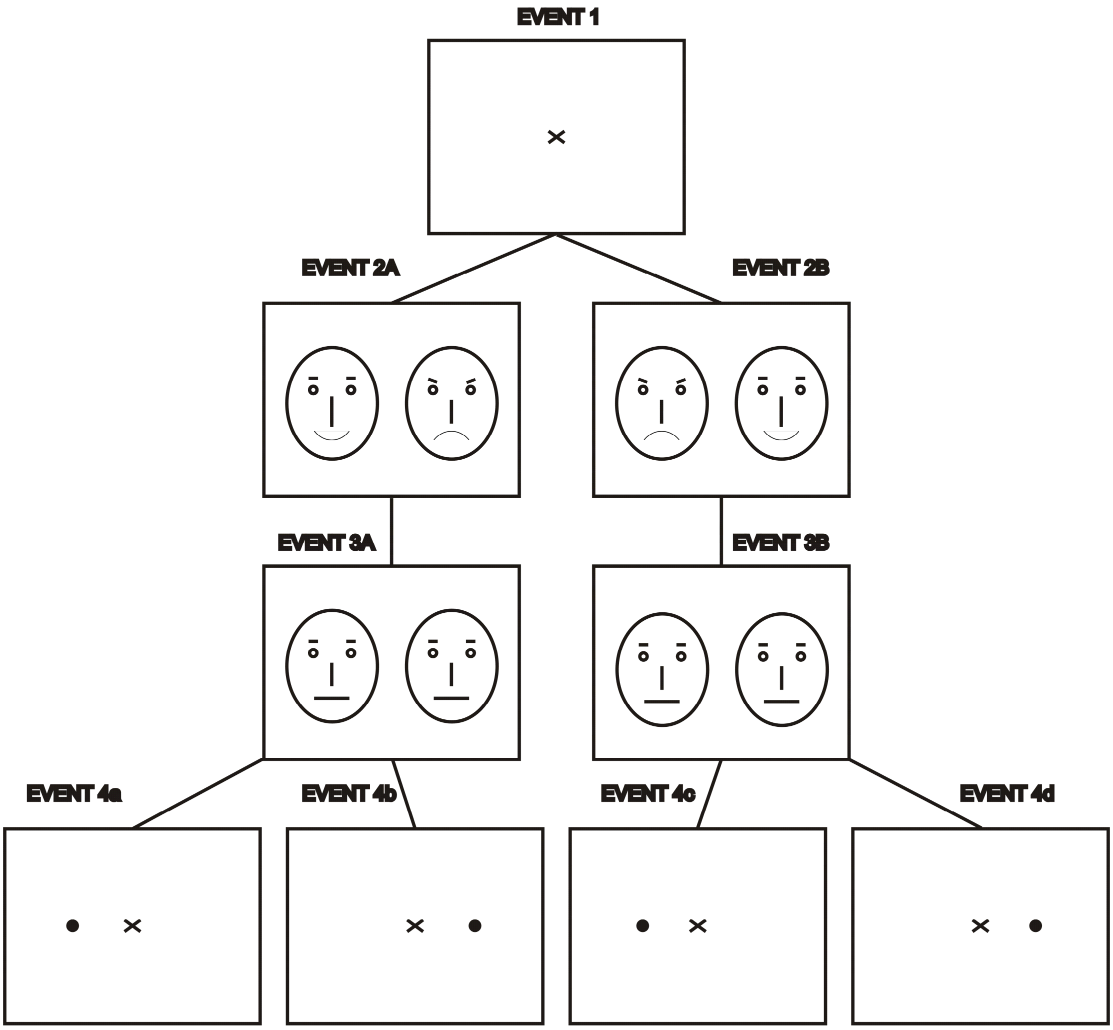
Figure 4. Dot probe task. Participants have to answer where the dot is (in the left or in the right side of the display) as fast as possible. Reaction time is shorter for Events 3b and 3c compared to Events 3a and 3d, because attention is allocated to a region of display in which a threatening stimulus is presented.



The next method for measuring the directing of attention to a specific type of stimuli is the dot probe task. This paradigm is usually used to assess selective attention, especially to threatening stimuli. These tasks begin with presentation of a fixtion mark in the center of the display. After fixation mark, two stimuli (one threatening and one nonthreatening) 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 two stimuli (Figure 4). Participants' task is to indicate the location af the dot. The logic is simple: reactions are expected to be faster if the dot is presented in an attended region of visual display. 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 (Broadbent & Broadbent, 1988; MacLeod & Mathews, 1988; Mogg & Bradley, 1999; Armony & Dolan, 2002; Fox, 1993, 2002; Hunt, Keogh & French, 2006; Pourtois, Grandjean, Sander &

Vuilleumier, 2004; Beaver, Mogg & Bradley, 2005; Pourtois, Schwartz, Seghier, Lazeyras & Vuilleumier, 2006).

Figure 5. Dot probe task with backward masking. In Events 3A and 3B, masks are presented in order to limit the extent of processing of stimuli presented in Events 2A and 2B. However, reaction time is shorter for Events 4b and 4c compared to Events 4a and 4d, even if stimuli in Events 2A and 2B are presented subliminally.



In a modified version of a dot probe task, backward masking is used in order to limit the extent of the processing or to completely prevent the awareness of stimuli (Figure 5). This procedure allows studying the role of perceptual awareness in emotional processing. In such a technique, briefly presented target visual stimuli are immediately followed by masking stimuli. Even when masked target stimuli are not consciously perceived, they can influence cognitive processess of the observer (e.g.

Whalen, Rauch, Etcoff, McInerney, Lee & Jenike, 1998; Mogg & Bradley, 1999). Backward masking paradigm procedure can be used independently of the dot probe tasks if that is required by the experimental design.

Eye movement monitoring paradigm 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 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 usually combined with visual search task paradigm (e.g. Bradley et al., 2000; Calvo et al., 2006; Reynolds, Eastwood, Partanen, Frischen & Smilek, 2009).

1.4 Change detection and cognitive processes

Change detection paradigm is a method which is in a wide range of its variations often used in various areas of psychological research. The core of the procedure is mutual to all its subcategories and it comprises of two or more displays which can differ in some segment. These displays are presented to participants, and their task is to answer if they are identical or not. Accuracy of responding and reaction times are then measured and analyzed (Rensink, 2002).

1.4.1 Change detection and attention

One of the most fascinating studies based on change detection paradigm is Simons & Levin's (1998). The experimenter who was walking down the street holding a map, approached a passer by and asked him if he could show him a direction to a nearby building. After 10-15 seconds of their conversation, two experimenter's assistants approached them. They were carrying doors and passed between the experimenter and the passer by. During that short period of time (about 1 second), participant's view was covered by the doors, and exactly at that time the experimenter who asked for direction seized the back part of the doors and began to walk after the first assistant-carrier. The second assistant, who carried the doors till that moment, released them, remained to stand on the same spot the experimenter was standing at, and continued to listen to passer by's instructions. Even though the experimenter and his assistant that replaced him differ in height, physical structure, clothing, hairstyle and voice, less then 50% of participants noticed the change! That phenomenon is known as change blindness, and it is defined as an inability to detect various changes in visual environment.

Inattentional blindness is a familiar phenomenon, and it can be described the most illustratively by Simons & Chabris 's (1999) experiments. Although it seems unbelievable, their participants failed to notice a man wearing a gorilla suit walking through a basketball field, because they were instructed to direct all avaliable attentional resources to a particular segment of game (eg. they had to count ball passes). Similarly, Haines (1991) conducted experiments with a flight simulator, and found that when experienced pilots have a task to land their plane, they direct all their visual attention to the control panel, and as a consequence they do not percive a clearly visible aircraft blocking a runway, which is located just in front of them. When they finaly noticed it, it was too late to avoid collision. As it is shown in these two examples, inattentional blindness is defined as the inability to spot conspicuous objects (even if they are directly looked at) because attention is directed elsewhere (Mack, 2003).

Therefore, although people are convinced that they can detect almost any change in their visual field (Levin, Momen, Drivdahl & Simons, 2000; Levin, Drivdahl & Momen, 2002), that is not correct. We are strikingly unsuccessful in detecting changes, even when they are large, anticipated, and repetitive (Simons & Levin, 1997; Rensink, 2000a; Simons & Ambinder, 2005; Simons & Rensink, 2005).

But, why are we so poor at detecting changes? Rensink, O'Regan & Clark (1997) believe that the main reason for change blindness is attention. They reckon that a change in a display can be perceived and detected only if attention is directed to the area of display where change occurs, and to investigate that experimentally, they used a flickering paradigm – a variant of change detection paradigm in which original and modified displays are swapping until participant detects a change. Specifically, in each trial they presented two similar, but not identical photographs (each photograph was visible for 240 ms), which alternated continuously. The presentation of photographs was divided by short (80 ms) blank intervals, and it lasted until the participants detected a change. Results have shown that it was very difficult for participants to detect changes, and that is in conformity with Rensink et al.'s (1997) hypothesis that attention is crucial for detecting a change. In explanation, Rensink et al. (1997) stated that change blindness observed in other variants of change detection paradigm (e.g. procedures in which change occurs only once during an inter-stimulus interval or during a saccade) can be explained alternatively (e.g. lack of time for constructing adequate representations of scenes), but not in this experiment. Another finding also goes in favour of the same hypothesis: the area of photograph at which change was occurring had a significant effect on time needed for detecting a change. Even when the size of changing objects was held constant, if a change occurred on a central part of a photograph (either on a central object, or on a central region) it was perceived easily, while marginal changes were detected hardly.

Although they were unable to give a detailed model of attentional mechanisms involved in change detection, Rensink et al. (1997) concluded that allocation of attention enables storage into visual working memory (as Coltheart, 1980, and Irwin, 1991, claimed), and therefore consequently allows comparisons of scenes detached by short inter-stimulus intervals. At the same time, representations of objects from areas that did not receive attention are deleted, and their space is taken by representations of other objects that appear there later. In other words, a relatively long time required for the detection of a change in Rensink et al.'s (1997) experiment suggests that change detection is an active search process in which attended individual objects of a scene are encoded into visual working memory, and then compared to representations of objects from another scene. Grounds of that theory are strong, because participans had difficulties detecting a change although inter-stimuli intervals lasted only 80 ms. If the allocation of attention did not have a crucial function as Rensink et al. (1997) claimed, changes would be detected extremely easily by virtue of iconic memory, which lasts more than 80 ms.

Nevertheless, other studies have shown that although attention is necessary for successful change detection, it is possible that changes on attended areas of displays remain unnoticed (e.g. Ballard, Hayhoe & Pelz, 1995; Simons, 1996; Levin & Simons, 1997; Simons & Levin, 1997, 1998).

Attentional capture phenomenon was well explained by Mack & Rock (1988), Simons (2000a) and Mack (2003). Research of attentional capture reveals that capture can be explicit or implicit. Explicit attentional capture refers to situations when an unattended stimulus attracts attention, and a consequence of that is consciousness of its presence (e.g. when somebody waves from the other side of a room, we direct attention there and become aware of the person waving). Research of explicit attentional capture revealed that observers are unable to notice other objects if they are focused on some other event, and as mentioned earlier, that phenomenon is called the inattentional blindness (Simons, 2000a). The goal of such research is to investigate what types of changes are noticable, and it has been found that participants are poor in detecting practically any kind of unexpected changes (e.g. Levin & Simons, 1997; Simons & Levin, 1997; Simons, 2000b) or emerging objects (Neisser, 1979; Rock, Linnett & Grant, 1992; Newby & Rock, 1998; Mack & Rock, 1998; Simons & Chabris, 1999). Only recently, Franconeri and his associates found that attention is easily captured by a change of luminance of an object or of the area of display where the object is located (Franconeri & Simons, 2003; Franconeri, Hollingworth & Simons, 2005).

Mack, Rock and their associates developed a paradigm for investigating attentional capture and inattentional blindness (Rock et al., 1992; Newby & Rock, 1998; Mack & Rock, 1998). Mack & Rock (1998) presented crosses to participants, and gave them a task to answer which part of the cross is longer. Several such trials were followed by a critical trial, in which an unexpected object was presented along with a cross. Half of participants did not notice an unexpected object – it did not explicitly capture their attention, although it might have an implicit effect on their performance. However, reviewers criticised that and similar experiments because the presentation of stimuli was short and static. Because of these characteristics stimuli were thought to be unable to attract attention. As a consequence, selective looking paradigm became more popular.

Selective looking paradigm was first developed by Neisser and Becklen together with their associates (Neisser & Becklen, 1975; Neisser, 1976; Littman & Becklen, 1976; Neisser, 1979; Becklen & Cervone, 1983; Stoffregen & Becklen, 1989). The first study using that paradigm was a well-known Neisser & Becklen's (1975) experimental classic. They simultaneously presented two films to their participants, one over another, in such a manner that both films were equally faintly visible all the time. One film was showing a game of hand clapping, while the other presented three basketball players passing a ball. Participants were instructed to carefully watch one of two films, and after some time a critical trial occurred. In a critical trial, something unexpected happened in the ignored scene. In one critical trial models stopped hand clapping game and shook hands, while in the other critical trial the ball disappeared and basketball players continued to pass an imaginary ball. Results have shown that when attention was directed to one scene, an unexpected event in the other scene failed to attract attention. These results undoubtedly indicate that likelihood of attentional capture is reduced if attention is already engaged to a particular object, event or a region of space.

1.4.2 Change detection and the nature of visual representations

Various prominent experts claim that visual system never forms coherent detailed representations of the world surrounding us (e.g. Marr, 1982; Dennet, 1991; Grimes, 1996; O'Regan, 1992; Becker & Pashler, 2002). Earlier studies based on different methods supported that view – their results indicated that there are no precise visual representations which are able to «survive» at least a blink or a saccade (Simons & Levin, 1997). Philosopher Noe (2005) even took an extreme standpoint ragarding that question, and rejected «the representationalistic view» in its entirety.

According to coherence theory of attention, which is elaborated in detail by Rensink (2000a, 2000b, 2000c), a change of a stimulus can only be detected if attention is directed to it during the change. Only attended areas of displays (divided by inter-stimulus interval) can be successfully compared, and the lack of successful comparisons results in change blindness. Since attention can be simultaneously directed to not more then 4 objects (e.g. Pylyshyn & Storm, 1988), majority of a scene will not have detailed coherent representations. In other words, coherence theory indicates that our perception is based on representations, quality of which differs from the quality of the world they represent: our visual representations of the world surrounding us are not detailed nor stable. According to Rensink (2000a, 2000b, 2000c), instead of durable static representations (such as Marr's, 1982, primal scatches or intrinsic images), dynamic virtual representations are the bases for visual perception. These representations have limited the amount of details[2], but they are always accessible, making it appear as if all the detailed, coherent structure is present simultaneously. In other words, vision is a dynamic process, guided by a system whose representations are in a constant flux. Focused attention is a precondition for stabilization and coordination of these dynamic representations, and these processes lead to successful detection of changes.

[2] Rensink (2000a) believes that our representations contain less than 10% of information about a scene we are viewing.

On the other hand, authors of the most recent research oppose Rensink. Simons (2000b), Hollingworth, Williams & Henderson (2001), Hollingworth & Henderson (2002), Hollingworth (2003), Simons & Rensink (2005), Simons & Ambinder (2005), and Varakin & Levin (2006) emphasize that poor detection of changes does not have to imply that people form scarce representations. Mitroff, Simons & Levin (2004) discovered that some information are maintained although participants do not detect a change, and even the extreme Noe (2005) admits that change blindness phenomenon is compatible with the presence of internal representations (Noe, Pessoa & Thompson, 2000; Noe, 2005). In explanation, for a successful detection of a change, it is necessary to form representations of the first and of the second scene, and to compare them afterwards. Provided that attention is not directed to a changing object, it is possible that a change is not detected although representations of both scenes were formed. Thus, change blindness can be a consequence of unsuccessful comparison process (Scott-Brown, Baker & Orbach, 2000; Hollingworth & Henderson, 2002; Angelone, Levin & Simons, 2003; Mitroff et al., 2004) or a consequence of the inability to retain representations from the first scene (Landman, Spekreijse & Lamme, 2003). For example, it was demonstrated that observers can recognize the object they perceived before a change and also the modified object, on a memory recognition test, even though they failed to detect a change on that object (Hollingworth & Henderson, 2002; Mitroff et al., 2004; Castelhano & Henderson, 2005). In addition, it is also possible that changes are difficult to detect due to severe limitations of visual working memory capacity (Vogel, Woodman & Luck, 2001; Wheeler & Treisman, 2002; Alvarez & Cavanagh, 2004; Švegar, 2008): visual representations may be easily built, but only some of them can be retained in working memory.

Most recently, Hollingworth (2006) investigated whether visual representations of objects merge with a context of a scene as Zelinsky & Loschky (2005) and himself speculated. His participants looked at photographs, and after 20 seconds a mask was presented in duration of 1 second. At the end of each trial, two pictures followed the mask. In the first condition, one of the two pictures was identical to the initial photograph, while on the other one, one of the objects was rotated or changed. In the second condition, mask was again followed by two pictures, only this time background was removed. Only the object that might have changed was presented.

Naturally, in one picture that object was identical as the corresponding object from the initial picture, while in the other picture it was rotated or changed. In both conditions participants had to answer which of two test pictures did not contain a change. Responding was more accurate in condition where background was present, and that corroborated the hypothesis that representations of objects are stored as parts of large representations of scenes.

1.4.3 Change detection and visual working memory

Philips (1974) was one of the first researchers who used change detection paradigm to investigate visual working memory. He exposed his participants to tachistoscopical presentation of displays filled with dots. Each trial consisted of two displays separated by a flexible inter-stimulus interval. Displays within a trial were either identical, or differed in the addition or the removal of one dot. Analyses of participants' performance have shown that accuracy of responding was nearly 100% with short inter-stimulus intervals (shorter then 100 ms), while the prolongation of retention interval resulted in a decreased change detection accuracy. These experiments were extremely valuable because they have brought detailed insight into the nature of iconic and working memory, and clarified boundaries between them: iconic memory has a vast capacity, but very short duration, while visual working memory is capable of storing only a small amount of information, but can maintain them for a longer period of time (Phillips, 1974). Since the early 1970s and Phillips, change detection paradigm became the most popular procedure for investigating visual working memory.

Pashler (1988) was the first author who managed to construct a procedure for quantifying visual working memory capacity, and in his experiments he used similar paradigm as Phillips (1974). Alvarez & Cavanagh (2004) and Švegar (2008) developed improved methods for estimating visual working memory capacity, also following Phillips's (1974) pioneering method. The conclusions of these and other studies (e.g. Vogel et al., 2001; Wheeler & Treisman, 2002) are consistent regarding visual working memory capacity and indicate that not more than 4 objects can be simultaneously stored in it.

Besides approximating visual working memory capacity, Vogel et al. (2001) were occupied with another important problem within the same study: does the storage of multi-feature objects occupy more working memory capacity than the storage of single-feature objects? In order to examine that, they used lines defined by color and orientation as stimuli. In the *color* condition, participants were required to remember only the colors of the bars, while in the *orientation* condition they had to memorize only the orientations. In the *conjunction* condition, they had to memorize the colors and the orientations of the bars, because any of these features could change during the retention interval. Thus, when *n* lines were presented, participants had to memorize information about *2 x n* features in the conjunction condition, while in each of the other two conditions, they had to memorize information about only *n* features. Statistical analyses revealed that their participants performed equally well in all three conditions. They were as successful in retaining information about both features (color and orientation) as in retaining only one feature. This finding encouraged Vogel et al. (2001) to conclude that objects are stored into visual working memory in an integrated manner rather than as separate features. That consequently means that visual working memory capacity is not limited by the number of features, but by the number of objects that have to be stored. Several control experiments corroborated that theory. Vogel et al. (2001) even managed to demonstrate that objects defined with four features do not occupy more space in visual working memory than single-feature objects.

Following their striking findings, Vogel et al. (2001) composed a theory about a neural storage mechanism. The starting point of the theory is the proposal given by several researchers (e.g. Gray, König, Engel & Singer, 1989; Hummel & Biederman, 1992), that separate neurons which code individual features of the same object can bind together through their synchronized neural firing during visual object identification.

Elevated firing rates of neurons, which code certain features of objects is the first component of storage of objects into visual working memory. However, when multi-feature object have to be coded, elevated firing rates are not sufficient for an adequate coding. In that case, Vogel et al. (2001) illustrate that it would be simple to represent a red vertical bar in working memory (due to the sustained firing of red-selective and vertical-selective neurons), but impossible to represent a red vertical bar together with green horizontal bar (because of the inability to distinguish between a memory for red horizontal and green vertical bar from a memory for red vertical and green horizontal bar). Therefore, Vogel et al. (2001) introduce a second component into their model – a component that enables binding of different features of an object. That additional binding mechanism has the semblance of Hebb's (1949) cell assembly. The neurons inside a cell assembly fire synchronously with each other, but asynchronously with neurons of other cell assemblies. For illustration, when a red vertical and a green horizontal bar are presented simultaneously, neurons coding red and neurons coding vertical fire synchronously to each other, but asynchronously with respect to neurons coding green and to neurons coding horizontal. This model assumes that each neuron has two output values: first of them indicates which object is coded by that neuron, while the second indicates the extent to which the feature coded by the neuron is present. In other words, firing rate provides information about features that are present, while via synchronization it can be specified which object is composed of which features.

Wheeler & Treisman (2002) took a different standpoint. They claim that visual working memory capacity is limited by the number of features rather then by the number of objects that need to be stored. According to their theory, features from different dimensions (such as color, shape, orientation etc.) are stored into parallel stores in such a manner that each dimension has its own independent store. Inside each such parallel feature-specific memory store, features compete over limited capacity, but between the stores there is actually no rivalry.

Besides the described parallel feature-specific memory stores, Wheeler & Treisman's (2002) model also presumes the existence of integrations between features. Integrated information (*chunks*) can be retained in visual working memory if that is required, but such maintenance (as well as encoding) is heavily dependent on attentional resources (e.g. Horowitz & Wolfe, 1998; Wolfe, 1999; Rensink 2000c). Perceiving, encoding and retaining information as integrated wholes will be impaired in case of absence of attention.

To recapitulate, Wheeler & Treisman (2002) claim that in the condition when the task does not require binding of features, they are stored into separate stores (which do not compete amongst themselves), each of which has limited capacity. However, when people are required to memorize integrated objects, features can still be stored into parallel stores, but links between these features can be retained via separate mechanism that relies on limited resources (primarily on attention). In a sequence of experiments (which are too complex and not directly relevant for the present study to be described here) Wheeler & Treisman (2002) managed to confirm their theory. Also, the results of two later studies (Alvarez & Cavanagh, 2004; Švegar & Domijan, 2007) corroborate the model of Wheeler & Treisman (2002).

All of the experiments mentioned above were based on the change detection paradigm, and even today, that paradigm is the most common procedure for investigating visual working memory.

1.4.4 Change detection and consciousness

Even unattended information can reach consciousness. An excellent example pro that claim is a cocktail-party phenomenon: people can easily detect that someone articulated their name even if they are engaged in a conversation and surrounded by other people who talk amongst themselves. Most, Scholl, Clifford & Simons (2005) believe that other visual information, which do not reach consciousness, are also similarly processed.

Simons & Rensink (2005) emphasize that the connection between attention and consciousness is asymmetrical: although attention is needed for conscious perception of a change, it is sometimes not sufficient, especially when participants do not expect a change (e.g. Williams & Simons, 2000; Triesch, Ballard & Hayhoe, 2003).

Although in real life situations explicit attentional capture and awareness of a certain stimulus is much more important, implicit or unconscious perception is also often investigated. In the research of implicit attentional capture, stimuli irrelevant for the participants' task are presented together with relevant stimuli. Eye movements and time required for completing the task is then measured. In this way Theeuwes (1994) and Theeuwes, Kramer & Hahn (1998) demonstrated that in visual search tasks participants focus attention to irrelevant objects even when they are known to be irrelevant (for example to a blue object in an array of red ones, or to an object presented with a delay). Participants direct attention to such objects, and they are usually not aware of that. Even subliminally presented stimuli can implicitly capture attention and affect performance (McCormick, 1997). These findings, together with Kentridge, Heywood & Weiskrantz's (1999, 2004), undoubtedly prove that certain proportion of visual perception surely takes place unconsciously.

Since objects of central interest capture attention more easily compared to objects of peripheral interest (e.g. Rensink et al., 1997), it seems that the meaning of objects is analysed before attentional capture. Accordingly, even the stimuli that did not capture attention had to be processed, because on the contrary it would not be possible to establish which objects are of central interest, and which are not (Mack, 2003). If that is indeed so, does that mean that we really process and evaluate every single stimulus that reaches our retina? Lavie (1995) made an attempt to answer this difficult question. He speculated that perception is a limited capacity process and that processing is mandatory up to the point that this capacity is exhausted. Accordingly, the extent to which unattended objects are processed is a function of the difficulty of the perceptual task. In a condition of high perceptual load, only attended objects are encoded, but otherwise all stimuli are processed, including the unattended ones. Yet, Mack, Pappas, Silverman & Gay's (2002) finding that observers see their own names even when they are presented among stimuli that must be ignored in order to perform a demanding perceptual task, disproves Lavie's (1995) theory.

Attention and consciousness is well integrated in Neisser's (1976) perceptual cycle model, which was later enhanced by Most et al. (2005). Such a model explains top-down and bottom-up processing at the same time. According to it, stimuli do not enter consciousness immediately when attention is allocated to them – conscious perception is on the contrary determined by cyclical process of visual interpretation and reinterpretation. After an initial directing of attention, expectations (which are based on limited preconscious information) govern its further orientation. Each attentional shift provides new information, and they modify observer's interpretation of stimuli.

Such cycle of attentional guidance continuously enriches oncoming representations and modifies observers expectations. The result of such a process is a conscious percept (Most et al., 2005). That model was experimentally proven to be valid by Most et al. (2005), who conducted series of experiments, task of which was to track moving objects. As an illustration, in one of their experiments, trials consisted of eight stimuli differing in color (four of them were black and four were white), which moved in various directions randomly, and participants had to track either white or black stimuli and to count the number of bounces they make of the display edges. In critical trials, a new stimulus would appear at the edge of a screen, and started to move horizontally over the display. Participants were asked if they had noticed the stimulus moving horizontally, and the analyses of the results have shown that the observation of that critical stimulus depends on attentional set: critical objects were noticed easily only if they were visually similar to objects participants were tracking.

In the last few years, the relationship between consciousness and perception is intensively researched, and probably the most controversial study regarding that subject was carried out by Rensink (2004)[3]. Using a flicker paradigm, he presented pairs of photographs divided by 80-ms inter-stimulus intervals. Three types of changes were possible: appearance or disappearance of object, color changes and changes of location. Participants were instructed to respond twice: the first time when they sense a change (when they have a feeling that a change is occuring), and the second time when they see a change. The experiment consisted of 48 trials, 42 of which contained a change, but participants were deceived that in all 48 trials change is going to occur. Statistical analyses (which are too complex to be presented here) have shown that for approximately one third of participants, sensing a change was not a result of guessing, but an output of a certain informative process. Without seeing or locating a change, these participants were aware it had occurred. In explanation of these striking results, Rensink (2004) began with a simple hypothesis that sensing is based on the same mechanisms as seeing, but with different thresholds for responding. In other words, sensing is a weaker form of seeing which activates when mechanisms of seeing are activated in low intensity. However, Rensink (2004) discarded that view, because if sensing is a stage of perception which always precedes seeing, then a

[3] Even more controversial studies exist, but their authors are not as respectable as Rensink.

correlation between the onset of sensing and the onset of seeing relative to sensing should exist. Since there was no such correlation ($r < 0.05$), he concluded that sensing and seeing are based on processes that involve separate mechanisms. Via this study, Rensink (2004) even managed to explain the experiencing of external world through a nonsensory way – the «sixth sense» phenomenon. He speculates that the belief regarding that phenomenon may have arisen on the grounds of untrue premise that any awareness resulting from visual input must be accompanied by a corresponding visual experience. The absence of visual experience implies the absence of visual input, and that further implies the involvement of a different sensory modality – the «sixth sense». In Rensink's (2004) study, such logic is shown to be incorrect. His results show that although subjective experience of mindsight differs from the experience provided by normal vision, there is no need to assume separate modality for it.

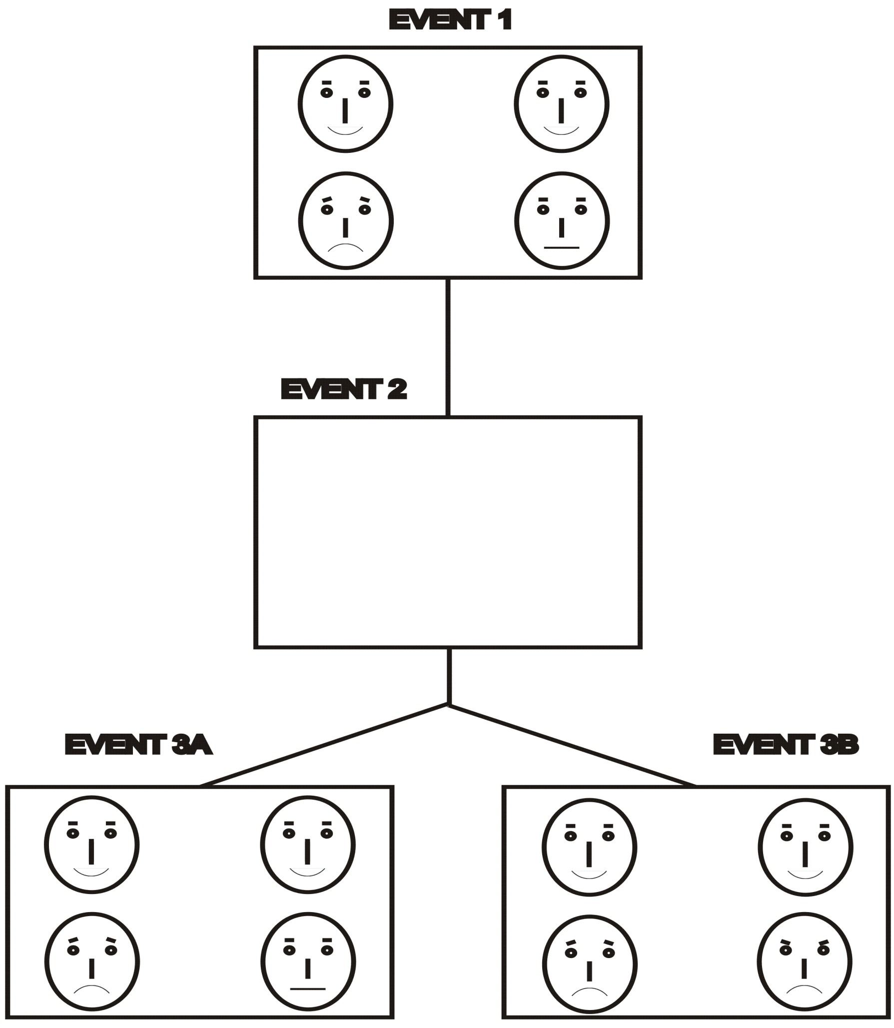
Simons, Nevarez & Boot (2005) replicated Rensink's (2004) experiments. They reckoned that Rensink's (2004) participants had already consciously detected a change when they responded «change sensed», only at that moment they were unsure, and exactly because of that they required more time to become convinced and to respond «change seen». Thus, not the sensing of changes, but the verification of changes caused a lag between the «sense» and «saw» responses, and exactly that was experimentally confirmed in Simons et al.'s (2005) study, results of which elegantly disprove Rensink's (2004) theory. The dillema regarding mindsight may remain opened, but Simmons et al.'s (2005) conservative theory is much more realistic.

1.4.5 Classification of change detection paradigm types

The best classification of change detection paradigm variations is presented in a magnifficent Rensink's (2002) overview. According to contingency of change, Rensink (2002) distinguishes eight categories. Changes can occur during interstimulus interval, in the course of a saccade, throughout a shift of the entire display, during an eyeblink, at the same time as a brief distractor (*splat*) appears, when the changing item is briefly occluded, at the moment of a cut from one camera position to another, or gradually.

Operations in which a change occurs during interstimulus interval (also known as gap-contingent techniques, because changes take place during a temporal gap between a pair of stimuli) are the most common (Figure 6), as it is visible from the studies mentioned so far (e.g. Phillips, 1974; Pashler, 1988; Simons, 1996; Luck & Vogel, 1997; Rensink et al., 1997; Vogel et al, 2001; Wheeler & Treisman, 2002; Alvarez & Cavanagh, 2004; Simons et al., 2005; Švegar & Domijan, 2007; Švegar, 2008). In the period in which the change takes place, blank screen (or sometimes a mask) is presented.

Figure 6. Gap-contingent technique (one-shot approach). After initial presentation of stimuli (Event1) a blank screen appears (Event 2). Test display follows at the end of each trial. Changes occur during the retention interval in some trials (Event 3B), or the test display remains identical as the initial display (Event 3A). This is the most common technique of all change detection paradigm variations.



Splat-contingent technique is similar to gap-contingent procedure, with a distinction that the part of the picture where a change happens is visible all the time. Instead of presenting a mask or a fully blank screen, a distractor (splat) is presented simultaneously as a change occurs on the other side of the display (e.g. O'Regan, Rensink & Clark, 1999; Rensink, O'Regan & Clark, 2000).

In contrast to splat-contingent technique in which a part of the display that does not contain a changing item is covered by a splat, in occlusion-contingent method, a change takes place while the changing item is shortly occluded. Simons & Levin's (1998) study, in which two experimenters changed while the doors covered them, is the best example for occlusion-contingent method. Such a technique was also used in experiments of Moore, Yantis & Vaughan (1999) and Rich & Gillam (2000).

Bridgeman, Hendry & Stark (1975), McConkie & Zola (1979), Grimes (1996), Henderson & Hollingworth (1999), Brockmole & Henderson (2005) and Droll, Hayhoe, Triesch & Sullivan (2005) applied a technique in which change could happen during a saccade. In these experiments change occurs exactly at the moment when the shift of gaze exceeds critical limit specified in terms of visual angle. In a very similar technique developed and explored by Sperling & Speelman (1965), a change takes place during a shift of the entire display. That operation actually simulates a saccade. In all such studies, participants are quite poor at detecting changes. For example, in the study of Blackmore, Brelstaff, Nelson & Troscianko (1995), who investigated working memory for complex pictures, participants did not manage to perform any better than random guessing. However, the main drawback of such experiments are technical flaws. For illustration, in Blackmore et al.'s (1995) study, more then 10% of the obtained data had to be discarded due to imperfection of the instrument that registers eye movement. Because of that problem, such procedures are not as popular as gap-contingent techniques.

Blink-contingent variant of change detection paradigm suffers from similar problem. Device used to register eyeblinks has severe problems with incomplete partial eyeblinks. When an observer initiates a blink, the device registers that and initiates a change, but if the eyeblink is not completed, it is very easy to detect a change. In

O'Regan, Deubel, Clark & Rensink's (2000) study, more then 10% of data had to be discarded for that reason.

In cut-contingent procedures (e.g. Levin & Simons, 1997, 2000), movie clips are presented to observers. In the first Levin & Simon's (1997) experiment, changes occurred during each of nine cuts from one camera position to another, and they involved colors of objects, posture of actors, disappearing of objects, etc. Only one of ten participants managed to notice any of the changes. In their second experiment, the only actor was replaced by another one during a cut, and such a crucial change was detected by only one third of the observers! In this, as well in Simons & Levin's (1998) study, the anticipation of change affected the results: participants could not assume that a change might occur.

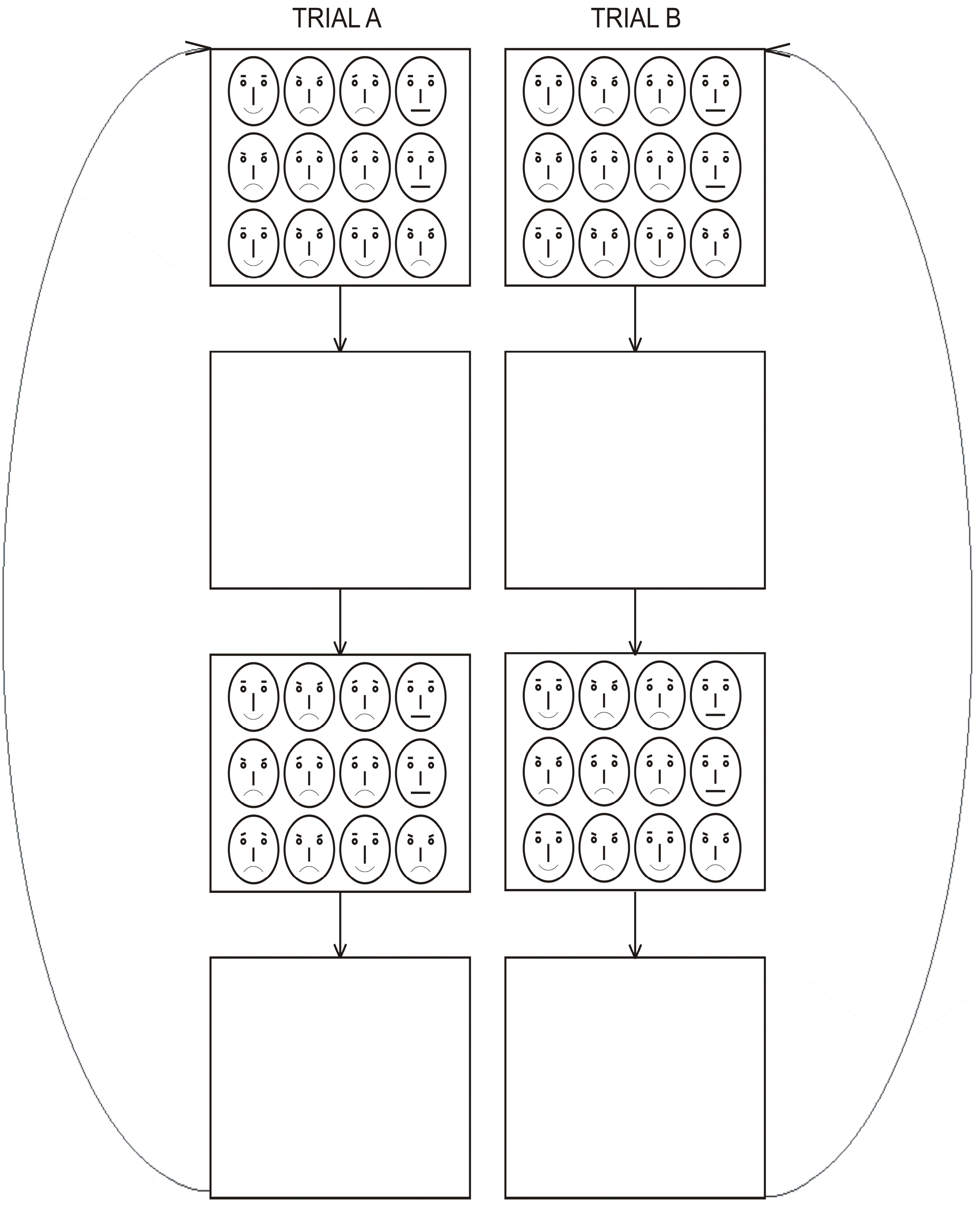
The last variant within this category is gradual change, a technique devised by Simons, Franconeri & Reimer (2000). To investigate ability of change detection, they modified their original display slowly, in a period of 12 seconds. As stimuli, they used photographs, that is, films to be more precise, in each of which one object was changing color, or fading until it completely dissapeared. Although that does not seem as a difficult task, participants were poor in detecting these changes.

Besides contingency of change, Rensink (2002) talks about repetition of change as another category, and differs *one-shot* approach and the *repeated-change approach*, which is also called the *flicker paradigm*.

In one-shot approach (Figure 6), change occurs only once within a trial (e.g. Blackmore et al., 1995; Luck & Vogel, 1997; Levin & Simons, 1997; Vogel et al., 2001; Wheeler & Treisman, 2002; Alvarez & Cavanagh, 2004; Švegar & Domijan, 2007; Švegar, 2008), while in the flicker paradigm (e.g. O'Regan et al., 2000; Aginsky & Tarr, 2000; Wallis & Bülthoff, 2000; Rensink, 2004; Hoffman, McDowd, Atchley & Dubinsky, 2005) the original and the modified display alternate until participants detect a change (Figure 7). Thus, in the repeated-change approach, the time needed to detect a change is another dependent variable. For example, Hoffman et al. (2005) conducted an interesting study using the flicker paradigm, in which they presented alternating photographs from real traffic situations to participants older then 63 years.

They modified the color of light on a semaphore, distance between vehicles location of persons passing by, etc.

Figure 7. The flicker paradigm. In Trial *A* displays alternate until the change is detected, while in Trial B displays are identical. Time required to detect a change is also measured.



The next dimension in Rensink's (2002) classification is the content of display, which varies from simple static objects presented on a computer screen to dynamic scenes in real life. The most simple displays contain dots, lines or squares (e.g. Luck & Vogel, 1997; Vogela et al., 2001; Wheeler & Treisman, 2002; Švegar, 2008), while on the other pole there are for example Simons & Levin’s (1998) and Levin, Angelone, Simons & Chabris’s (2002) experiments, in which experimenters were swapped during a conversation with participants. Between these two extremes, Rensink (2002) distinguishes three categories: drawings of objects and scenes (e.g. Simons, 1996; Henderson & Hollingworth, 1999; Scholl, 2000; Williams & Simons, 2000), photographs of objects and scenes (e.g. Blackmore et al., 1995; Rensink et al., 1997; Ro, Russell & Lavie, 2001; Brockmole & Henderson, 2005) and dinamyc displays such as Levin & Simons’s (1997) movie clips. When selecting a context of display from these five categories, experimenter has to consider an important trade-off: complexity of display content correlates positively with ecological validity – a possibility to make valid inferences about everyday human behaviour, but on the other hand, complex displays imply poor experimental control.

Apart from the contingency of change, the repetition of change and the content of display, experiments using change detection paradigm can be also classified by the content of change, observers' expectations, types of task and types of response.

According to content of change, the most simple procedure is addition or deletion of objects (e.g. Rensink et al., 1997; Aginsky & Tarr, 2000; Mondy & Coltheart, 2000). In other experiments certain simple features (color, shape, size, orientation, etc.) change (e.g. Grimes, 1996; Simons, 1996; Luck & Vogel, 1997; Vogel et al., 2001; Wheeler & Treisman, 2002, Švegar, 2008), or change refers to the relocation of objects (Wang & Simons, 1999; Jiang, Olson & Chum, 2000).

Alternatives differing by expectation of a change were mentioned earlier. Incidental approach was applied in the studies of Levin & Simons (1997) and Simons & Levin (1998), while on the other hand, Pashler's (1988), Jiang et al.'s (2000) and Wright, Green & Baker's (2000) procedures in which participants know that changes are going to occur, are called the intentional approach.

Although in the vast majority of experiments (e.g. Phillips, 1974; Verfaillie, de Troy & van Rensbergen, 1994; Luck & Vogel, 1997; Scott-Brown et al., 2000; Švegar, 2008) participants' task is to detect a change (to answer if a change had occurred or not), there are some exceptions. In some other reseach (e.g. Fernandez-Duque & Thornton. 2000; Smilek, Eastwood & Merikle, 2000), observers are required to localize changes, while Brawn & Snowden (1999) asked participants to answer if a changed object is darker or lighter then it was before it had changed.

Finally, participants responding can be explicit, semi-explicit, implicit or visuomotor (Rensink, 2002). Explicit responding is divided into two variants: «yes/no» responding, in which participant has to answer if he had or had not seen a change, and «go/no-go» responding, where participant only rsponds «yes» if he saw a change. In contrast to explicit responding, where observers respond after conscious visual experience (eg. Vogel et al., 2001; Wheeler & Treisman, 2002; Alvarez & Cavanagh, 2004; Švegar & Domijan, 2007; Švegar, 2008), semi-explicit responses are triggered by a feeling that a change is taking place, but with no visual experience involved, like in Rensink's (2004) study described earlier at the boundary between cognitive psychology and paranormal. Unlike explicit and semi-explicit, implicit responses are measured via conscious behavior which is influenced by unconsciously perceived changes (e.g. Thornton & Fernandez-Duque, 2000; Williams & Simons, 2000). At the end, there are visuo-spatial responses, such as eye-fixation to a change, or manual pointing (Bridgeman, Lewis, Heit & Nagle, 1979; Goodale, Pelisson & Prablanc, 1986; Hayhoe, Bensinger & Ballard, 1998).

In the present study, gap-contingent technique with one-shot approach was used. Because of the trade-off mentioned earlier, the content of display was moderately complex (on a 5-point complexity scale it occupies third rank). According to content of change, a variant in which one entire item is replaced by another one, was used. Before the beginning of experimental session, observers were thoroughly informed about changes that were going to occur, and their task was just to answer if a change had occurred or not. Explicit «yes/no» responding technique was applied.

1.4.6 Recapitulation

When everything presented in this chapter is considered, it is obvious that an all-embracing theory of human cognitive processes does not exsist, nor it can even be expected in the near future. So many clashes of theories took place, and although many of them were successfully resolved, many questions still remain unanswered. The only conclusion that can be made with absolutely no risk is that change detection paradigm is a constant in the research of various human cognitive processes, such as attention, vision, working memory and even consciousness. However, that procedure has practically never been used in the research of human emotional expressions. In the present study, such an attempt is going to be made.

1.5 Facial stimuli databases and methodological issues

In a mass of various facial stimuli sets, three of them will be presented here, each of which include all six prototypical facial expressions (together with neutral).

One of the oldest sets of emotional facial expressions is Ekman & Friesen's (1976) *Pictures of Facial Affect* (PFA). The PFA contains 110 black and white frontal-view photographs of Caucasian models. Although published more then 40 years ago, these stimuli are still popular amongst various researchers. They are used in numerous recent studies (e.g. Calder, Young, Rowland, Perrett, Hodges & Etcoff, 1996; Blair, Morris, Frith, Perrett & Dolan, 1999; Harmer, Bhagwagar, Perrett, Völlm, Cowen & Goodwin, 2003; Somerville & Whalen, 2006; Wu, Xu, Dayan & Qian, 2009).

Lundqvist, Flykt & Öhman's (1998) *The Karolinska Directed Emotional Faces* (KDEF) is leastwise as popular as the Ekman's (1976) PFA, in particular recently (e.g. Schupp, Öhman, Junghofer, Weike, Stockburger & Hamm, 2004; Singer, Kiebel, Winston, Dolan & Frith, 2004; Adolphs, Gosselin, Buchanan, Tranel, Schyns & Damasio, 2005; Eisenbarth, Alpers & Pauli, 2005; Holmes, Winston & Eimer, 2005; Harrison, Singer, Rotshtein, Dolan & Critchley, 2006; Juth et al., 2005; Kolassa & Miltner, 2006; Putman, Hermans & van Honk, 2006; Koster, Verschuere, Burssens, Custers & Crombez, 2007; Pessoa & Padmala, 2007; Calvo & Lundqvist, 2008). Incorporating 4900 photographs of human faces, the KDEF is a much bigger set then the PFA. Each of 70 Caucasian models was photographed 70 times – 10 times (twice from five different angles) per each emotional expression. For the purpose of their research, Calvo & Lundqvist's (2008) adaptated the KDEF set. They selected 280 frontal-view photographs of 40 models displaying all seven expressions. Using Adobe Photoshop they cropped the original KDEF stimuli. The hair, neck, and other emotionally unexpressive parts were removed in such a manner that each face fits within an oval window. Lundqvist & Litton (1998) developed *The Averaged Karolinska Directed Emotional Faces* (AKDEF) database, which embodies 70 pictures of averaged human expressions. They used the entire KDEF stimuli material and sorted it into 70 different stacks: 7 expressions x 5 viewing angles x 2 gender. Average pictures were calculated afterwards for each stack.

The next set is *The Cohn-Kanade AU-Coded Facial Expression Database*. It consists of approximately 500 short (about second-lasting) movie clips, each of which begins with neutral expression and finishes with one of six prototypical emotions (Cohn, Zlochower, Lien & Kanade, 1999). In the construction of this set 100 students participated as models. Although this set is coded by FACS experts and includes African American, Asian and Latino models, it is rarely used compared to the PFA and the KDEF.

Various other sets exist, but they will not be mentioned here because they either do not contain all of six basic facial expressions, or they are rarely used in scientific studies.

The most recent databases contain not only angry, disgusted, frightened, happy, sad and surprised faces, but also some other expressions that are not prototypical. For example, Tracy, Robins & Schriber's (2009) *University of California, Davis, Set of Emotion Expressions* (UCDSEE) is the first FACS-verified set that includes self-conscious emotions known to have recognizable expressions. Embarrassment, pride and shame are incorporated into the UCDSEE, together with six prototypical emotional expressions. Although Tracy et al.'s (2009) set is indeed promising, it contains expressions of only four models. However, the need for this kind of facial stimuli databases is increasing, so many sets similar to UCDSEE are certainly going to be constructed soon.

1.6 Problems and aims of the present study

Cognitive processing of emotional facial expressions is investigated via various specialized methodology. Most common procedures in that area of research are visual search tasks, eye movement monitoring and dot probe paradigm. However, experimental research of emotional facial expressions encountered serious obstacles, which are impossible to unravel using the methods mentioned. On the other hand, the most common method in the research of various human cognitive processes, such as attention, vision, working memory and even consciousness, is change detection paradigm. That method has practically never been used in the research of human emotional expressions. In the present study, such an attempt is going to be made.

With an implementation of change detection paradigm, a new dimension of facial expression research will come into existance. As a result, three valuable outcomes can occur:

a) disagreement between existing theories can be explained and resolved,
b) previous studies addressing perception can be extended to higher cognitive processes (e.g. memory),
c) some untestable hypothesis can become testable.

1.6.1 Problem 1: Threat vs. negativity vs. emotionality

Which affective component facilitates detection of facial emotional expressions? Although numerous studies were conducted in order to answer that question, none of the three clashed theories prevailed. Therefore, the first problem of the present study is to contribute to the solution of the puzzle, by investigating which affective component (threat, emotionality or negativity) facilitates detection of facial emotions.

More specifically, the first problem is to explore whether:

a) angry facial expressions have an advantage in attracting attention and cognitive processing over all other emotional and neutral expressions (as the threat hypothesis predicts), or

b) emotional expressions have an advantage in attracting attention and cognitive processing over neutral expressions (as the emotionality hypothesis predicts), or

c) negative facial expressions (such as anger or sadness) have an advantage in attracting attention and cognitive processing over positive emotional and over neutral expressions (as the negativity hypothesis predicts).

Results are expected to fit well into one of these three frames:

a) according to the threat hypothesis, the highest proportion of correct answers is 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;

b) according to the emotionality hypothesis, the lowest proportion of correct answers is expected to occur in trials in which test stimulus is presented at a location initially occupied by a neutral face;

c) if the negativity hypothesis is true, the proportion of correct answers should be higher 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.

When findings of previous relevant studies are summarized, the threat hypothesis received more empirical support then the other two hypotheses, but it still requires more experimental corroboration.

1.6.2 Problem 2: Experimental evaluation of Williams et al.'s (2005) hypothesis

Williams et al. (2005) discovered that although fearful faces are generally considered to indicate potential threat, they are not detected faster than sad, happy or angry faces. In explanation of that unexpected result, authors speculated that an angry face and a fearful face do not express equivalent types of threat: while an angry face transmits potential danger signals from that particular individual, a fearful face signalizes that potential threat is somewhere else in the environment. Thereafter, focal attention is allocated to an angry face because it is the source of danger, but rather than allocating attention to a fearful face, it is diverted elsewhere to locate the threat.

In accordance with Williams et al.'s (2005) speculation, participants are expected to be poor at detecting changes in trials in which test stimulus is presented at a location initially occupied by a frightened face.

1.6.3 Problem 3: Fear and surprise – one or two expressions?

Another focus of the present study is to investigate whether fearful and surprised expressions are independent facial expressions, or not.

Paul Ekman, who is probably the most respectable scientist in the area of facial expressions, claimed that there are six prototypical emotional facial expressions: anger, disgust, fear, happiness, sadness and surprise (Ekman, 1972; Ekman & Friesen, 1976). However, several studies indicate that the changes of surprised faces into frightened faces (and vice versa) are more difficult to detect then any other changes (e.g. Russell, 1994; Rapcsak et al., 2000; Adolphs, 2002; Palermo & Coltheart, 2004;

Calvo & Lundqvist, 2008). Such findings suggest that fear and surprise are actually facially expressed in a very similar manner.

If Ekman's theory is not valid, then the detection of an angry face changing into a surprised face (and vice versa) is expected to be extremely poor compared to the detection of any other type of change. Such results would be in conformity with the findings of Russell (1994), Rapcsak et al. (2000), Adolphs (2002), Palermo & Coltheart (2004) as well as Calvo & Lundqvist (2008). Contrariwise results would corroborate Ekman's theory according to which surprise and fear are two separate expressions.

1.6.4 Problem 4: Estimation of visual working memory capacity for facial expressions

Visual working memory capacity is limited to no more then four items (e.g. Pashler, 1988; Vogel et al., 2001; Wheeler & Treisman, 2002). Some experimental findings suggest that the capacity is limited by the total amount of information that needs to be memorized. For example, Alvarez & Cavanagh (2004) discovered inverse relation between the information load per object and the number of objects that can be stored into visual working memory. They found that visual working memory capacity is the lowest for shaded cubes or Chinese letters, and highest for colored squares. The objective of the present study is to assess and quantify visual working memory capacity for emotional facial expressions.

2 METHOD

2.1 Participants

Twenty-four psychology students (age range 20-26) from The University of Rijeka, Croatia, participated in the experiment. The number of male and female participants was equal, and all of them reported to have normal or corrected to normal visual acuity.

2.2 Instruments

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 by keyboard.

2.3 Stimuli and procedure

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 et al., 1998) were used for the construction of stimuli material for the present study. Four sets of stimuli were prepared:

1) pictures of male facial expressions from Calvo & Lundqvist's (2008) adaptation of the KDEF database (Figure 8)
2) pictures of female facial expressions from Calvo & Lundqvist's (2008) adaptation of the KDEF database (Figure 9)
3) pictures of male facial expressions from the AKDEF database (Figure 10)
4) pictures of female facial expressions from the AKDEF database (Figure 11).

Each set contained seven pictures – one picture for every of the following facial expressions: afraid, angry, disgusted, happy, neutral, sad and surprised.

Regarding to Calvo & Lundqvist's (2008) norming data, expressions of only two of the models from their facial database were identified with extremely high accuracy. Under self-paced presentation, more then 90% participants managed to correctly recognize all of their seven facial expressions. Therefore, only the sets of photographs of these two models (labelled as F09 and M13) were used in the present study (together with two AKDEF averaged sets of photographs). Pictures of other models were excluded from the experiment, because validation data indicated that at least one of their facial expressions was not accurately recognized by 90% or more participants (recognition was indeed poor for some models). In order to keep idiosyncratic facial features constsnt, 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 & Lundqvist's (2008) adaptation of KDEF stimuli, while the AKDEF stimuli were left intact.

The experiment was divided into four experimental sessions, in each of which only one stimuli set was used. In order to expose all participants to all four stimuli sets, every participant went through all four experimental sessions. Serial order of experimental sessions was different for all participants (there were 24 (4!) possible differing serial orders and thus 24 participants were engaged). Each of these four sessions was composed of 260 trials (8 of which were used for practice only and were discarded from the analyses), and lasted for approximately 30 minutes. Therefore, every participant went through a total of 1008 experimental trials. In order to ease such a difficult activity, participants took 7-days break between two experimental sessions.

Figure 8. Stimuli set containing pictures of male facial emotional expressions from Calvo & Lundqvist's (2008) adaptation of the KDEF database.

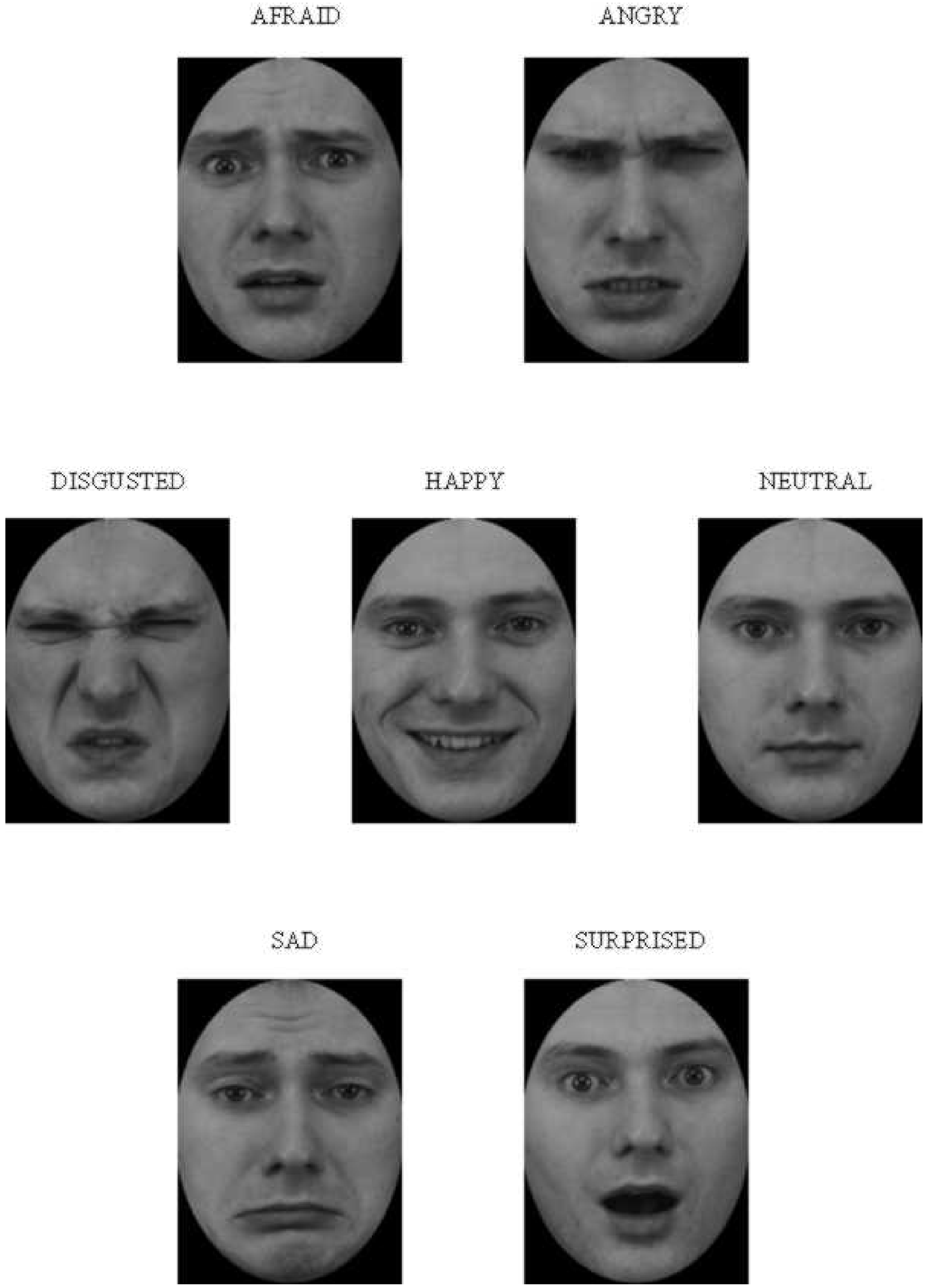


Figure 9. Stimuli set containing pictures of female facial emotional expressions from Calvo & Lundqvist's (2008) adaptation of the KDEF database.

Figure 10. Pictures of male facial expressions from the AKDEF database.

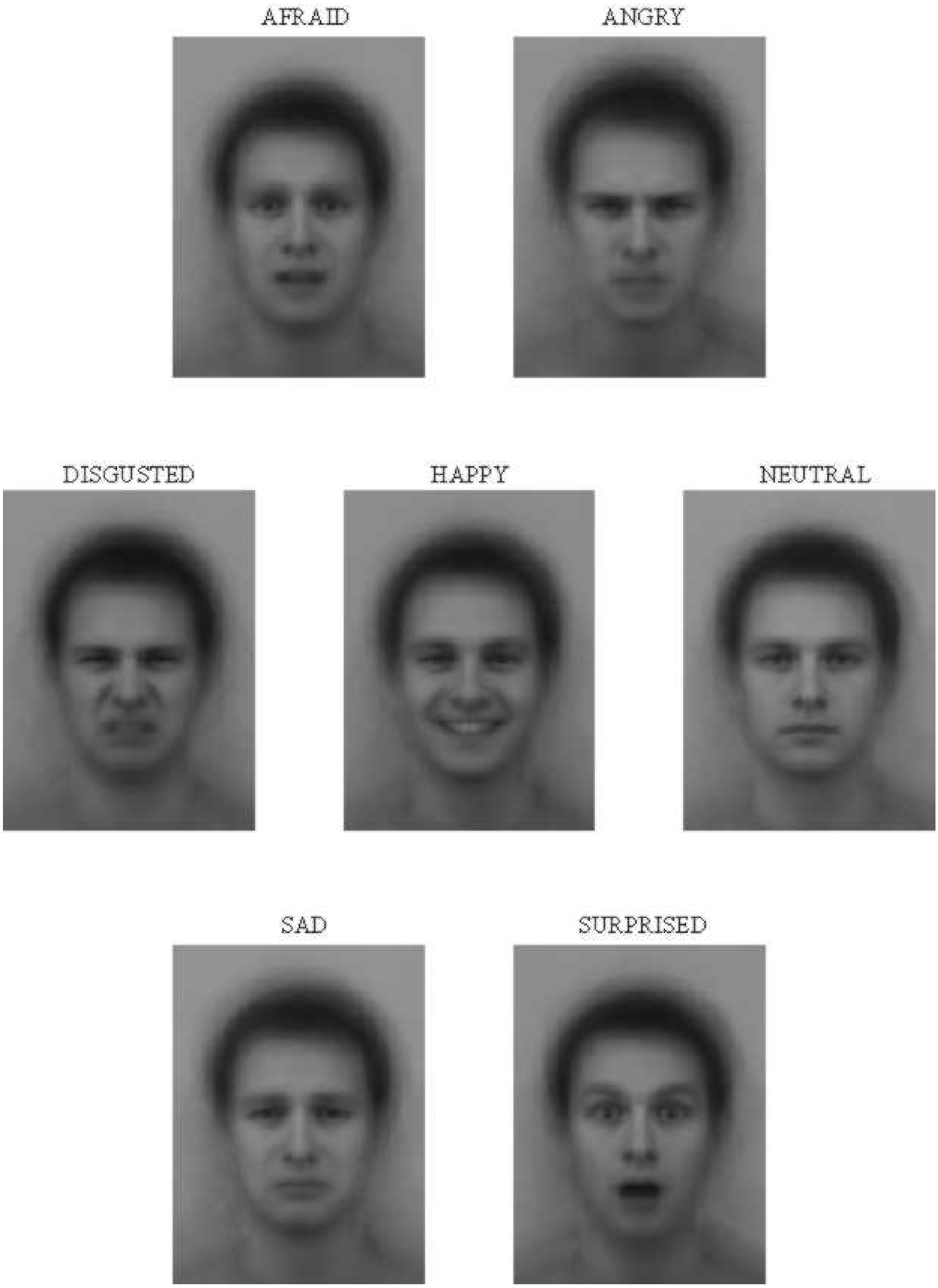


Figure 11. Pictures of female facial expressions from the AKDEF database.

All participants went through the experiment in a laboratory under equal conditions. Noise was minimized, and illumination as well as air temperature were held constant. Participants sat with their eyes at a distance of 100 cm from a 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 º x 12.27 º of visual angle. The initial stimuli display consisted of six different facial expressions, each of which always occupied 3.38 º x 2.58 º. To generate initial stimuli display, six pictures were randomly pulled from a set of seven pictures, with 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 (under certain limitations, which are going to be discussed later), as shown in Figure 12.

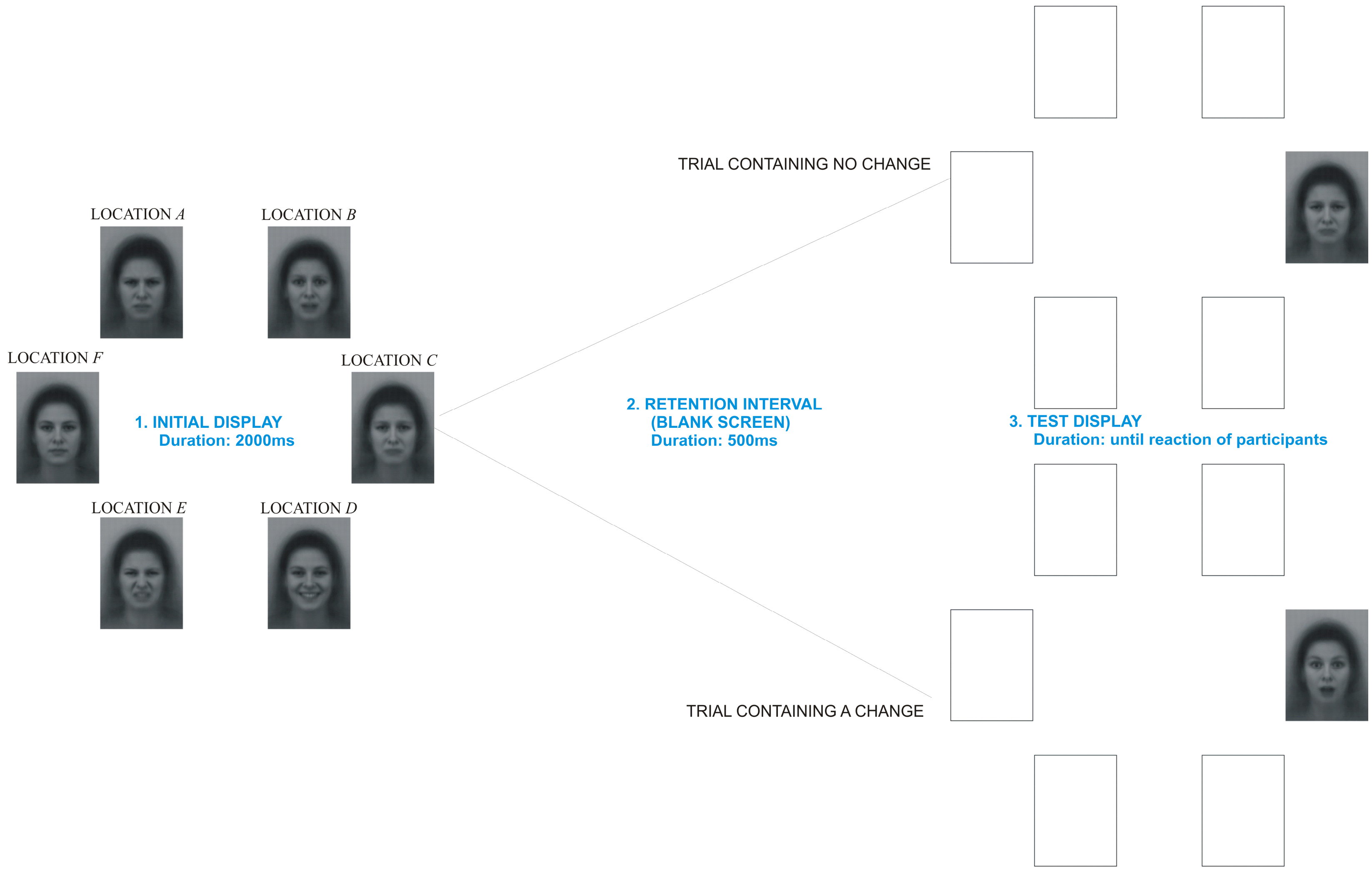
Figure 12. An example of spatial arrangement of stimuli in the initial display. (Notice that all facial expressions in the initial display differ.)

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 – only one facial expression was presented per test display, and it was placed on one of six locations previously occupied in the initial display. 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, 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 initial display.

Consider the following example for clarification (Figure 13): in the initial display *Location A* is occupied by an angry face, *Location B* by a frightened face, *Location C* by a sad face, *Location D* by a happy face, *Location E* by a disgusted face and *Location F* by a neutral face. After a retention interval, a test face is presented at *Location C*. In that case, the expression of a test face could be either sad (trial containing no change) or surprised (trial containing a change). None of the remaining five expressions could be presented at *Location C* in test display, because they were presented in the initial display, in which they occupied irrelevant locations (The term *irrelevant location* refers to any location in the initial display different from the location of a facial expression presented at test display. Therefore, irrelevant locations in this trial are *Locations* A, B, D, E and F. Correspondingly, the term *relevant location* will be used when referring to a location in the initial display which is the same as the location of the test expression. In this trial *Location C* is relevant location).

As mentioned earlier, test face was presented 168 times at each of six locations. 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 *Location A*, 24 times at *Location B*, 24 times at *Location C*, 24 times at *Location D*, 24 times at *Location E and* 24 times at *Location F*. Therefore when only test displays are considered, every expression was presented at each location in 24 trials, with a restriction that in each of such 42 expression x location technical conditions, 12 trials always did contain a change, and 12 trials did not.

Figure 13. Example of a trial containing a change and a trial containing no change. *Location C* is the relevant location.



There was another extremely important requirement regarding the 12 trials containing a change: each of the remaining six expressions had to appear twice at the relevant location in the initial display, while other expressions were randomly assigned to irrelevant locations with no restriction. In trials containing no change, the expression presented at test was identical as the expression presented at relevant location in the initial display, which means that one of the remaining six expression had to be eliminated from the initial display. Expression that was eliminated in trials containing no change, was always selected randomly with no restriction, and the remaining five expressions were distributed to irrelevant locations randomly, without any restriction, similar as in trials containing a change.

Viewed from another angle, each facial expression occupied relevant location in equal number of trials (N =144). In 72 trials, facial expression occupying relevant location remained unchanged during the retention interval, and was again presented on the same spot in test display. In the other 72 trials it changed during the retention interval, exactly 12 times into each of the 6 remaining expressions (Table 1 and Table 2).

After the presentation of the test display, participants were instructed to hit the «1» key if a change occurred (if the emotion in the test display differs from the emotion occupying relevant location in the initial display), or to hit the «0» key if a change did not occur (if the emotion in the test display is the same as the emotion presented at the relevant location in the initial display). They were emphasised to aim for accuracy, not speed. In trial in which they were uncertain if a change had occurred or not, they were told to respond by chance.

Immediate feedback followed immediately after each participants' reaction. If the response was correct, the word «correct» appeared in blue color at the centre 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.

Table 1. Overview of the experimental design.

Category	*Number of trials per condition*	*Number of conditions*
Location of the test face (A/B/C/D/E/F)	168	6
Expression of the test face (afraid/angry/disgusted/happy/neutral/sad/surprised)	144	7
Expression at relevant location (same as the test face/different then the test face)	504	2
Expression of the test face x Location of the test face	24	42
Expression of the test face x Expression at the relevant location	72	14
Location of the test face x Expression at the relevant location	84	12
Expression of the test face x Location of the test face x Expres. at the relevant location	12	84

Table 2. Technical specifications the entire experiment according to the expression presented in the test display.

Expression of the test face	*Location of the test face*											
	Location A		*Location B*		*Location C*		*Location D*		*Location E*		*Location F*	
Afraid	12	12	12	12	12	12	12	12	12	12	12	12
Angry	12	12	12	12	12	12	12	12	12	12	12	12
Disgusted	12	12	12	12	12	12	12	12	12	12	12	12
Happy	12	12	12	12	12	12	12	12	12	12	12	12
Neutral	12	12	12	12	12	12	12	12	12	12	12	12
Sad	12	12	12	12	12	12	12	12	12	12	12	12
Surprised	12	12	12	12	12	12	12	12	12	12	12	12

Facial expression at the relevant location is same as expression of test face

Facial expression at the relevant location is not same as expression of test face

3 RESULTS

In order to analyse participants' performance, percentages of correct answers were subjected to analyses. Reaction times were also processed, as a supplementary measure. For the purpose of eliminating the impact of extreme results, median reaction times were determined for every participant across each experimental condition. Only these median values were used in all subsequent descriptive and inferential processing of reaction times.

In conformity with findings of other experiments investigating effects of gender on processing of facial expressions (e.g. Palermo & Coltheart, 2004; Calvo & Lundqvist, 2008), gender of participants had no effect on performance, regardless of criterion variables. It had no impact neither on accuracy of responding nor on reaction times, nor on working memory capacity for emotional expressions. Also, 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 analysed, because external validity of obtained conclusions would be poor, since there were only two sets of stimuli per gender.

3.1 Performance as a function of emotional expressions

Analysis of participants' performance (especially percentage of correct answers) as a function of emotional expression that occupies relevant location in the initial display, is of central interest for the present study. All experimental trials will be included in that analysis. However, to obtain more detailed insight into cognitive processessing during the execution of the experiment, performance will also be analysed 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 (for thorough elaboration see Švegar, 2008).

Participants' performance is also going to be analysed as a function of emotional expression in the test display for the same reasons – to gain a more detailed insight into cognitive processes (such as strategy of memorizing, criterion of responding, comparison of test expression to memorized items from the initial display, etc.).

3.1.1 All trials

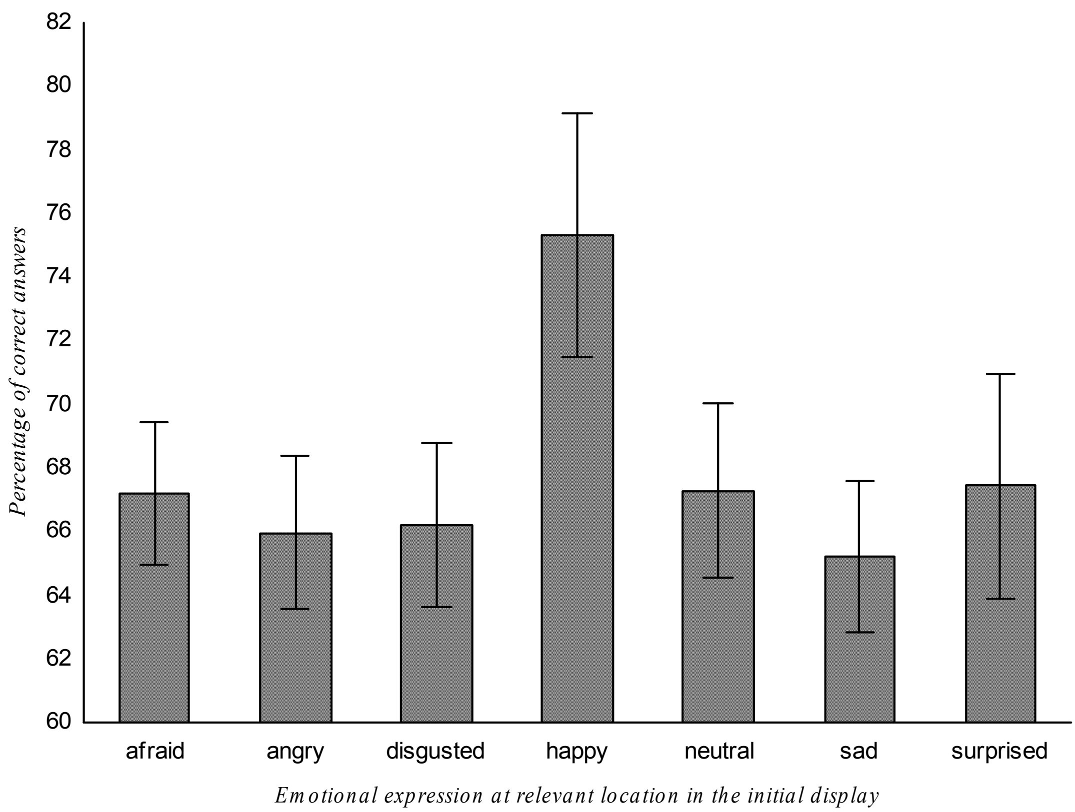
In the first set of analyses, all trials were considered, and the independent variable was defined as the emotional expression occupying relevant location in the initial display. The emotional expression presented after the retention interval is irrelevant for these analyses. The obtained descriptive results are presented in Table 3. Each participant went through 144 trials per each level of the independent variable. After initial descriptive analysis, two one-way repeated measures ANOVAs were conducted.

The percentage of correct answers was set as dependent variable in the first one. The main effect of emotional expression occupying relevant location in the initial display was significant ($F (6, 138) = 8{,}57$, $p < .001$). 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 14).

Table 3. Percentage of correct answers and reaction time, as a function of emotional expression that occupies relevant location in the initial display. All trials are considered.

	Percentage correct		*Reaction time (ms)*	
Emotional expression	*Mean*	*SD*	*Mean*	*SD*
Afraid	67,22	5,33	1017,77	140,42
Angry	65,97	5,68	1028,15	149,26
Disgusted	66,20	6,15	1025,96	156,82
Happy	75,32	9,04	969,54	128,37
Neutral	67,30	6,55	1016,17	149,65
Sad	65,22	5,59	1030,15	155,99
Surprised	67,45	8,42	1006,83	143,15

Figure 14. Percentage of correct answers as a function of emotional expression that occupies relevant location in the initial display. All trials are considered.



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 ($F(6, 138) = 8{,}51$, $p < .001$). Tukey HSD post-hoc test established that participants responded 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, amongst which none of the differences was statistically significant (Figure 15).

Emotional expression presented in the test display was defined as the independent variable for the second set of analyses, thus emotional expressions presented before the retention interval are not relevant for these analyses. Each participant went through 144 trials per each level of the independent variable. The obtained descriptive results are presented in Table 4.

Figure 15. Reaction time as a function of emotional expression that occupies relevant location in the initial display. All trials are considered.

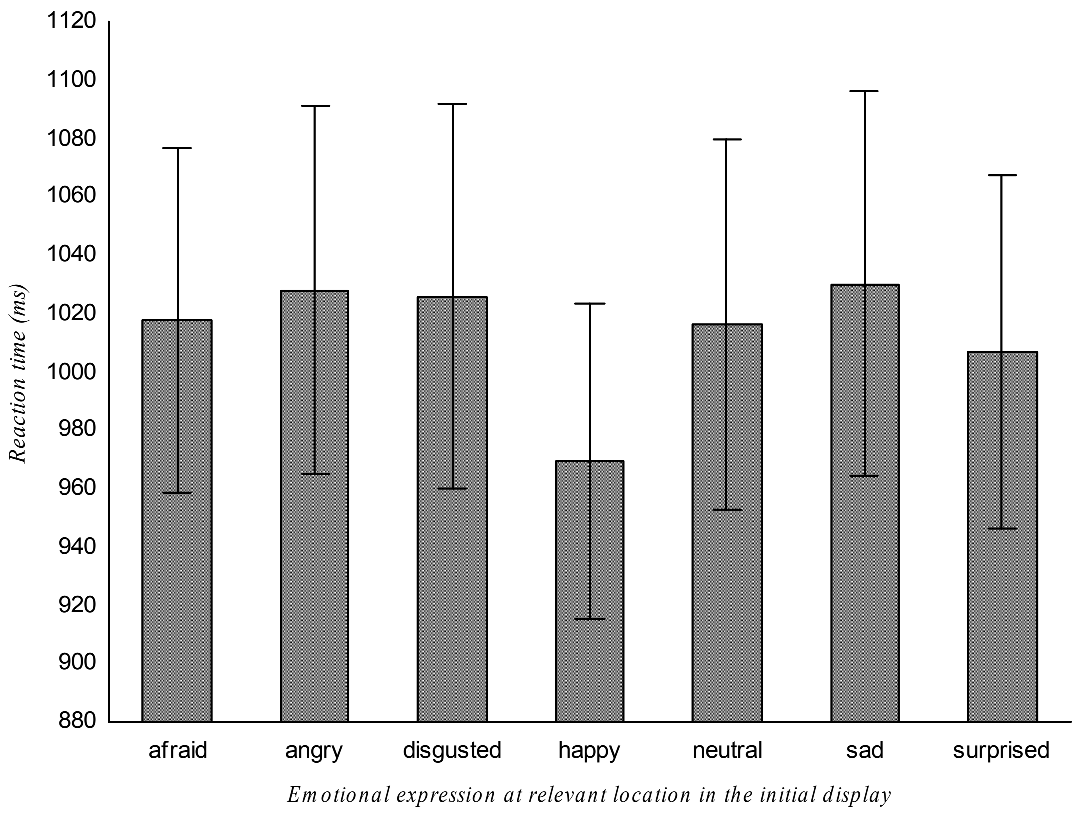
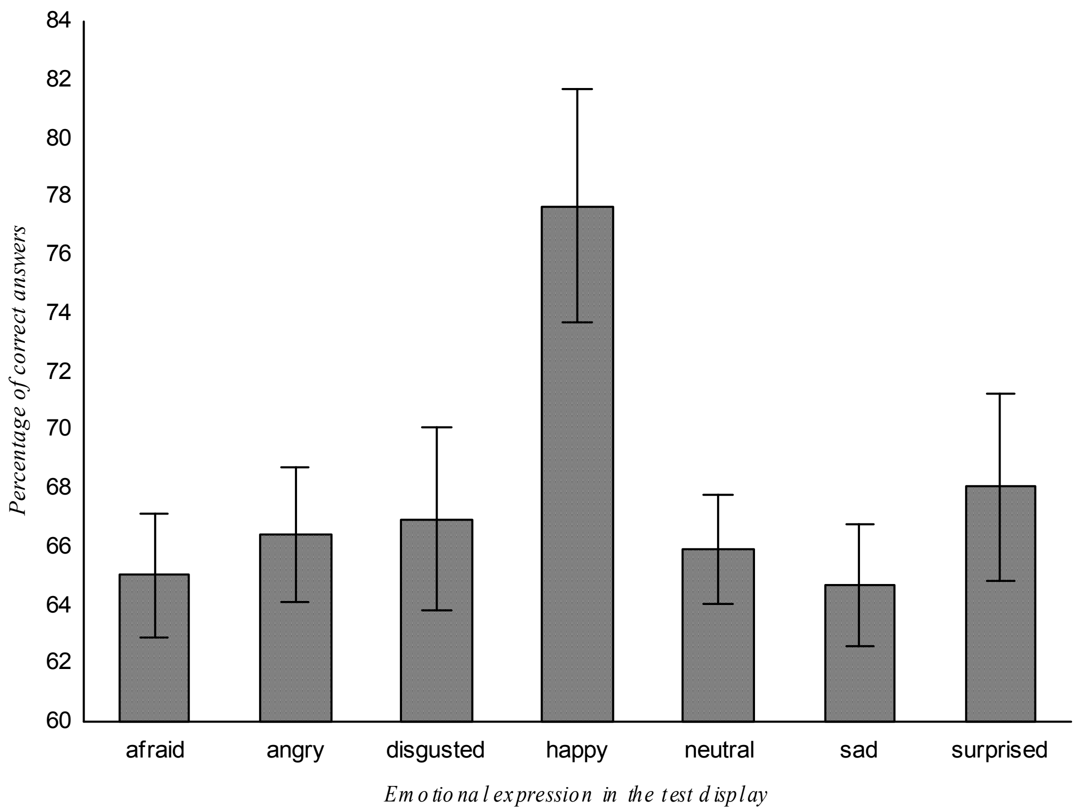


Table 4. Percentage of correct answers and reaction time, as a function of emotional expression in the test display. All trials are considered.

	Percentage correct		*Reaction time (ms)*	
Emotional expression	*Mean*	*SD*	*Mean*	*SD*
Afraid	65,02	5,00	1039,10	154,15
Angry	66,41	5,48	1029,08	149,62
Disgusted	66,96	7,41	1027,88	159,76
Happy	77,69	9,52	966,02	141,51
Neutral	65,89	4,44	1003,19	142,08
Sad	64,67	4,94	1029,62	156,00
Surprised	68,06	7,60	1006,96	133,37

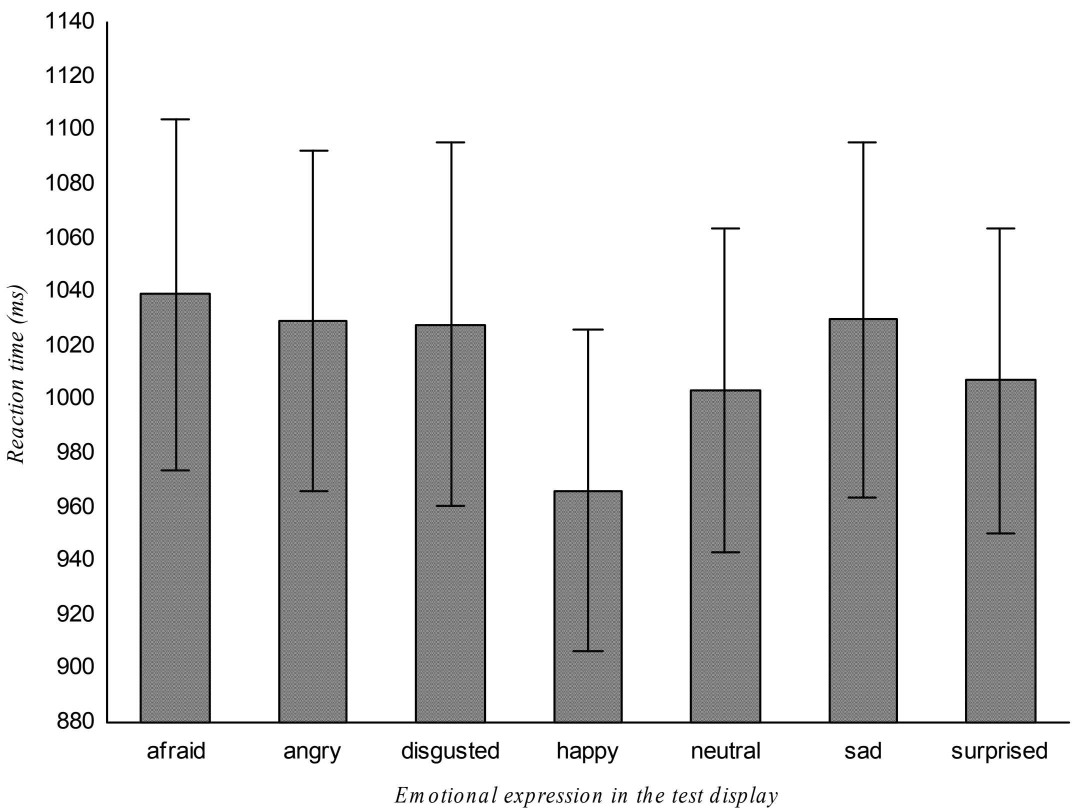
Figure 16. Percentage of correct answers as a function of emotional expression in the test display. All trials are considered.



When one-way repeated measures ANOVA, with the percentage of correct answers as dependent variable, is conducted, the main effect of emotional expression in the test display is significant ($F (6, 138) = 16{,}90$, $p < .001$). Tukey HSD post-hoc test showed that in the condition of happy face presented at test, participants' performance was significantly more accurate compared to any of the other six experimental conditions. Besides that, there were no other significant differences (Figure 16).

In another one-way repeated measures analysis of variance, reaction times were inserted as a dependent variable. The main effect of emotional expression presented in the test display was again significant ($F (6, 138) = 9{,}23$, $p < .001$). Responding was fastest in the condition of happy face presented at test. According to Tukey HSD post-hoc comparison, no other differences were significant (Figure 17).

Figure 17. Reaction time as a function of emotional expression in the test display. All trials are considered.



3.1.2 Trials containing no change

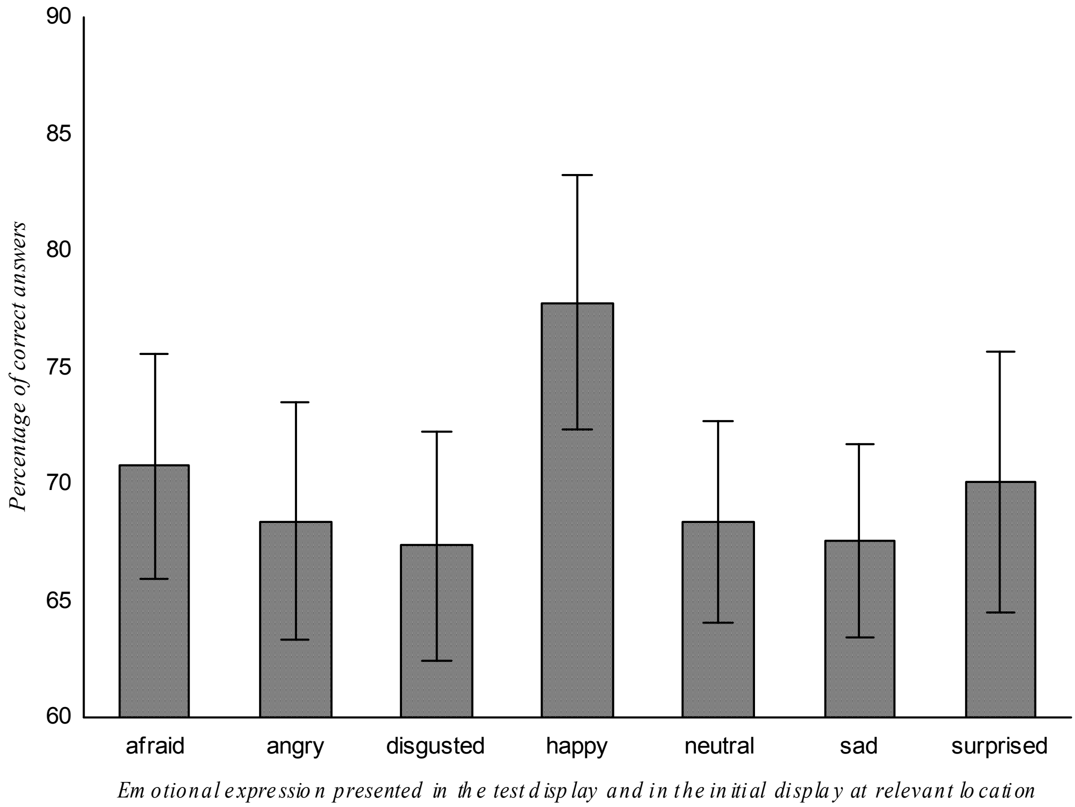
In the next set of analyses, only trials containing no change are considered. The emotional expression occupying relevant location in the initial display was in these trials identical to emotional expression presented in test display. Thus, the independent variable can be defined as the emotional expression presented in the test display and in the initial display at relevant location. The obtained descriptive results are presented in Table 5. Each participant went through 72 trials per each level of the independent variable.

Table 5. Percentage of correct answers and reaction time, as a function of emotional expression presented in the test display and in the initial display at relevant location. Only trials containing no change are considered.

	Percentage correct		*Reaction time (ms)*	
Emotional expression	*Mean*	*SD*	*Mean*	*SD*
Afraid	70,78	11,38	1022,96	157,08
Angry	68,40	12,08	1032,56	151,01
Disgusted	67,36	11,68	1031,31	154,21
Happy	77,78	12,89	955,40	118,91
Neutral	68,34	10,26	999,71	147,51
Sad	67,53	9,79	1032,71	158,03
Surprised	70,08	13,25	1003,08	144,13

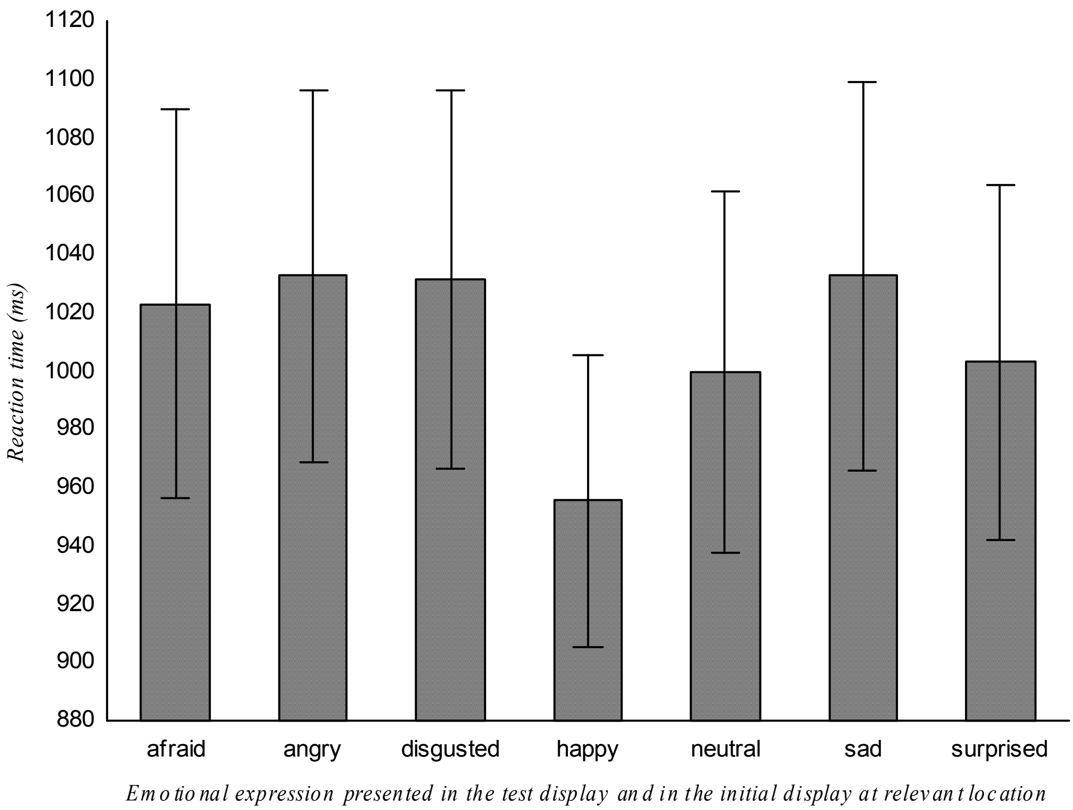
When the percentage of correct answers was selected as dependent variable, one-way repeated measures ANOVA revealed that the main effect of emotional expression is significant ($F (6, 138) = 4,66$, $p < .001$). Tukey HSD post-hoc comparison showed that the participants were significantly most accurate in condition where they had to answer that happy face remained unchanged during the retention interval. The only slight exception was the condition of frightened face presented in the test display and in the initial display at relevant location. Participants performance in that condition was only marginally worse compared to the condition in which happy face remained unchanged. According to Tukey HSD, risk level equalled p = ,052 (Figure 18).

Figure 18. Percentage of correct answers as a function of emotional expression presented in the test display and in the initial display at relevant location. Only trials containing no change are considered.



In one-way repeated measures analysis of variance conducted on reaction times as dependent variable, the main effect of emotional expression was again significant ($F(6, 138) = 8{,}08$, $p < .001$). Tukey HSD post-hoc comparison showed that in the condition of unchanged happy face, participants' responding was significantly faster, compared to any of other six corresponding conditions. No differences amongst the remaining six conditions were significant (Figure 19).

Figure 19. Reaction time as a function of emotional expression presented in the test display and in the initial display at relevant location. Only trials containing no change are considered.



3.1.3 Trials containing a change

After analysing trials containing no change, the next group of statistical tests is conducted only on trials that do contain a change. In the first of them, the independent variable was defined as the emotional expression occupying relevant location in the initial display. The type of emotional expression presented after the retention interval is irrelevant for these analyses (with restriction that it had to be different than the expression occupying relevant location in the initial display). The obtained descriptive results are presented in Table 6. Each participant went through 72 trials per each level of the independent variable.

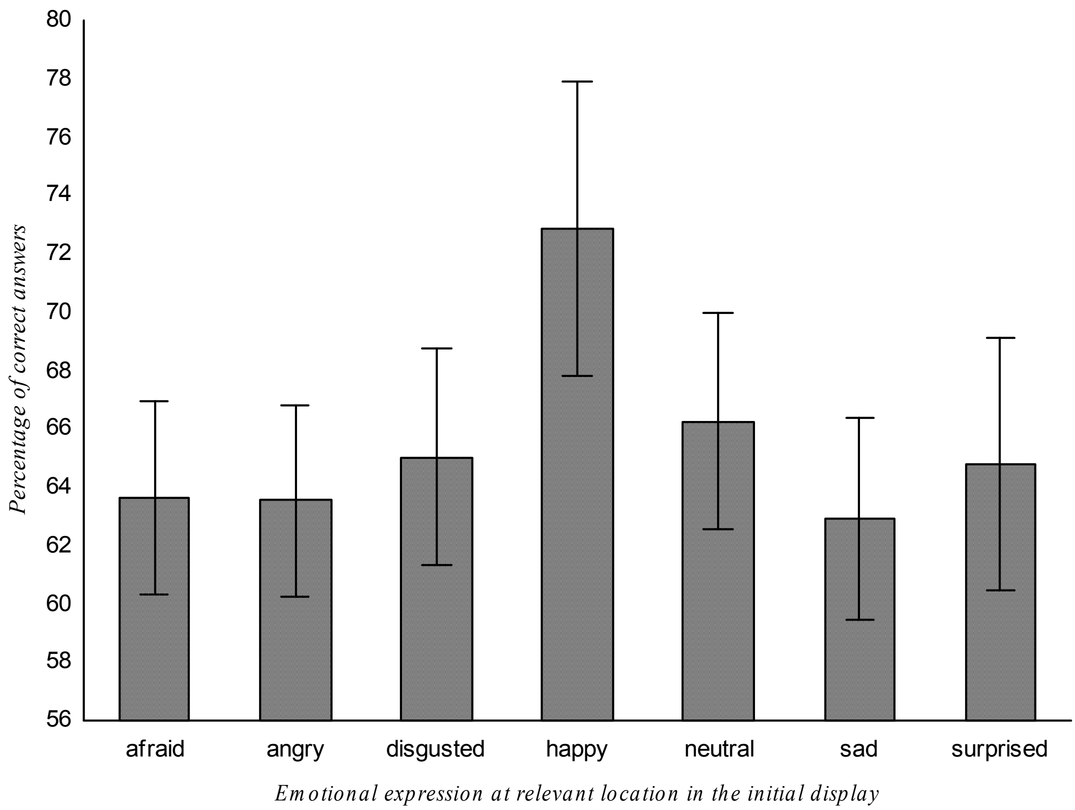
Table 6. Percentage of correct answers and reaction time, as a function of emotional expression presented in the initial display at relevant location. Only trials containing a change are included.

	Percentage correct		*Reaction time (ms)*	
Emotional expression	*Mean*	*SD*	*Mean*	*SD*
Afraid	63,66	7,86	1020,85	136,16
Angry	63,54	7,77	1023,40	157,63
Disgusted	65,05	8,78	1021,92	160,26
Happy	72,86	12,00	986,04	150,14
Neutral	66,26	8,77	1032,00	150,45
Sad	62,91	8,18	1028,98	160,16
Surprised	64,81	10,25	1010,50	150,85

After initial descriptive analysis, two one-way repeated measures ANOVAs were conducted.

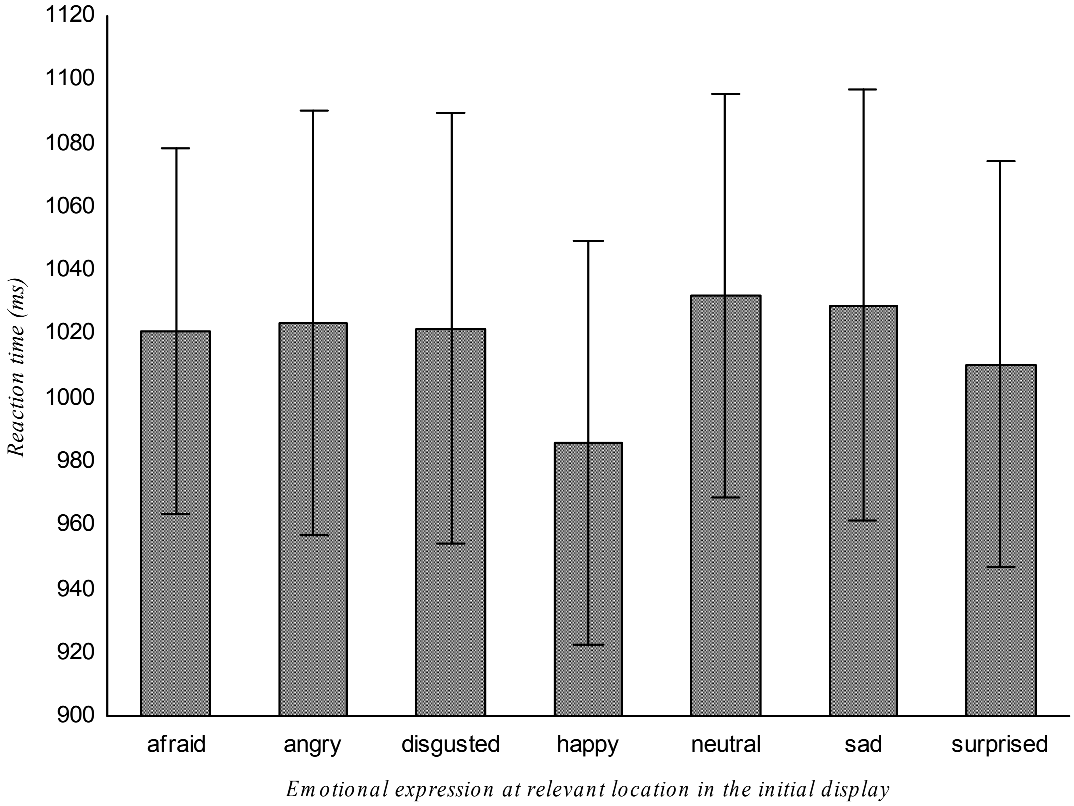
When the percentage of correct answers was set as dependent variable, the main effect of emotional expression occupying relevant location in the initial display was significant ($F(6, 138) = 6{,}28$, $p < .001$). By Tukey HSD post-hoc comparison, it was established that, compared to any of the corresponding 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 20).

Figure 20. Percentage of correct answers as a function of emotional expression that occupies relevant location in the initial display. Only trials containing a change are considered.



In another one-way repeated measures ANOVA, reaction times were entered as a dependent variable. The main effect of emotional expression occupying relevant location in the initial display was significant ($F (6, 138) = 3{,}85$, $p < .01$). Tukey HSD post-hoc test showed that participants were significantly faster in condition of happy facial expression occupying relevant location in the initial display, compared to any of other six corresponding conditions, with one exception: the condition of surprised expression presented at relevant location in the initial display did not differ from the condition of happy face presented at relevant location in the initial display – in both of these conditions participants were responding roughly equally fast (Figure 21).

Figure 21. Reaction time as a function of emotional expression that occupies relevant location in the initial display. Only trials containing a change are considered.



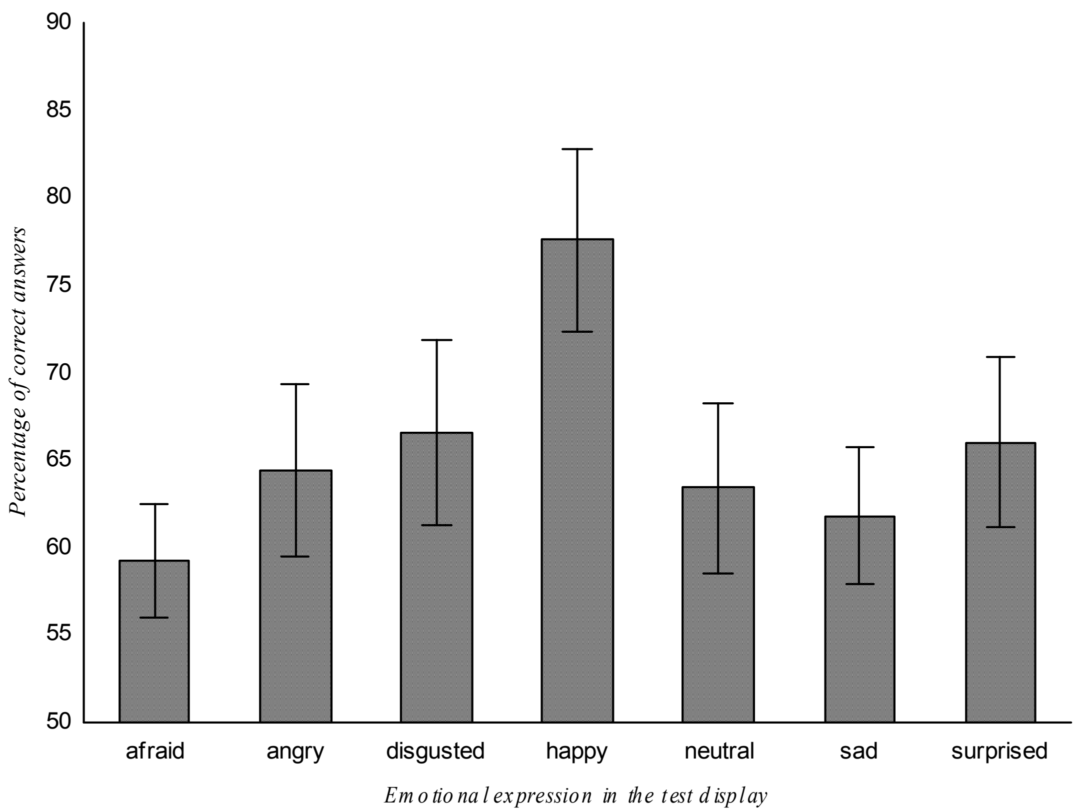
In the next two ANOVAs, emotional expression in the test display is defined as independent variable. Emotional expressions presented before the retention interval are irrelevant for these analyses (with restriction that the emotion occupying relevant location in the initial display had to differ from the expression presented in the test display). The obtained descriptive results are presented in Table 7. Each participant went through 72 trials per each level of the independent variable.

When one-way repeated measures ANOVA, with percentage of correct answers as dependent variable, is conducted on trials containing a change, the main effect of expression in the test display is significant ($F (6, 138) = 9{,}38$, $p < .001$). Tukey HSD post-hoc test revealed that in the condition of happy face presented at test, participants' performance was significantly more accurate compared to any of the other six corresponding experimental conditions. Besides that, no other differences were significant (Figure 22).

Table 7. Percentage of correct answers and reaction time, as a function of emotional expression presented in the test display. Only trials containing a change are included.

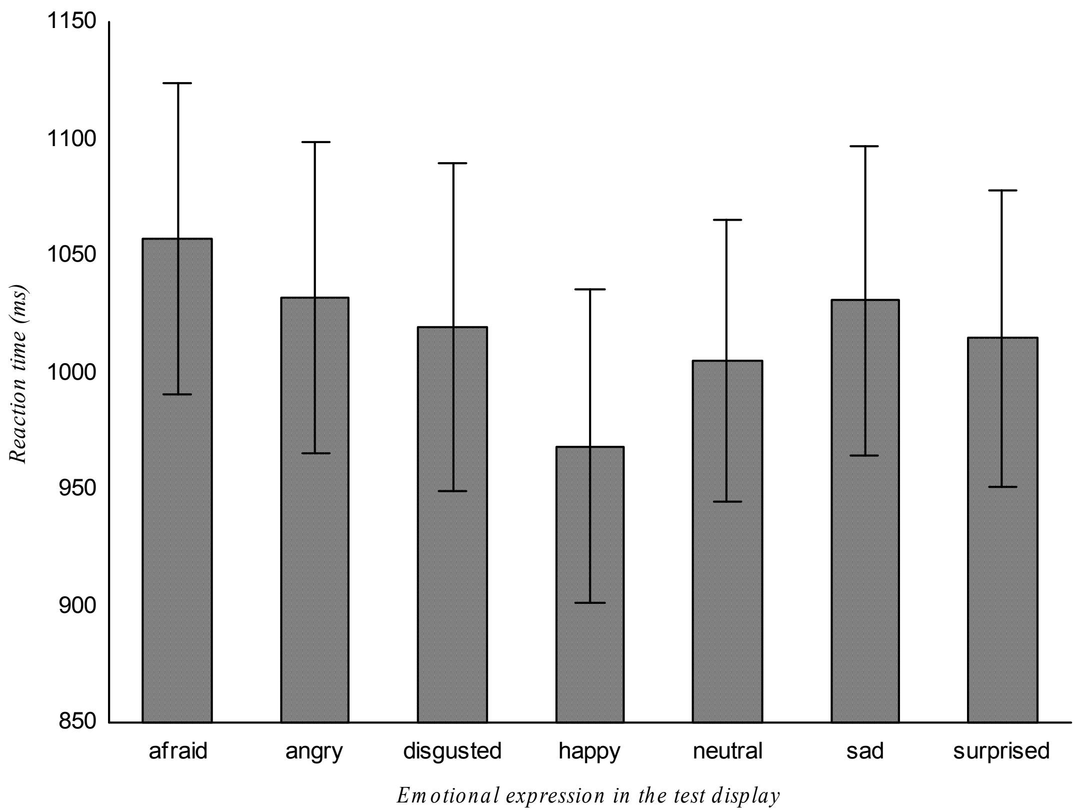
	Percentage correct		*Reaction time (ms)*	
Emotional expression	*Mean*	*SD*	*Mean*	*SD*
Afraid	59,26	7,72	1057,12	158,67
Angry	64,41	11,75	1032,02	158,21
Disgusted	66,55	12,47	1019,25	166,74
Happy	77,60	12,33	968,19	159,18
Neutral	63,43	11,53	1004,85	142,83
Sad	61,81	9,27	1030,71	157,32
Surprised	66,03	11,41	1014,60	150,87

Figure 22. Percentage of correct answers as a function of emotional expression in the test display. Only trials containing a change are considered.



In another one-way repeated measures analysis of variance conducted only on trials containing a change, reaction times were inserted as a dependent variable. The main effect of emotional expression presented in the test display was again significant ($F (6, 138) = 5{,}21$, $p < .001$). Tukey HSD post-hoc comparison revealed that in the condition of happy face presented in the test display, participants responded significantly faster than in the conditions of frightened, angry, disgusted or sad expression presented in the test display. Also, participants responded faster when neutral face was presented in the test display, in reference to condition of frightened face appearing in the test display. Other differences were statistically insignificant (Figure 23).

Figure 23. Reaction time as a function of emotional expression in the test display. Only trials containing a change are considered.



3.2 Detectability of changes as a function of their content

In all preceding statistical processing, emotional expression presented in the test display was irrelevant when the independent variable was defined as emotional expression occupying relevant location in the initial display, or vice versa (emotional expression occupying relevant location in the initial display was irrelevant if emotional expression presented in the test display was set as independent variable).

In the current two analyses, both emotional expressions are simultaneously taken into account: one that occupies the relevant location in the initial display, and one that is presented in the test display. Therefore, these two analyses will reveal how certain types of changes are easy/difficult to be detected. Only trials containing a change were considered in these analyses.

Each of the seven emotional expressions presented in the initial display changed into each of the six remaining expressions in the test display in exactly 12 trials (there were 504 trials containing a change distributed across 42 conditions). This means that participants could score from zero to 12 correct answers for each condition. Since random answering would lead to approximately 50% of correct answers, the scale of dependent measure would be discriminatively poor – in all or almost all conditions participants would probably achieve 6 or more (maximally 12) correct detections. For that reason, pairs of complementary conditions were merged. For example, trials in which angry expression was presented in initial display at relevant location and happy expression was presented in the test display, were merged to trials in which happy expression was presented in initial display at relevant location and angry expression was presented in the test display. In other words, the direction of a change became irrelevant: trials containing angry face that changes into happy one during the retention interval, were combined to trials containing a happy face that changes into an angry one. Thereby, a total of 42 conditions composed of 12 trials, was reduced to a total of 21 condition each of which now contained 24 trials. Participants' performance across these conditions is presented in Table 8.

Table 8. Percentage of correct answers and reaction time, relating to type of change. Only trials considering a change are considered.

.	*Percentage correct*		*Reaction time (ms)*	
Altered expressions	*Mean*	*SD*	*Mean*	*SD*
Afraid and angry	62,85	11,32	1073,94	169,46
Afraid and disgusted	64,24	11,12	1060,77	187,24
Afraid and happy	73,44	14,53	980,33	133,02
Afraid and neutral	60,76	8,94	1053,48	147,48
Afraid and sad	53,13	10,87	1061,08	178,81
Afraid and surprised	54,34	10,32	1045,54	158,09
Angry and disgusted	59,20	11,12	1061,96	212,55
Angry and happy	75,52	14,76	974,06	172,57
Angry and neutral	61,63	14,38	1056,31	151,36
Angry and sad	58,85	13,19	1031,73	141,94
Angry and surprised	65,80	13,23	1006,92	161,04
Disgusted and happy	77,43	14,59	972,85	168,45
Disgusted and neutral	67,19	12,00	1021,15	169,06
Disgusted and sad	58,33	11,98	1032,46	167,34
Disgusted and surprised	68,40	11,12	1007,81	165,33
Happy and neutral	73,96	16,22	961,81	148,13
Happy and sad	77,78	10,26	1010,44	190,11
Happy and surprised	73,26	13,00	990,77	158,67
Neutral and sad	60,42	9,36	1024,77	157,75
Neutral and surprised	65,10	12,76	1009,79	153,84
Sad and surprised	65,63	13,91	1019,69	166,26

In order to directly compare participants' efficacy among these conditions, two one-way repeated measures analyses of variance with Tukey HSD post-hoc comparisons were conducted. When the percentage of correct answers was set as dependent variable (Figure 24), ANOVA revealed that the main effect of type of change was significant ($F(20, 460) = 11,38$, $p < .001$). Tukey HSD post-hoc test comparisons are presented in the Table 9.

Figure 24. Percentage of correct answers per each combination of altering expressions. Only trials containing a change are considered.

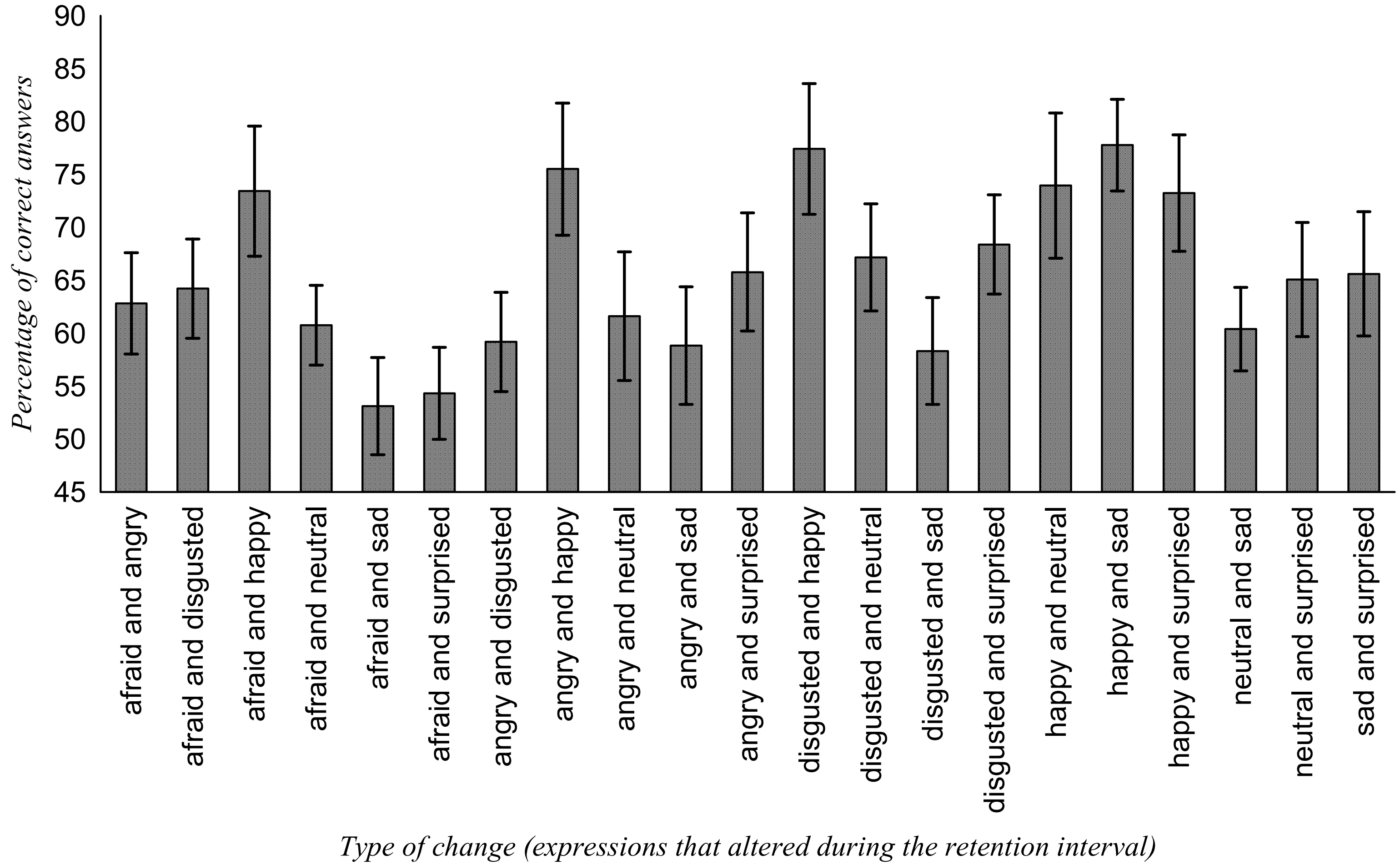


Table 9. Tukey HSD post-hoc comparisons for each combination of altering expressions, with percentage of correct answers as a dependent variable. Significant p-values are colored red.

		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*
	altered expressions \ means	*62,85*	*64,24*	*73,44*	*60,76*	*53,13*	*54,34*	*59,20*	*75,52*	*61,63*	*58,85*	*65,80*	*77,43*	*67,19*	*58,33*	*68,40*	*73,96*	*77,78*	*73,26*	*60,42*	*65,10*	*65,63*
1	*afraid and angry*		1,00	0,08	1,00	0,17	0,41	1,00	0,01	1,00	1,00	1,00	0,00	1,00	1,00	0,97	0,05	0,00	0,09	1,00	1,00	1,00
2	*afraid and disgusted*	1,00		0,26	1,00	0,05	0,15	0,99	0,04	1,00	0,98	1,00	0,00	1,00	0,94	1,00	0,17	0,00	0,29	1,00	1,00	1,00
3	*afraid and happy*	0,08	0,26		0,01	0,00	0,00	0,00	1,00	0,02	0,00	0,63	1,00	0,91	0,00	0,99	1,00	1,00	1,00	0,00	0,45	0,58
4	*afraid and neutral*	1,00	1,00	0,01		0,63	0,88	1,00	0,00	1,00	1,00	0,99	0,00	0,88	1,00	0,63	0,00	0,00	0,01	1,00	1,00	0,99
5	*afraid and sad*	0,17	0,05	0,00	0,63		1,00	0,93	0,00	0,41	0,96	0,01	0,00	0,00	0,99	0,00	0,00	0,00	0,00	0,71	0,02	0,01
6	*afraid and surprised*	0,41	0,15	0,00	0,88	1,00		0,99	0,00	0,71	1,00	0,03	0,00	0,01	1,00	0,00	0,00	0,00	0,00	0,93	0,07	0,04
7	*angry and disgusted*	1,00	0,99	0,00	1,00	0,93	0,99		0,00	1,00	1,00	0,86	0,00	0,54	1,00	0,26	0,00	0,00	0,00	1,00	0,94	0,88
8	*angry and happy*	0,01	0,04	1,00	0,00	0,00	0,00	0,00		0,00	0,00	0,17	1,00	0,45	0,00	0,75	1,00	1,00	1,00	0,00	0,09	0,15
9	*angry and neutral*	1,00	1,00	0,02	1,00	0,41	0,71	1,00	0,00		1,00	1,00	0,00	0,97	1,00	0,82	0,01	0,00	0,03	1,00	1,00	1,00
10	*angry and sad*	1,00	0,98	0,00	1,00	0,96	1,00	1,00	0,00	1,00		0,79	0,00	0,45	1,00	0,20	0,00	0,00	0,00	1,00	0,91	0,82
11	*angry and surprised*	1,00	1,00	0,63	0,99	0,01	0,03	0,86	0,17	1,00	0,79		0,03	1,00	0,67	1,00	0,50	0,02	0,67	0,98	1,00	1,00
12	*disgusted and happy*	0,00	0,00	1,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,03		0,11	0,00	0,29	1,00	1,00	1,00	0,00	0,01	0,02
13	*disgusted and neutral*	1,00	1,00	0,91	0,88	0,00	0,01	0,54	0,45	0,97	0,45	1,00	0,11		0,33	1,00	0,82	0,08	0,93	0,82	1,00	1,00
14	*disgusted and sad*	1,00	0,94	0,00	1,00	0,99	1,00	1,00	0,00	1,00	1,00	0,67	0,00	0,33		0,13	0,00	0,00	0,00	1,00	0,82	0,71
15	*disgusted and surprised*	0,97	1,00	0,99	0,63	0,00	0,00	0,26	0,75	0,82	0,20	1,00	0,29	1,00	0,13		0,97	0,23	0,99	0,54	1,00	1,00
16	*happy and neutral*	0,05	0,17	1,00	0,00	0,00	0,00	0,00	1,00	0,01	0,00	0,50	1,00	0,82	0,00	0,97		1,00	1,00	0,00	0,33	0,45
17	*happy and sad*	0,00	0,00	1,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,02	1,00	0,08	0,00	0,23	1,00		1,00	0,00	0,01	0,01
18	*happy and surprised*	0,09	0,29	1,00	0,01	0,00	0,00	0,00	1,00	0,03	0,00	0,67	1,00	0,93	0,00	0,99	1,00	1,00		0,01	0,50	0,63
19	*neutral and sad*	1,00	1,00	0,00	1,00	0,71	0,93	1,00	0,00	1,00	1,00	0,98	0,00	0,82	1,00	0,54	0,00	0,00	0,01		1,00	0,99
20	*neutral and surprised*	1,00	1,00	0,45	1,00	0,02	0,07	0,94	0,09	1,00	0,91	1,00	0,01	1,00	0,82	1,00	0,33	0,01	0,50	1,00		1,00
21	*sad and surprised*	1,00	1,00	0,58	0,99	0,01	0,04	0,88	0,15	1,00	0,82	1,00	0,02	1,00	0,71	1,00	0,45	0,01	0,63	0,99	1,00	

Figure 25. Mean reaction time per each combination of altering expressions. Only trials containing a change are considered.

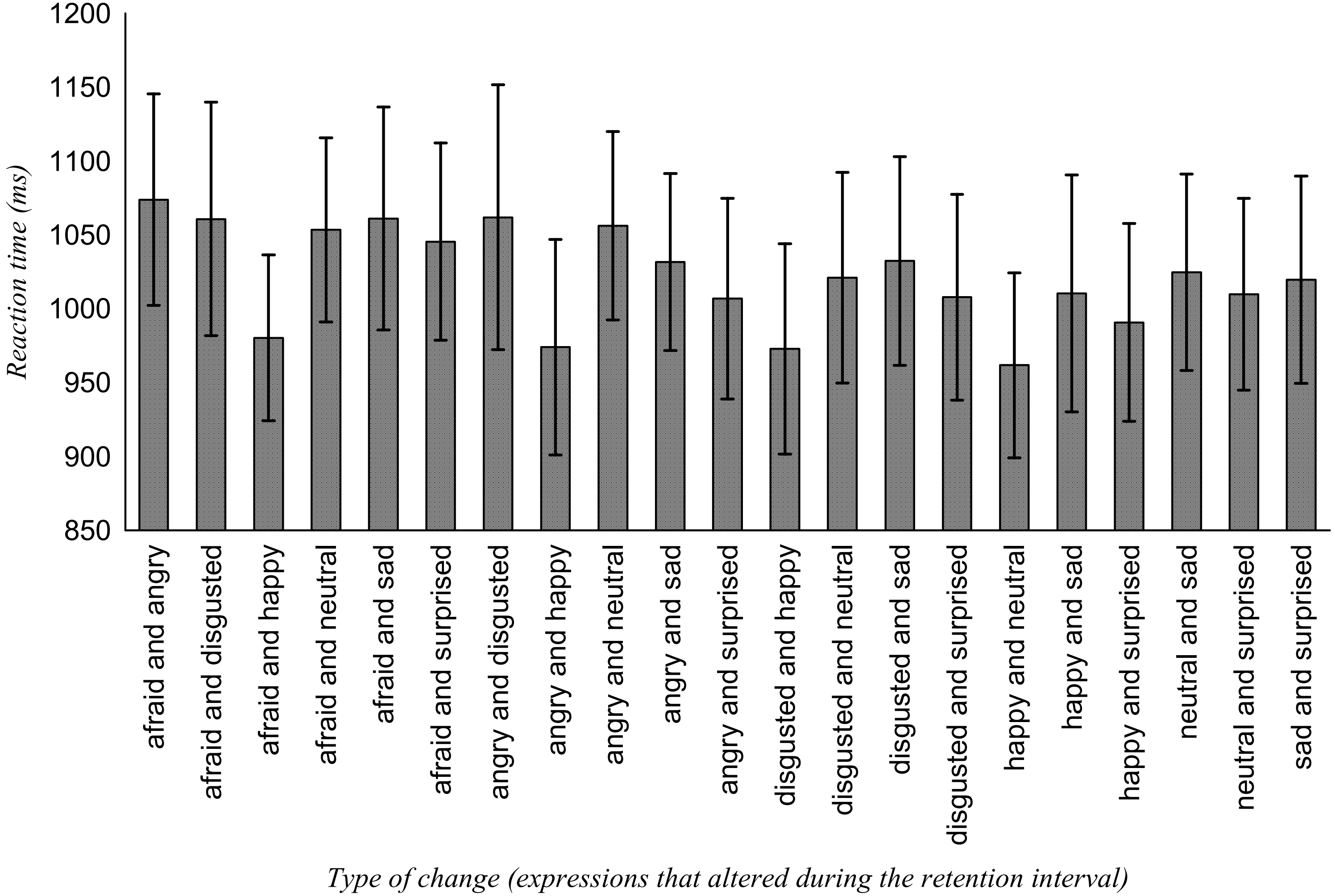


Table 10. Tukey HSD post-hoc comparisons for each combination of altering expressions, with reaction time as a dependent variable. Significant p-values are colored red.

	altered expressions \ means	1 1073,94	2 1060,77	3 980,33	4 1053,48	5 1061,08	6 1045,54	7 1061,96	8 974,06	9 1056,31	10 1031,73	11 1006,92	12 972,85	13 1021,15	14 1032,46	15 1007,81	16 961,81	17 1010,44	18 990,77	19 1024,77	20 1009,79	21 1019,69
1	*afraid and angry*		1,00	0,00	1,00	1,00	1,00	1,00	0,00	1,00	0,92	0,17	0,00	0,63	0,94	0,19	0,00	0,26	0,02	0,75	0,24	0,57
2	*afraid and disgusted*	1,00		0,02	1,00	1,00	1,00	1,00	0,01	1,00	1,00	0,59	0,01	0,96	1,00	0,62	0,00	0,72	0,12	0,99	0,69	0,94
3	*afraid and happy*	0,00	0,02		0,08	0,02	0,22	0,02	1,00	0,05	0,68	1,00	1,00	0,94	0,65	1,00	1,00	1,00	1,00	0,88	1,00	0,96
4	*afraid and neutral*	1,00	1,00	0,08		1,00	1,00	1,00	0,03	1,00	1,00	0,83	0,02	1,00	1,00	0,85	0,00	0,91	0,28	1,00	0,90	0,99
5	*afraid and sad*	1,00	1,00	0,02	1,00		1,00	1,00	0,01	1,00	1,00	0,58	0,01	0,95	1,00	0,61	0,00	0,70	0,12	0,98	0,68	0,94
6	*afraid and surprised*	1,00	1,00	0,22	1,00	1,00		1,00	0,10	1,00	1,00	0,97	0,08	1,00	1,00	0,97	0,01	0,99	0,55	1,00	0,99	1,00
7	*angry and disgusted*	1,00	1,00	0,02	1,00	1,00	1,00		0,01	1,00	1,00	0,54	0,01	0,94	1,00	0,58	0,00	0,67	0,10	0,98	0,65	0,92
8	*angry and happy*	0,00	0,01	1,00	0,03	0,01	0,10	0,01		0,02	0,45	0,99	1,00	0,82	0,42	0,99	1,00	0,98	1,00	0,70	0,99	0,85
9	*angry and neutral*	1,00	1,00	0,05	1,00	1,00	1,00	1,00	0,02		1,00	0,75	0,01	0,99	1,00	0,77	0,00	0,85	0,21	1,00	0,83	0,98
10	*angry and sad*	0,92	1,00	0,68	1,00	1,00	1,00	1,00	0,45	1,00		1,00	0,41	1,00	1,00	1,00	0,12	1,00	0,94	1,00	1,00	1,00
11	*angry and surprised*	0,17	0,59	1,00	0,83	0,58	0,97	0,54	0,99	0,75	1,00		0,99	1,00	1,00	1,00	0,87	1,00	1,00	1,00	1,00	1,00
12	*disgusted and happy*	0,00	0,01	1,00	0,02	0,01	0,08	0,01	1,00	0,01	0,41	0,99		0,78	0,38	0,99	1,00	0,98	1,00	0,66	0,98	0,82
13	*disgusted and neutral*	0,63	0,96	0,94	1,00	0,95	1,00	0,94	0,82	0,99	1,00	1,00	0,78		1,00	1,00	0,39	1,00	1,00	1,00	1,00	1,00
14	*disgusted and sad*	0,94	1,00	0,65	1,00	1,00	1,00	1,00	0,42	1,00	1,00	1,00	0,38	1,00		1,00	0,11	1,00	0,93	1,00	1,00	1,00
15	*disgusted and surprised*	0,19	0,62	1,00	0,85	0,61	0,97	0,58	0,99	0,77	1,00	1,00	0,99	1,00	1,00		0,85	1,00	1,00	1,00	1,00	1,00
16	*happy and neutral*	0,00	0,00	1,00	0,00	0,00	0,01	0,00	1,00	0,00	0,12	0,87	1,00	0,39	0,11	0,85		0,77	1,00	0,28	0,79	0,44
17	*happy and sad*	0,26	0,72	1,00	0,91	0,70	0,99	0,67	0,98	0,85	1,00	1,00	0,98	1,00	1,00	1,00	0,77		1,00	1,00	1,00	1,00
18	*happy and surprised*	0,02	0,12	1,00	0,28	0,12	0,55	0,10	1,00	0,21	0,94	1,00	1,00	1,00	0,93	1,00	1,00	1,00		0,99	1,00	1,00
19	*neutral and sad*	0,75	0,99	0,88	1,00	0,98	1,00	0,98	0,70	1,00	1,00	1,00	0,66	1,00	1,00	1,00	0,28	1,00	0,99		1,00	1,00
20	*neutral and surprised*	0,24	0,69	1,00	0,90	0,68	0,99	0,65	0,99	0,83	1,00	1,00	0,98	1,00	1,00	1,00	0,79	1,00	1,00	1,00		1,00
21	*sad and surprised*	0,57	0,94	0,96	0,99	0,94	1,00	0,92	0,85	0,98	1,00	1,00	0,82	1,00	1,00	1,00	0,44	1,00	1,00	1,00	1,00	

When reaction time was set as dependent variable (Figure 25), ANOVA revealed that the main effect of type of change was significant ($F(20, 460) = 4,84$, $p < .001$). Results obtained via Tukey HSD post-hoc comparisons are presented in the Table 10.

3.3 Working memory capacity for emotional expressions

3.3.1 Pashler's (1988) method

The most frequently used method for quantification of visual working memory capacity was developed by Pashler (1988). Inspired by the work of Phillips (1974) and Purdy, Eimann & Cross (1980), Pashler (1988) constructed a method which is now generally accepted as one of the best approaches for estimation of visual working memory span. The procedure is adopted from signal detection theory, and it is applicable in change detection tasks in which one item can change between two displays.

According to signal detection theory, each trial can have four outcomes:

a) hit - change occurs and observer detects it
b) miss – change occurs, but observer fails to detect it
c) false alarm – change does not occur, but observer reports it occurred
d) correct rejection – change does not occur and observer correctly reports it had not occurred.

Only hits and false alarms (together with set size) are relevant for Pashler's (1988) formula:

$$H = \frac{C}{IP} + \frac{IP - C}{IP} * FA$$

When this formula is transformed, visual working memory capacity can be extracted:

$$C = \frac{IP*(H - FA)}{1 - FA}$$

C – number of objects stored in memory (visual working memory capacity),
H – hit rate,
IP – set size (total number of items presented in the initial display),
FA – false alarm rate.

To obtain a hit rate, the number of hits has to be divided by the number of all trials containing a change. Analogously, for computing false alarm rate, the number of false alarms needs to be divided by the number of all trials that do not contain a change.

In order to compute visual working memory capacity, hit and false alarm rates were extracted, and entered into the equation above separately for each participant. The output of these analyses reveals that mean visual working memory capacity for emotional facial expressions equals 3.07 (SD = 0,51), ranging from 1,53 through 4,02 expressions.

3.3.2 Švegar's (2008) calculation

Švegar (2008) argued that Pashler's (1988) method has several serious drawbacks and thus recommended another procedure for quantifying visual working memory capacity. The equation constructed by Švegar (2008) takes the percentage of correct answers into account, rather then hit and false alarm rate:

$$C_{\%} = \frac{IP*(PC-50)}{50}$$

$C_{\%}$ – visual working memory capacity estimated via percentage of correct answers,

PC – percentage of correct answers,

IP – set size (number of initially presented items).

In order to calculate visual working memory capacity for emotional facial expressions according to method of Švegar (2008), percentages of correct answers (in all 1008 experimental trials) were extracted, and entered into the equation above separately for each participant. The executed analysis reveals that the participants managed to hold between 1,13 and 3,17 emotional facial expressions in their visual working memory. Mean memory capacity equalled 2,14 expressions (SD = 0,52), according to estimation approach provided by Švegar (2008).

4 DISCUSSION

The experiment was designed primarily to explore which affective component facilitates detection of facial emotional expressions. However, the results obtained do not fit into any of the existing theoretical models which were subjected to experimental evaluation in the present study. Anyhow, statistical effects are consistent and imply that happy facial expressions are heavily prioritized by our cognitive system.

Before introducing a novel model that manages to explain the results acquired, answers to the initial research questions are going to be provided.

Other objectives were to test Williams et al.'s (2005) hypothesis, to check whether surprised expression changing into frightened (and vice versa) is the most difficult to detect amongst all types of changes, and to estimate visual working memory capacity for facial expressions.

Williams et al.'s (2005) hypothesis received no support, while findings regarding the question about surprised and frightened expressions are inconclusive.

Visual working memory capacity for emotional facial expressions was successfully quantified.

4.1 Threat vs. negativity vs. emotionality (Problem 1)

In various studies using visual search tasks, dot probe paradigm, eye-movement monitoring and other paradigms, it was demonstrated that angry facial expressions are prioritised by our cognitive system.

a) An angry face in a crowd of happy faces is detected faster than a happy face in a crowd of angry faces (Henson & Henson, 1988; Horstmann & Bauland, 2006).
b) An angry face in a crowd of neutral faces is detected faster than a happy face in a crowd of neutral faces (Fox et al., 2000; Calvo et al., 2006) or a sad face in a crowd of neutral faces (Calvo et al., 2006).
c) Dwell time is longer for angry relative to happy crowds (Fox et al., 2000).
d) Responding to a probe stimulus in dot probe tasks is faster if the probe is presented at location previously occupied by a masked angry face (Mogg & Bradley, 1999).
e) Search slopes are slower for angry faces compared to happy faces (Fox et al., 2000).
f) Angry faces are more likely to be processed preattentionally in parafoveal vision (Calvo et al., 2006).

All these conclusions present clear 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.

Most of these conclusions are at the same time consistant with the negativity hypothesis. To be precise, it would be more accurate to state that they are not contradictory to the negativity hypothesis (because these studies were not designed to test the negativity, but emotionality or threat hypothesis). Some other findings suggest that negatively valenced facial expressions are detected more efficiently compared to positive expressions (e.g. Eastwood et al., 2001; Hahn & Gronlund, 2007; Horstmann, 2007), and that is also in accordance with the negativity hypothesis.

Other previous findings fit well into the emotionality hypothesis.

a) In the condition of increased exposure time, 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).
b) All emotional faces receive first eye-fixation more often than neutral faces (Calvo et al., 2006).
c) All emotional faces are more likely to be refixated than neutral faces, which reveals late attentional engagement on emotional faces (Calvo et al., 2006).
d) Search performance is better for emotional faces among neutral distractors compared to neutral targets among emotional distractors (Williams et al., 2005).

4.1.1 The threat hypothesis

When the present study is considered, according to the threat hypothesis, accuracy is expected to be the highest in trials in which an angry face is presented at 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 relevant location in the initial display.

In a hypothetical attempt to extend the threat hypothesis in order to enable it to assimilate these results, the following speculation was taken into consideration: maybe teeth, which were most visible in happy faces, are somehow responsible for activation of some kind of threat-governed mechanism. Such idea is derived from certain behavioral studies conducted on animals (Wilson, 2000), which suggest that in some rare circumstances, showing teeth might be a sign of dominance and aggression. Therefore, just like animals can sometimes show their teeth in order to intimidate, humans might also do that for the same reason. Thus, visibility of teeth might be a sign of potential attack.

Furthermore, Ekman & Friesen (1976) diversify two variations of anger expressing, when lower part of face is considered. In the first of them lips are pressed together, while in the second they are detatched and teeth are visible. According to the speculation mentioned above, happy faces might be considered as threatening to a certain degree, because they contain a mark that is characteristic for some angry facial expressions – visible teeth.

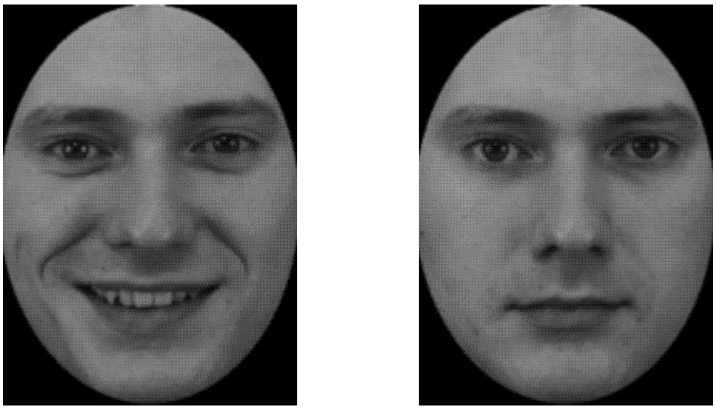
Moreover, Ekman (1992) differentiates various types of smiling, each of which has a different meaning. Smiles usually express enjoyment, but other type of smiles also exist (e.g. social smiles, masking smiles, deceivable smiles...). There are several methods for distinguishing genuine enjoyment smiles from other types of smiling (Ekman, 1992), and in all types of smiles, the facial muscle «zygomaticus major» is activated.

However, the facial muscle «orbicularis oculi» gets activated only when a person experiences happiness (Ekman & Friesen, 1982), and that is the most reliable indicator of genuine smiling. Besides the «orbicularis oculi», genuine enjoyment smiling can be diversified from other types of smiling by the action of certain other muscles, by the extent of bilateral symmetry and by the timing of smiling.

When all facial actions and bilateral symmetry are considered (especially the upper part of the face), happy expressions in the present study clearly lack any indications of threat – all happy faces were smiling genuinely (Figure 26). Moreover, Calvo & Lundqvist (2008) conducted a validation study and established that participants can accurately diversify all photographs displaying facial expressions, which were used in the present study. Therefore, the speculation that teeth, which were most visible in happy faces, activated some sort of threat-governed mechanism was discarded.

Even if that speculation was correct, the overall results would be in contradiction with the threat hypothesis. The spaculation would only explain the priority of happy expression, but the lack of superiority of angry expression over frightened, disgusted, sad, surprised and neutral expressions would still remain unexplained – if threat-governed mechanism was activated by teeth which made happy faces threatening, then angry faces (which surely are threatening) should at least be as prioritised as the happy ones.

Figure 26. Comparison of happy and neutral stimuli used in the present study. The activation of «orbicularis oculi», a mark of genuine enjoyment (Ekman & Friesen, 1982), is clearly visible on the happy face. The slightly curved horizontal line/wrinkle just below each eye is a mark which indicates that «orbicularis oculi» is active. On the neutral face that muscle is inactive.



Finally, when ecological relevance issue is considered, an additional argument against the threat hypothesis emerges: according to the evolutionary threat-advantage hypothesis, angry faces should be especially prioritised in the studies using real faces as stimuli compared to studies using schematic faces (Horstmann & Bauland, 2006). In the present study real faces were used, therefore the results obtained are not contradictory to the threat hypothesis due to the imperfection of stimuli.

4.1.2 The negativity hypothesis

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 acuracy. Reactions were the fastest in trials where the relevant location in the initial display was occupied by a happy face.

In the previous section it was explained that happy faces can not be considered as threatening or negative, but even if they could, neither angry, nor disgusted, nor sad, nor frightened faces had priority over neutral, so the results of the present study are clearly in disagreement with the negativity hypothesis too.

4.1.3 The emotionality hypothesis

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 (except 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 analysed.

Also, according to the emotionality hypothesis, no differences are expected between emotional expressions. Therefore, the advantage of happy expression over angry, frightened, sad, disgusted and surprised expressions also does not fit into the emotionality hypothesis.

4.1.4 Conclusion of «threat vs. negativity vs. emotionality» problem

Neither the threat hypothesis, nor the negativity hypothesis, nor the emotionality hypothesis manage to explain the results of the present study. The findings obtained do not even partially fit into any of these three hypotheses.

4.2 Williams et al.'s (2005) hypothesis (Problem 2)

The main goal of Williams et al.'s (2005) study was to investigate how threatening and nonthreatening facial expressions attract attention. In one of their experiments they used a modified search array in order to directly compare search times for happy, angry, sad and fearful expressions. They discovered that threatening facial expressions (angry and fearful) differ in their effect: angry faces were detected faster than frightened faces.

According to the theory of Öhman & Mineka (2001), angry and fearful faces are expected to be more efficient in attracting attention compared to nonthreatening stimuli, because they are processed via mechanisms that have evolved to alert us of danger. However, even though frightened faces were considered to indicate potential threat, angry and happy faces resulted in shorter search times compared to fearful faces (Williams et al., 2005).

In explanation of these results, authors claim that their findings only at first sight differ from Öhman & Mineka’s (2001) theory. In explanation, Williams et al. (2005) clarify that a threat expressed by a fearful face differs from a threat displayed by an angry face, because angry faces signal a potential threat from that particular individual, while frightened faces signal potential threat from the environment. Accordingly, angry faces summon focal attention, while fearful faces repel attention elsewhere in order to locate a threat.

Therefore, performance is expected to be the worst for trials in which a frightened face occupies the relevant location in the initial display, because these expressions are expected to receive the minimum of focal attention and because it is unreasonable to waste cognitive resources for memorizing the location of fearful expression.

The results of the present study reveal nothing special about frightened faces. They were processed neither better nor worse than other expressions, with the exception that they received lower priority compared to happy faces. Ergo, Williams et al.’s (2005) hypothesis received no support in the present study.

4.3 Fear and surprise – one or two expressions (Problem 3)

Resemblance between emotions of fear and surprise was first observed by Darwin (1872), who noticed that these two emotions are mixed and claimed that fear is often preceded by surprise and that these two emotions share the common element of physiological arousal.

The results of more recent cross-cultural studies reveal that facial expression of fear is the most difficult emotion to be recognized. Recognition accuracy for fearful expression is approximately 70% (Russell, 1994; Biehl, Matsumoto, Ekman, Hearn, Heider, Kudoh & Ton, 1997). Another important fact is that fearful faces are most often confused with surprised expressions (Ekman & Friesen, 1971, 1976; Russell, 1994; Rapsack et al., 2000; Huang et al., 2001; Adolphs, 2002; Palermo & Coltheart, 2005; Calvo & Lundqvist, 2008).

According to these studies, it is plausible to presume that facial expressions of fear and surprise might actually be the expressions of the same emotion. If these two descrete expressions could be merged into one, that would mean that there are not six, as Ekman claims (1976, 1982), but only five prototypical facial emotional expressions.

If participants' performance in the condition of fearful expression changing into surprised and vice versa is extremely poor compared to any other conditions, that would be an argument against Ekman's (1982) theory of six prototypical emotional expressions. Opposite findings would be in conformity with the theory of Ekman (1982, 2003), according to which surprised and frightened expressions are discrete.

The results of the present study suggest that changes of surprised into fearful expression and vice versa, were somewhat harder to detect than some other types of changes (Figure 24). Tukey HSD post-hoc comparisons revealed that participants detected changes significantly less accurate in trials which contained alteration of fearful and surprised expression, compared to trials containing alteration of: frightened and happy, angry and happy, angry and surprised, disgusted and happy, disgusted and neutral, disgusted and surprised, happy and neutral, happy and surprised, as well as sad and surprised (Table 9).

Tukey HSD post-hoc comparisons also revealed that participants' accuracy in detecting alterations of frightened and surprised expressions did not differ significantly compared to any of the following types of changes: frightened and angry, frightened and disgusted, frightened and neutral, frightened and surprised, angry and disgusted, angry and neutral, angry and sad, disgusted and sad, neutral and sad, as well as neutral and surprised (Table 9).

The analyses of reaction times indicate that the responding in trials containing alterations of surprised and fearful faces was no faster than the responding in other trials (Figure 25). Tukey HSD revealed that responding in detecting the changes of surprised and fearful expressions is as fast as detecting the changes of any other expressions, with the exception of trials in which happy and neutral expressions altered (Table 10).

When everything is taken into consideration, there are no strong evidence against the theory of Ekman (1982, 2003), according to whom emotions of fear and surprise are discrete. These two expressions are sometimes confused, probably because they are perceptually difficult to discriminate since they share several common features: eyes wide opened, eyebrows elevated, mouth opened (Figure 27).

Figure 27. Expressions of fear (left photograph) and surprise (right photograph).

4.4 Estimation of visual working memory capacity for facial expressions (Problem 4)

According to Pashler's (1988) procedure, 3,07 emotional expressions can be simultaneously held in visual working memory, while the method constructed by Švegar (2008) reveals that only 2,14 expressions can be maintained in visual working memory. In order to explain which of these estimations is more accurate, both procedures are going to be illustrated and compared.

Pashler's (1988) method is based on signal detection theory, and has a correction for guessing. In his original paper, Pashler (1988) considers all possible outcomes for the change detection trials in which only one or none of the items may change. He states that participants always hold a certain number of items in their memory. A hit follows if one of these items changes, and if one of the items that are not held in memory changes, then a miss occurs. However, when participants do not detect a change, they should answer that change is absent, but Pashler (1988) warns that occasionally participants answer that change is present although they did not detect it. If that happens, a false alarm actually occurs, or in other words, participants are guessing.

This is Pashler's (1988) formula:

$$H = \frac{C}{IP} + \frac{IP - C}{IP} * FA\,,$$

C is number of objects stored in memory (visual working memory capacity);
H is hit rate;
IP is total number of presented items;
FA is guessing rate (false alarm rate);
(*C* / *IP*) is proportion of trials in which an item that is stored in memory changes;
(*IP* – *C*) is number of objects that are not stored in memory;
(*IP* - *C*) / IP is proportion of trials in which an item that is not stored in memory changes.

When these symbols are translated into words, Pashler (1988) believes that the probability of hit equals the proportion of correctly detected changes in trials in which the changed item was stored into working memory (*C / IP*), added up with guessing, which refers to trials in which participants answer that change is present, but change actually did not occur. When the original formula is transformed, visual working memory capacity gets extracted:

$$H = \frac{C}{IP} + \frac{IP - C}{IP} * FA$$

$$H * IP = C + (IP - C) * FA$$

$$H * IP = C + IP * FA - C * FA$$

$$C - C * FA = H * IP - IP * FA$$

$$C * (1 - FA) = H * IP - IP * FA$$

$$C = \frac{H * IP - IP * FA}{1 - FA}$$

$$C = \frac{IP * (H - FA)}{1 - FA}$$

Švegar (2008) argued that although Pashler's (1988) method has a correction for guessing, that procedure still tends to overestimate visual working memory capacity. In a series of simulations, Švegar (2008) first demonstrated that Pashler's (1988) procedure is heavily dependent on criterion of responding. According to Švegar (2008), in trials in which participants are uncertain if a change occurred or not, they answer by chance. Some participants indeed answer by chance (approximately 50:50) on such trials, but some participants answer that change was absent in much more then 50% (even up to 100%) of trials in which they are unsure if a change had occurred. Analoguously, some participants answer that change was present in much more then 50% (even up to 100%) of trials in which they are unsure if a change had occurred. Thus, these three groups of participants use different criterions of responding: strict, normal and lenient. When only the trials in which participants are unsure if a change had occurred are considered, participants who tend to answer «change present» on majority of these trials have lenient criterion of responding, while participants who tend to answer «change absent» on majority of such trials have strict criterion of responding. In a series of theoretical simulations, Švegar demonstrated that Pashler's (1988) formula tends to overestimate true visual working memory capacity. Švegar (2008) also found that the size of overestimation positively correlates with the leniency of responding criterion. In other words, although Pashler's (1988) formula has a correction for guessing, the more participants guess, the higher memory capacity they have, according to Pashler's (1988) calculation.

In his simulations, Švegar (2008) also observed that the relationship of true visual working memory capacity and the percentage of correct answers in change detection tasks is linear. Therefore, Švegar (2008) suggested that visual working memory capacity should be measured via the percentage of correct answers, rather then via hit rates and false alarm rates as in Pashler's (1988) method.

This is the formula constructed by Švegar (2008):

$$\boldsymbol{C_{\%}} = \frac{IP * (PC - 50)}{50}$$

$\boldsymbol{C_{\%}}$ is visual working memory capacity estimated via percentage of correct answers;
PC is percentage of correct answers;
IP is set size (number of initially presented items).

A series of simulations have revealed that the formula of Švegar (2008) is better compared to the formula of Pashler (1988), because it neither overestimates (nor underestimates) true visual working memory capacity, nor is biased by the criterion of responding (Švegar, 2008).

In the present study, participants managed to store 2,14 (according to the method of Švegar, 2008) or 3,07 expressions (according to the method of Pashler, 1988). So, which of these two estimations are correct? As elaborated above, calculation via Pashler's (1988) method is overestimated, but however, the present study was specific, because it was exhausting for the participants (it contained 252 trials per session), so it is possible that tiredness had negative impact on their performance. When all these facts are taken into consideration, it can be concluded that people can hold between two and three emotional facial expressions in their visual working memory.

4.5 Happy face superiority effect

The results of the present study reveal happy face superiority in cognitive processing. In all of the analyses, the same effect was observed: performance was the best and the fastest for trials containing happy expressions either in the test display or at the relevant location in the initial display. But, is it possible that perceptual properties of stimuli had an important role in the guidance of cognitive processing? Some experiments proved that it is possible (e.g. White, 1995; Purcell et al., 1996), and that would mean that a happy face superiority effects, which were found in the present study, might for example be attributed to the visibility of teeth, which was the largest for happy facial expressions.

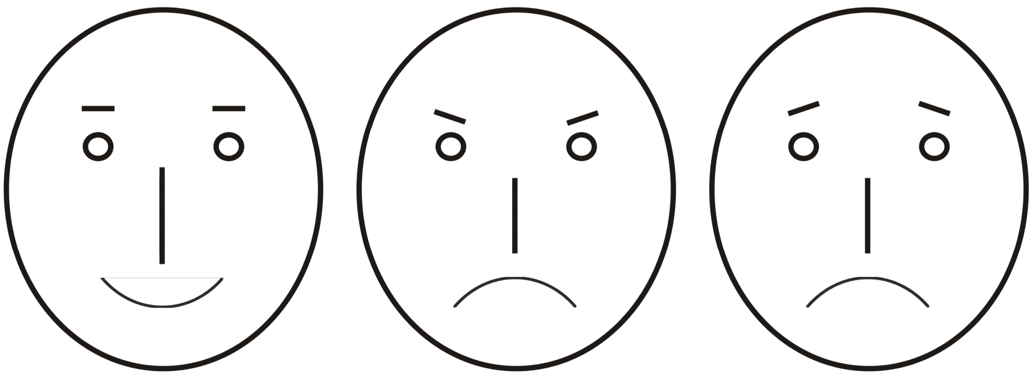
4.5.1 What guides cognitive processing: emotional component of facial expressions or their low-level perceptual properties?

As mentioned in the introduction, Purcell et al. (1996) managed to demonstrate that visual attention in Hansen & Hansen's (1988) experiment was guided by dark spots, which were present only on angry facial stimuli. When the original stimuli were turned into grey-scale, results altered: the search was no longer more efficient for discrepant angry faces in a crowd of happy faces then vice-versa. Thus, Purcell et al. (1996) demonstrated that search was guided by contrast differences, rather then facial expressions. In order to avoid effects of perceptual properties, such as in Henson and

Henson's (1988) study, researchers sometimes use grey-scale images or schematic faces to obtain pure effects of emotional expressions.

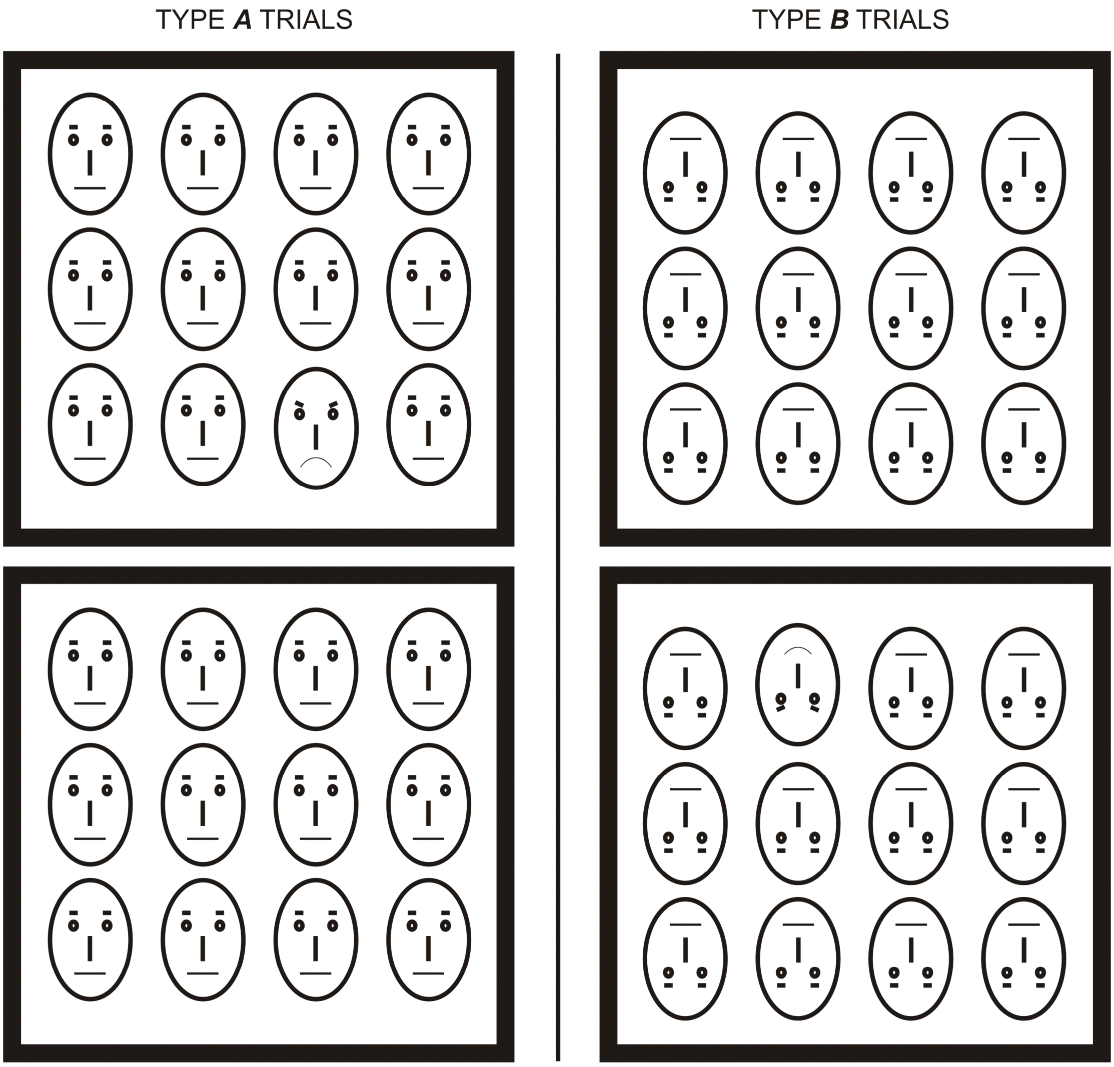
However, although experimental control is much more exact with drawings than with photograhps, schematic stimuli are also imperfect – they are excessively artificial and stereotyped (Frischen et al., 2008), and may introduce certain perceptual factors. For example, in smiling faces, curvature of mouth is in an excessive congruence with curvature of circular facial contour. Simultaneously, in frowning faces these curvatures are in an exaggerated incongruence (Figure D1). Such problems are absent in photographs of models' facial expressions. 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).

Figure D1. Happy, angry and sad schematic stimuli. Besides being extensively artificial and stereotyped, these stimuli may introduce certain undesired perceptual factors. For example, curvature of mouth in a smiling face is in excessive congruence with curvature of circular facial contour. On the other hand, these curvatures are in an exaggerated incongruence in angry and sad faces.



Convincing evidence contra hypothesis that perceptual properties of stimuli affect cognitive processing arise from experiments in which photographs of facial expressions are inverted. By invertion of stimuli it can be tested if low-level perceptual properties of stimuli or emotional expressions affect participants' performance. The logic is simple: if the results are identical for upright and inverted displays, then all experimental effects are the consequence of low-level physical properties (Figure D2). Using such procedures, Fox et al. (2000), Eastwood et al. (2001) and Williams et al. (2005) demonstrated that emotional expressions, rather then low-level physical properties, guide cognitive processing.

Figure D2. Visual search task with inverted stimuli. In a condition of upside-down presented stimuli (Type *A* trials) an angry face in display of neutral faces is detected faster then a happy face among neutral distractors. Also, dwell time is longer for displays containing only angry faces compared to displays containing only neutral faces. When inverted displays containing identical stimuli are presented (Type *B* trials), all these effects vanish: search speed is practically identical for all conditions using inverted displays (e.g. Fox et al., 2000). This finding disproves hypothesis that low-level perceptual properties affect cognitive processing, and suggests that the experimental effects are caused by emotional expressions.



Another creative experiment confirms the crucial importance of emotional component rather then low-level perceptual properties. Gerritsen, Frischen, Blake, Smilek & Eastwood (2008) 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. They conditioned participants to associate hostile and peaceful etiquette to two different target faces, which were both neutral and perceptually identical. They found that 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 (Osgood & Hoosain, 1983; Feyereisen et al., 1986; Stenberg, Wiking & Dahl, 1998), and 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 (e.g. visibility of teeth) do. That conclusion is valid for all the stimuli used in the present study.

4.5.2 Happy face superiority effects in previous studies

Although numerous miscellaneous experiments found the advantage of angry or negative stimuli, there are a few interesting findings revealing the happy face superiority effect. Happy faces were not in the main focus of the present study, and for that reason, only few experiments that found any kind of superiority in cognitive processing of happy expressions were metioned so far (e.g. Palermo & Coltheart, 2004; Calvo & Lundqvist, 2008).

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

The results of these studies revealed that facial expression of happiness is recognized faster and/or more correct than the expression of:

- anger (Harrison, Corelczenko, Cook, 1990; Billings, Esteves & Öhman, 1993; Harrison & Alden, 1993; Hugdahl, Iversen & Johnsen, 1993; Palermo & Coltheart, 2004; Goren & Wilson, 2006; Montagne, Kessels, De Haan & Perrett, 2007; Calvo & Lundqvist, 2008; Milders, Sahraie & Logan, 2008),
- disgust (Stalans & Wedding, 1985; Leppänen & Hietanen, 2004; Palermo & Coltheart, 2004; Montagne et al., 2007; Calvo & Lundqvist, 2008),
- fear (Palermo & Coltheart, 2004; Goren & Wilson, 2006; Montagne et al., 2007; Calvo & Lundqvist, 2008; Milders et al., 2008),
- sadness (Stanners, Byrd & Gabriel, 1985; Feyereisen et al., 1986; Crews & Harrison, 1994; Palermo & Coltheart, 2004; Goren & Wilson, 2006; Montagne et al., 2007; Calvo & Lundqvist, 2008),
- surprise (Palermo & Coltheart, 2004; Montagne et al., 2007; Calvo & Lundqvist, 2008) and
- neutral expression (Esteves & Öhman, 1993; Hugdahl et al., 1993; Leppänen & Hietanen, 2004; Palermo & Coltheart, 2004; Milders et al., 2008).

In other, cross-cultural studies, recognition scores were also the highest for happy facial expressions (e.g. Ekman & Friesen, 1976; Ekman, 1982; Russell, 1994). Leppänen & Hietanen (2004) clearly demonstrated that the observed advantages of happy faces in recognition speed studies can not be attributed to low-level physical differences between happy and other facial expressions.

In similar recognition studies, Hess, Blairy & Kleck (1997) and Palermo & Coltheart (2004) varied the intensity of emotional expressions. Hess et al. (1997) investigated the relation between the physical intensity and recognition accuracy, while Palermo & 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 & Wilson (2006) discovered that peripheral recognition of emotional expressions is impaired compared to foveal recognition. However, that 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 anyway. In line with the findings of Goren & Wilson (2006), Mack & 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).

Although in other paradigms the happy face superiority was almost never observed (with some exceptions, such as Juth et al. (2005), who applied visual search tasks, or Leppänen et al., (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.

4.5.3 Prior exposure to happy and other faces

Before providing an explanation of the happy face superiority effect observed in the present experiment, special attention must be given to Somerville & Whalen's (2006) study. These two authors emphasize the importance of participants' prior experience, which can have an undesirable impact on the results if it is unequal between experimental conditions. That is a serious problem for methodologists, because we lack the ability to control prior experiences of human participants. Bearing these thoughts in their minds, Somerville & Whalen (2006) decided to investigate our exposure to primary emotional facial expressions. They presented a list of the six primary (together with neutral) facial expression labels to an impressive sample of circa 1500 subjects, and instructed them to rank these labels with regard to the frequency with which they assumed they had encountered these expressions in their lifetimes. To increase clarity, two words were presented per each expression category: angry/mad, disgusted/yuck, fearful/afraid, happy/smiling, sad/unhappy, surprised/startled, neutral/expressionless. Analyses showed that happy expressions were reported being seen the most often. When other expressions are sorted by frequency with which they were encountered, happy expressions were followed by neutral ones, than by sad, angry, surprised, disgusted and finally fearful expressions which were reported as having been seen the least frequent.

Although Somerville & Whalen (2006) used verbal labels instead of photographed facial expressions, and although their results rely on participants' ability to accurately quantify their past experience, their finding is robust and relevant for the present study, especially the result that people see more happy facial expressions even than neutral ones in their lifetime. Such a familiarity bias might underlie the happy face superiority effects in recognition studies and in the present study too.

Öhman et al. (2001) attempted to avoid the frequency problem by using schematic faces. They reasoned that all schematic faces are unfamiliar abstractions of real faces, but Leppänen & Hietanen (2004) presented a good counter-argument. Leppänen & Hietanen (2004) argued that similar differences as in real facial expressions may exist among simplified schematic emotional signals: smileys are probably the most frequent emoticons that we encounter.

Thus, the methodological issue of participants' prior exposure to different emotional facial expressions seems to be an insuperable barrier for providing theoretical explanation of the happy face superiority effect, but only at first sight, until Mack & Rock's (1998) findings are considered.

As mentioned earlier, Mack & Rock (1998) discovered that happy faces are efficiently recognized even when they are presented unexpectedly among a mass of other stimuli. Unlike happy faces, participants are not able to recognize other facial expressions under the condition of inattention. In order to examine whether familiarity of stimuli underlies the efficiency of their recognition, Mack & Rock (1998) presented highly frequent words or shapes in a similar paradigm, but even highly familiar stimuli did not generate even nearly as similar effect as happy faces did. These findings clearly support the view that the happy face advantage can not be explained by the high frequency of their appearance (Mack & Rock, 1998; Leppänen & Hietanen, 2004).

In explanation of these findings, Leppänen & Hietanen (2004) suggest the existence of a high-level asymmetry in the recognition of positive and negative signals, because not only happy faces but also positive words and positive pictures other than faces, were found to be recognized efficiently and fast (e,g, Lehr, Bergum & Standing, 1966; Stenberg et al., 1998). According to Leppänen & Hietanen (2004), possible origin of such asymmetry is normatively positive mood (Diener & Diener, 1996) and a tendency to form positively biased hypotheses about reality and first of all about other people (e.g. Sears, 1983; Peeters & Czapinski, 1990). Leppänen & Hietanen's

(2003) interesting findings support the existence of such asymmetry: they demonstrated that pleasant odour context improves the recognition of happy faces.

4.5.4 Evolution and function of smile

The diversity and flexibility of our facial behavior results from evolutionary requirements, and has a function to negotiate certain aspects of social interactions in relation to specific ecological conditions (Preuschoft & van Hooff, 1997; Mehu, Grammer & Dunbar, 2007).

Human smiling is an expression which originates from the primate lineage – human smile is the equivalent of nonhuman primates' silent bared-teeth display (van Hoof, 1972; Burrows, Waller, Parr & Bonar, 2006). When primate species are considered, the use of silent bared-teeth display is primarily dependent on the type of social relationships originating from particular ecological conditions rather than on phylogenetic aspects reflecting mutual ancestry (Preuschoft & van Hooff, 1997; Mehu et al., 2007). In a short review, Mehu et al. (2007) demonstrate that different primate spieces use silent bared-teeth display is diverse social situations:

a) in rhesus macaque and hamadryas baboon it is displayed in aggressive contexts only by subordinates in order to appease dominants (e.g. de Waal & Luttrell, 1985), while
b) chimpanzee and Tonkean macaque show silent bared-teeth display in various social situations ranging from appeasement to reconciliation (van Hoof, 1972; Thierry, Demaria, Preuschoft & Desportes, 1989).

Since one of the functions of silent bared-teeth display is to inhibit aggressive behavior, and the inhibition of aggressive tendencies is the first step toward social bonding (e.g. de Waal, 1986), Mehu et al. (2007) hypothesize that silent bared-teeth display may have emancipated into a behavior crucial for creating social relationships. To support their view, Mehu et al. (2007) highlight that various non-human primates use silent bared-teeth display in clearly affiliative context, such as greeting, grooming, embracing as well as huddling (van Hoof, 1967, 1972; de Waal, 1988; Thierry et al., 1989; Petit & Thierry, 1992). On the grounds of these findings and recent evidence that silent bared-teeth display positively correlates with the frequency of affiliative behaviors in captive chimpanzees (Waller & Dunbar, 2005) and in humans in natural environment (Mehu, 2006), Mehu et al. (2007) suggest that silent bared-teeth display is not limited only to the inhibition of aggressive tendencies in dominants – they belive that it has an important role in the development of cooperative relationships.

Social strategies based on aggressive behavior are unproductive in certain situations which require mutual action of several individuals (Dunbar, 1988). Therefore, cooperative relationships were developed in order to ensure efficient resource exploitation in situations in which that can not be achieved through strategies based on competition or aggressive behavior (Mehu et al., 2007). Effective signaling of the willingness to engage in a cooperative relationship and a successful identification of these signs are thus an extremely important aspect of social behavior, because in order to achieve valuable egalitarian cooperative relationships, individuals have to restrain their aggressive tendencies and signal their willingness to cooperate (Mehu et al., 2007). Mehu et al. (2007) believe that silent bared-teeth display emancipated from a signal of non-hostile intentions into a sign indicating willingness to cooperate. They also claim that smiling is a modern form of silent bared-teeth display in human.

Following the idea that smiling is a behavioral machanism crucial for cooperative interactions, Mehu et al. (2007) decided to experimentally investigate if people smile more in situations in which they must work together in order to exploit resources. They believed that the frequency of Duchenne smiles (spontaneous sincere smiles that include the activation of «orbicularis oculi» region) should be higher in cooperative interactions compared to non-cooperative control interactions. In an interesting experiment, they observed pairs of participants in a control and in the experimental situation in which they were required to agree about sharing 40 € reward for participation. The results of their experiment were fascinating: besides finding that the frequency of smiles was higher in situations when pairs of participants were engaged in an interaction of sharing financial resources, Mehu et al. (2007) also discovered that participants who expressed high altruistic intentions toward their partner also showed higher rates of smiling when they were engaged in active sharing. Another interesting result was found: smiling induced happiness in the observer, similarly as in the study of Surakka & Heitanen (1998). To check whether high frequency of smiles was just a result of feeling happy while sharing, Mehu et al. (2007) compared self-reported happiness scores in experimental and control situations. No relation between self-reported happiness and the frequency of smiling was found, so this alternative explanation was discarded.

The finding of Mehu et al. (2007) is consistant with the conclusions of several other studies. For example, the findings of Scharlemann, Eckel, Kacelnik & Wilson (2001), who investigated the importance of trustworthiness in bargaining also corroborate that smiling is involved in cooperative interactions. In their exciting and amusing experiment, authors tried to investigate whether smiling elicits trust among strangers. The inspiration for their experiment was found in the prisoner's dillema game.

In the original example of the prisoner's dilemma, two criminals are arrested for committing a serious crime. Although some evidence against them exist, they are insufficient for harsh conviction, so police investigators decide to interrogate the criminals in two separate rooms and offer each of them a deal: The criminal who makes a confession and offers evidence against his partner will be liberated. There are only three possible outcomes in this situation:

a) if only one criminal accepts the offer, he will be liberated, but the other one will be severely punished,
b) if both criminals confess and provide evidence against each other, both will be severely punished, and
c) if none of them betrays the other one, they will both be liberated with a small punishment.

Each of the prisoners has only two options – to accept or to reject the offer. The best outcome for the prisoners occurs if they both reject the offer. By doing so, they are in fact cooperating against the police. However, since they are isolated, it is difficult for them to make a good decision because they can not know what the other one will do.

On the example of the prisoner's dilemma game, Scharlemann et al. (2001) explain that in real-life situations it is also often the best choice for partners to choose cooperative strategy, but that can be risky because cheaters can take advantage of the cooperator. Therefore, choosing thrustworthy partners is extremely important for successful outcomes.

In their experiment, Scharlemann et al.'s (2001) participants played a simple trust game, similar to the prisoner's dilemma game with financial stakes. All participants were playing against a pre-programmed computer strategy, but they were deceived that they are playing against another human participant in the experiment. The game was structured in a manner that in the first move human participant can either take 1 € and finish the game immediately (in that case second player would receive 0,50 €), or pass a move to the other player who then has the option either to take 1,25 € and finish the experiment (in that case first player receives 0,80 €) or to pass the move back to the first player. In the third and final move, the first player has an alternative choice between 1 € or 1,20 € for each player. This final move was used only for control, in order to test if subjects are able to make rational choices or if they understood the instructions – subjects who selected 1 € were excluded from the analyses (there were only three such subjects). Human participants always took the first move, and all participants were informed about the alternative choices which are going to be offered in the second and in the third move. Before the game began, each participant was randomly presented with a picture of a person whom he believed he was playing with. A picture of a smiling face was presented to half of participants, while neutral expression of the same face was presented to the other half of subjects. The analyses showed significant effect of the facial expression of «co-player»: participants presented with a smiling face were more trustworthy and cooperative relative to participants presented with a neutral face. Scharlemann et al. (2001) concluded that smiling increases trust among strangers.

Mehu, Little & Dunbar (2008) explored the impact of smiling on the judgement of traits relevant to social relationship. Their participants judged 50 models who were photographed twice. In one photograph they expressed smile, while in the other their expression was neutral. Each participant was randomly assigned to either the experimental (happy faces) or control (neutral faces) condition and judged attractiveness, generosity, trustworthiness, competitiveness, health, agreeableness, extroversion, neuroticism, conscientiousness, and openness to experience for a total of 50 photographs. Gender of participants and gender of models were also included into analyses. When only the effect of emotional expression was taken into consideration, smiling faces were judged as significantly more attractive, generous, competitive, healthy, aggreeable and extraverted compared to neutral faces.

Some of Mehu et al.'s (2008) findings do not corroborate the conclusion of Scharlemann et al. (2001) about the importance of smiling for cooperation. However, similarly as Brown, Palameta & Moore's (2003) finding that smiling could be associated with the detection of altruists, Mehu et al.'s (2008) discovery that people who smile are perceived as more generous, actually is in confluence with Scharlemann et al.'s (2001) theory, because generous people and altruists are surely preferred as cooperative partners. Mehu et al.'s (2008) findings that extraversion and agreeableness is perceived higher for smiling faces also fit well into the evolutionary perspective, because it is reasonable to engage interactions with extroverted and agreeable (that trait is negatively correlated to hostility) people. In addition, compared to neutral ones, smiling faces are perceived as being more reliable and sincere (Otta, Lira, Delevati, Cesar & Pires, 1994).

Smiling faces are also perceived as more attractive compared to neutral ones (Lau, 1982; Otta, Lira, Delevati, Cesar & Pires, 1994; Otta, Abrosio & Hoshino, 1996; Mehu et al., 2008). The effects of gender are also interesting: if smiling is involved in mate choice it should be expected that opposite-sex faces should be rated as more attractive compared to same-sex faces. Mehu et al. (2008) discovered that women's smiling was particularly efficient in affecting men's judgments: women who smile are perceived as more attractive when observed by men. Since men are very vulnerable to the influence of women's smile, that means that women can increase attractiveness by smiling and benefit from such behavior in sexual relationships, because physical attractiveness (as well as health) is the most important attribute that males consider when evaluating female mate potential (Buss, 1989; Buss & Schmitt, 1993). In a study conducted in single's bars, Moore (1985) managed to observe that women are able to use non-verbal displays in order to increase a number of male approaches, which allows them to choose among a number of available men, and amongst all female non-verbal courtship behaviors, smiling is found to be the most frequent one (Moore, 1985). In addition, people who smile advertise their health (Mehu et al., 2008), and the detection of a healthy individual among a crowd of people is clearly valuable from an evolutionary point of view, because healthy individuals are eligible mating partners. Thus, smiling can also be considered as a part of a social strategy based on self-presentation.

4.5.5 Explanation of the results obtained in the present study

Pure happy face superiority effect, which was obtained in the present study, fits well into the evolutionary framework, after all. 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 et al., 2007). 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).

Smiling is efficient in changing the observer's attitude towards the sender. By smiling, people signal their willingness to engage into a cooperative relationship with the observer of their smile (Mehu et al., 2007). Besides signalling of readiness to cooperate through facial expressions, when people smile, they advertise their attractiveness and health to other people. 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). In addition, people who smile are considered to be more generous, competitive, agreeable and extraverted (Mehu et al., 2008). Smiling also increases trust among strangers (Scharlemann et al., 2001), and even has positive effects on attribution of leniancy to criminals (LaFrance & Hecht, 1995). 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 (Surakka & Heitanen, 1998; Mehu et al., 2007).

Therefore, smiling is a behavior adaptive for the sender and for the receiver, which consequently has positive effects, especially on social relationships (Scharlemann et al., 2001; Mehu et al., 2007), in accordance with the behavioral ecology approach (Fridlund, 1994).

Finally, one extremely important finding will be presented, in confluence with the results of the present study. Our visual system has evolved to enable detection of a face in the perifery, but only in order to direct attention, that is to direct gaze to that face. Once foveated, emotional expression of that face can than be processed. Peripheral recognition of facial expressions is extremely poor for all except happy expression. To recognize an angry, sad or fearful faces, observer first has to direct the gaze toward the face, but that is not at all necessary for the recognition of happy faces (Goren & Wilson, 2006).

So, according to all facts written above, whom should we rely on, whom should we mate with, whom should we trust, whom should we not avoid? **People who smile!** For that reason, it is very logical that smiling faces should receive priority in cognitive processing. Observers clearly benefit from detecting, recognizing and memorizing a location of a happy face in a crowd, because that is a location of their potential business or romantic partner. So, in order not to overlook a good opportunity for cooperation, romantic intercourse, or other beneficial social interaction, happy faces are given the priority in cognitive processing over other emotional expressions. In this way, our evolutionary fitness is optimized.

5 CONCLUSION

Neither the threat hypothesis, nor the negativity hypothesis, nor the emotionality hypothesis received any support. Williams et al.'s (2005) hypothesis was also not corroborated. No strong evidence against the theory of Ekman (1982, 2003) emerged. Instead, it was discovered that happy faces are prioritised by human cognitive system, and it was elaborated that the obtained happy face superiority effect was not just an artefact of methodological imperfection, such as visibility of teeth (which were most noticeable on happy faces), or familiarity (participants prior experience) with happy faces.

Also, it was calculated that people can store and retain 2-3 emotional facial expressions in their visual working memory.

The results obtained were explained within the evolutionary framework. It was elaborated that smiling is an evolutionally developed behaviour, which is adaptive for the receiver and for the sender and has positive effects on social relationships. Happy faces receive priority from our cognitive system, because observers clearly benefit from detecting, recognizing and memorizing the location of a happy face in a crowd – that is the location of their potential business or romantic partner.

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7 SLOVENE VERSION

7.1 Povzetek

Pričujoča raziskava skuša odgovoriti na štiri probleme:

Problem 1. Odkriti katera čustvena komponenta vodi kognitivno predelavo čustvenih obraznih izrazov. Trenutno o tem obstajajo tri hipoteze, od katerih ima vsaka določeno empirično podporo: *hipoteza grožnje*, *hipoteza negativnosti* in *hipoteza čustvenosti*.

Problem 2. Ovrednotiti hipotezo Williamsa in sodelavcev (2005), ki menijo, da opazovalci preusmerijo pozornost vstran od preplašenega obraza, da bi poiskali vir njegovega strahu, ker je lahko ta vir nevaren tudi zanje.

Problem 3. Ugotoviti, ali sta prestrašen in presenečen izraz neodvisna obrazna izraza ali ne.

Problem 4. Oceniti zmogljivost vizualnega delovnega spomina za čustveno izražanje.

Številne raziskave so z uporabo različnih metodoloških pristopov, specializiranih za eksperimentalno raziskovanje kognitivne predelave čustvenih izrazov obraza (npr. naloge vizualnega iskanja, paradigme iskanja pike, spremljanje očesnega gibanja) skušale odgovoriti na nekatera od teh vprašanj, vendar so bile pri tem neuspešne. Zato smo v pričujoči raziskavi na področju kognitivne predelave človeških čustvenih izrazov, uporabili postopek, izdelan predvsem za raziskave pozornosti, vida, delovnega spomina in zavesti (paradigma odkritja sprememb).

V eksperimentu so bile štiriindvajsetim udeležencem prikazane slike človeških čustvenih obraznih izrazov v 1008 poskusih po udeležencu. Vsak od poskusov se je začel s prikazom posnetka, ki mu je sledil kratek prikaz šestih čustvenih obraznih izrazov. Sledil je prikaz praznega zaslona. Po takem meddražljajskem intervalu je bil na eni od prej zasedenih šestih lokacij prikazan obrazni izraz. Udeleženci so morali odgovoriti, ali je testni obrazni izraz drugačen ali enak izrazu predstavljenem na isti lokaciji pred spominskim intervalom.

Analizirali smo odstotke pravilnih odgovorov in odzivne čase. Lahko sklenemo, da nobena od hipotez, ne hipoteza grožnje, ne hipoteza čustvenosti, ne hipoteza negativnosti, ni bila podprta. Tudi hipoteza Williamsa in sod. (2005) ni bila podprta. Nismo odkrili dokazov, ki bi nasprotovali teoriji o neodvisnosti čustev strahu in presenečenja. Vse analize so dosledno pokazale prednost srečnega obraza v kognitivni predelavi – srečnim izrazom na obrazu daje naš kognitivni sistem veliko prednost.

Čeprav so bili ti rezultati nepričakovani, dobro ustrezajo evolucijskem okvirju in se skladajo s številnimi dosedanjimi ugotovitvami. Smehljanje je evolucijsko razvito obnašanje, ki je prilagojevalno tako za prejemnika kot za pošiljatelja in ima pozitiven vpliv na socialne odnose. Srečnim obrazom daje naše kognitivni sistem prednost, saj opazovalcem nedvomno koristi zaznavanje, prepoznavanje in zapomnitev položaja srečnega obraza v množici.

7.2 Uvod

Ker je hiter odziv na prisotnost potencijalne grožnje v okolju očitno evolucijska prednost, ima hitro odkrivanje obraznega izražanja jeze očitno veliko prilagojevalno vrednost. Zato lahko domnevamo, da daje naš kognitivni system prednost hitremu prepoznavanju grožnje na obrazu in na področju prepoznavanja obraznih izrazov je ta hipoteza znana kot *hipoteza grožnje* (Fox in sod., 2000; Calvo in sod., 2006).

Po drugi strani, v skladu s *hipotezo negativnosti*, pritegne neprijetna človekova čustvena izkušnja pozornost, ne glede na to, ali predstavlja nevarnost ali ne. Torej, jezni obrazi ne pritegnejo pozornost ker predstavljajo nevarnost, ampak zato, ker prikazujejo negativno čustvo. Tako naj bi po hipotezi negativnosti veljala domneva, da naj bi bil v množici obrazov žalosten obraz odkrit enako dobro kot jezen (Calvo in sod., 2006).

Končno pa Martin in sod. (1991) menijo, da pozitivni čustveni izrazi lahko pritegnejo pozornost enako učinkovito kot negativni čustveni izrazi in temu pogledu pravimo *hipoteza čustvenosti*. Po hipotezi čustvenosti je posebna pozornost posvečena vsem čustvenim dogodkom (Fox in sod., 2000; Calvo in sod., 2006).

Razne raziskave z uporabo nalog vidnega iskanja, paradigme iskanja pike, spremljanja očesnih gibov in drugih paradigem so pokazale, da daje naš spoznavni sistem prednost jeznim obraznim izrazom: jezen obraz v množici srečnih obrazov bomo hitreje odkrili kot srečen obraz v množici jeznih obrazov (Henson in Henson, 1988; Horstmann in Bauland, 2006); jezen obraz v množici nevtralnih obrazov bo hitreje odkrit kot srečen obraz v množici nevtralnih obrazov (Fox in sod., 2000; Calvo in sod., 2006) ali žalosten obraz v množici nevtralnih obrazov (Calvo in sod., 2006); čas pozornosti je daljši za jezne, v primerjavi s srečnimi množicami (Fox in sod., 2000); odziv na iskane dražljaje pri nalogi iskanja pike je hitrejši, kadar je pika prikazana na lokaciji, ki jo je prej zasedal maskiran jezni obraz (Mogg in Bradley, 1999); iskalni nagibi so počasnejši za jezne obraze v primerjavi s srečnimi obrazi (Fox in sod., 2000); jezni obrazi bodo verjetneje predpozornostno predelani v parafovealnem vidu (Calvo in sod., 2006). Vse te ugotovitve predstavljajo jasen dokaz, da je odkrivanje jeznih obrazov olajšano, kot bi lahko pričakovali glede na hipotezo grožnje. Jezne obraze odkrivamo bolj učinkovito kot druge čustvene ali nevtralne obraze, kar pomeni, da je predelava obrazov usmerjena k odkrivanju nevarnosti.

Večina teh ugotovitev je hkrati v skladu z hipotezo negativnosti, ali natančneje niso v nasprotju z njo (zato ker te raziskave niso bile namenjene preverjanju hipoteze negativnosti, ampak hipoteze čustvenosti ali hipoteze grožnje). Nekatere druge ugotovitve kažejo, da odkrivamo negativno valenčne obrazne izraze bolj učinkovito v primerjavi s pozitivnimi izrazi (e.g. Eastwood in sod., 2001; Hahn in Gronlund, 2007; Horstmann, 2007). To je tudi v skladu z hipotezo negativnosti.

Ostale omenjene ugotovitve se lepo ujemajo s hipotezo čustvenosti: pod pogojem podaljšanega časa izpostavljenosti, odkrivanje odsotnosti neskladnega obraza ne traja dalj za jezne v primerjavi s srečnimi množicami (Fox in sod., 2000); na vse čustvene obraze se prvi pogled osredotoča bolj pogosto kot na nevtralne obraze (Calvo in sod., 2006); vse čustvene obraze so bolj pogosto ponovno pogledali kot nevtralne, kar kaže na pozno delovanje pozornosti na čustvene obraze (Calvo in sod., 2006); iskanje je boljše za čustvene obraze med nevtralnimi motilci v primerjavi z nevtralnimi tarčami med čustvenimi motilci (Williams in sod., 2005).

Pričujoča raziskava je nastala predvsem zato, da bi eksperimentalno ovrednotila omenjene tri hipoteze, od katerih je vsaka v dosedanjih raziskavah prejela določeno empirično podporo.

Drugi cilj te raziskave je bil ovrednotiti hipotezo Williamsa in sod. (2005) o prestrašenih obrazih. Williams in sod. (2005) so odkrili, da prestrašenih obrazov, kljub prepričanju, da na sploh kažejo na morebitno grožnjo, ne odkrijemo hitreje kot žalostnih, srečnih ali jeznih obrazov. Pri razlagi tega nepričakovanega rezultata so avtorji domnevali, da oba obraza, jezen in prestrašen, ne izražata enakovredne vrste grožnje: medtem, ko jezen obraz oddaja signale možne nevarnosti s strani danega posameznika, prestrašen obraz kaže, da je potencijalna grožnja nekje drugje v okolju. Zato je žariščna pozornost osredotočena na jezen obraz, ker je ta vir nevarnosti, toda namesto k prestrašenemu obrazu, bo pozornost preusmerjena v okolico, da odkrije grožnjo.

Drug cilj tega eksperimenta je bil odgovor na vprašanje strahu in presenečenja. Podobnost med obema čustvoma je prvi opazoval Darwin (1872), ki je odkril, da sta ti čustvi mešani in je menil, da presenečenje pogosto predhodi strahu ter da imata obe čustvi skupen element fiziološkega vzburjenja. Rezultati novejših medkulturnih raziskav kažejo, da je obrazni izraz strahu najtežje prepoznano čustvo: prepoznava točnosti prestrašenega izraza je približno 70% (Russell, 1994; Biehl in sod., 1997). Drugo pomembno dejstvo je, da prestrašene obraze najpogosteje zamenjujemo z izrazi presenečenja (Ekman in Friesen, 1971, 1976; Russell, 1994; Rapsack in sod., 2000; Huang in sod., 2001; Adolphs, 2002; Palermo in Coltheart, 2005; Calvo in Lundqvist, 2008). V skladu z vsemi temi raziskavami je smiselna domneva, da bi lahko bili obrazni izrazi strahu in presenečenja pravzaprav izrazi istega čustva. Če bi lahko ta dva ločena izraza združili v enega, bi to pomenilo, da ne obstaja šest prototipičnih čustvenih izrazov obraza, kot trdi Ekman (1976, 1982), ampak le pet.

Zadnji problem pričujoče raziskave je bil oceniti zmogljivost vizualnega delovnega spomina za čustvene izraze.

Kognitivna predelava čustvenih obraznih izrazov se raziskuje s pomočjo različnih specijaliziranih metod. Najbolj običajni postopki na tem raziskovalnem področju so naloge vidnega iskanja, spremljanje očesnih gibov in točkovno preskusna paradigma.

Naloga vidnega iskanja je najbolj priljubljena paradigma v raziskovanju pritegovanja pozornosti. Pri tej psihofizični metodi morajo udeleženci iskati med razvrščenimi obraznimi izrazi. Običajno kaže v polovici poskusov en obrazni izraz posebno čustvo, medtem ko preostali obrazi (motilci) kažejo drugo čustvo. V preostali polovici poskusov so vsi obrazni izrazi enaki. Udeleženci morajo odgovoriti, ali se dani obrazni izraz razlikuje od ostalih ali ne. Merijo in analizirajo se odzivni časi (Frischen in sod., 2008). V prvi vrsti analiz se ocenijo samo poskusi, ki vsebujejo drugačen obraz. Logika je preprosta: analizirajo se iskalne asimetrije in odzivni čas negativno korelira z učinkovitostjo pritegovanja pozornosti. V analizah druge vrste se upoštevajo samo poskusi z enakimi obraznimi izrazi, analizira pa se čakalni čas. Čas čakanja je mera hitrosti ki jo dosežejo udeleženci medtem, ko iščejo neskladne obraze v množici enakih obraznih izrazov. Čas čakanja se pozitivno povezuje z jakostjo s katero pritegujejo pozornost posebni čustveni izrazi: vidno iskanje v množici obraznih izrazov, ki učinkovito pritegnejo pozornost je počasno, ker vsak tak obrazni dražljaj teži k temu, da bi obdržal pozornost in zato upočasnjuje premik pozornosti k drugemu dražljaju ter posledično upočasni hitrost iskanja (npr. Fox in sod., 2000). Naslednji običajni postopek v paradigmi vidnega iskanja je spreminjanje velikosti množice in merjenje učinkovitosti iskanja preko iskalnih nagibov. Iskalni nagib je odnos med časom iskanja in številom motilcev (npr. Wolfe, 1998). V kolikor uvajanje dodatnega dražljaja ne povzroči bistvenega podaljšanja časa iskanja, naj bi tarča pritegovala pozornost (npr. Williams in sod., 2005). Popolna neobčutljivost časa iskanja na število motilcev kaže, da tarča samodejno priteguje pozornost (Treisman in Souther, 1985). Seveda velja ta logika samo za poskuse z neskladnimi obrazi.

Nadalnja metoda merjenja usmerjanja pozornosti na določene vrste dražljajev je naloga iskanja pike. Ta paradigma se običajno uporablja za oceno selektivne pozornosti, še posebej na nevarne dražljaje. Naloga se začne s prikazom točke fiksacije v središču zaslona. Po tem se istočasno prikažeta dva dražljaja (nevaren in nenevaren), en v levem in en v desnem vidnem polju. Ko izgineta se na lokaciji, ki jo je prej zasedal eden od dražljajev prikaže tarčna pika. Udeleženčeva naloga je, da navede položaj pike. Logika je preprosta: odzivi naj bi bili hitrejši, če je pika prikazana v področju, na katerega je bil udeleženec pozoren. Če je pika prikazana na položaju, ki ga je prej zasedal nevaren dražljaj (npr. grozeč obraz, prestrašen obraz, pištola), je odzivni čas navadno krajši v primerjavi s poskusi, v katerih je pika prikazana na položaju, ki ga je prej zasedal nevtralni dražljaj (Broadbent in Broadbent, 1988; MacLeod in Mathews, 1988; Mogg in Bradley, 1999; Armony in Dolan, 2002; Fox, 1993, 2002; Hunt in sod., 2006; Pourtois in sod., 2004; Beaver in sod., 2005; Pourtois in sod., 2006).

V preoblikovani različici naloge iskanja pike, so uporabili maskiranje nazaj, da bi omejili obseg predelave ali v celoti preprečili zavedanje dražljajev. Ta postopek omogoča raziskovanje vloge zaznavnega zavedanja v predelavi čustev. Pri tej tehniki kratko prikazanim ciljnim vizualnim dražljajem takoj sledijo maskirni dražljaji. Tudi kadar maskirne ciljne dražljaje ne zaznavamo zavestno, lahko vplivajo na kognitivne procese opazovalca (npr. Whalen in sod., 1998; Mogg in Bradley, 1999). Paradigma postopka maskiranja nazaj se lahko uporablja neodvisno od nalog iskanja pike, če to zahteva eksperimentalni načrt.

Postopek spremljanja očesnega gibanja zagotavlja stalen kazalec pozornosti, zato se pogosto uporablja v raziskavah vidnega zaznavanja in prostorske pozornosti (Gitelman in sod., 2000; Rohner, 2002), v katerih se vzorci očesnih gibov uporabljajo za raziskovanje smeri pozornosti. Utemeljitev merjenja očesnih fiksacij je dokaj preprosta: fiksacije odražajo smer pozornosti, medtem ko trajanje pogleda kaže obseg pozornosti namenjeni prepoznavi dražljajev (Calvo in sod., 2006; Frischen in sod., 2008). Nadzor očesnih gibov se običajno kombinira s paradigmo nalog vidnega iskanja (npr. Bradley in sod., 2000; Calvo in sod., 2006; Reynolds in sod., 2009).

Eksperimentalne raziskave kognitivnih predelav čustvenih obraznih izrazov so naletele na resne ovire, ki jih ni bilo mogoče razrešiti z uporabo omenjenih metod (naloge vidnega iskanja, naloge iskanja pike z ali brez maskiranja nazaj, nadzor očesnega gibanja).

Po drugi strani je najbolj običajna metoda raziskovanja različnih človeških kognitivnih procesov, kot so pozornost, vid, delovni spomin in zavest, paradigma odkrivanja spremembe. Bistvo postopka je skupno vsem njegovim podkategorijam in ga sestavljajo dva ali več zaslonov, ki se lahko razlikujejo v določenih delih. Ti zasloni se zaporedno prikažejo udeležencem, ki morajo odgovoriti, ali so enaki ali ne. Nato se merijo in analizirajo točnost odziva in odzivni časi (Rensink, 2002).

Za ponazoritev naj omenimo Simonsovo in Levinovo (1998) raziskavo, eno najbolj zanimivih raziskav, ki temelji na odkrivanju spremembe. Eksperimentator je hodil z zemljevidom po ulici in se približal mimoidočemu ter ga vprašal, če mu lahko pokaže pot do bližnje stavbe. Po 10 do 15 sekundah pogovora sta k njima pristopila dva eksperimentatorjeva sodelavca, ki sta nosila vrata. Šla sta med eksperimentatorjem in tem mimoidočim. V tem kratkem času (približno 1 sekunda), ko so vrata zakrila udeležencu pogled, je eksperimentator prijel zadnji del vrat in zamenjal svoj položaj z zadnjim nosačem. Le ta, ki je nosil vrata do tedaj, jih je spustil in ostal na eksperimentatorjevem mestu ter nadaljeval pogovor z mimoidočim. Čeprav sta se eksperimentator in sodelavec, ki ga je zamenjal, razlikovala po višini, telesni zgradbi, oblačilih, pričeski in glasu, je manj kot 50% udeležencev opazilo spremembo! Ta pojav je znan kot slepota za spremembe in je opredeljen kot nezmožnost odkrivanja različnih sprememb v vidnem okolju.

Najboljšo razvrstitev različic paradigme odkrivanja sprememb je podal v Rensink (2002) v svojem pregledu. Glede na kontingenco spremembe razlikuje Rensink (2002) osem kategorij. Spremembe se lahko pojavijo v medražljajskem intervalu, v teku sakade, v premiku celotnega zaslona, med mežikom, istočasno ko se pojavi kratek motilec (packa), kadar je spreminjajoča se postavka za kratek čas zakrita, v trenutku spremembe položaja kamere, ali postopno. Glede na ponovitev spremembe, razlikuje Rensink (2002) *enkraten* pristop (v katerem se sprememba zgodi samo enkrat v poskusu) in pristop ponavljajočih sprememb, ki se imenuje tudi *paradigma utripanj* (v kateri se izmenjujeta prvotni in spremenjeni zaslon dokler udeleženci ne opazijo spremembe). Naslednja razsežnost v Rensinkovi (2002) razvrstitvi je vsebina zaslona, ki se spreminja od enostavnih mirujočih predmetov prikazanih na računalniškem zaslonu do dinamičnih prizorov v resničnem življenju. Poleg kontingence spremembe, ponovitev spremembe in vsebine zaslona, lahko eksperimente s paradigmo odkrivanja sprememb razvrstimo tudi po vsebini sprememb, pričakovanjih opazovalcev, vrsti nalog in vrsti odgovorov.

Paradigme odkrivanja spremembe niso praktično nikoli uporabili v raziskovanju človekovih čustvenih izrazov. To smo poskusili v tej raziskavi, ker raziskave z uporabo nalog vidnega iskanja, nalog iskanja pike in paradigme spremljanja očesnega gibanja niso uspele rešiti ključnih težav v zvezi s kognitivno predelavo obraznih izrazov.

V pričujoči raziskavi smo uporabili tehniko pri kateri se sprememba pojavlja med dražljajskim intervalom (gap-contingent) z enkratnim pristopom (one-shot). Zaradi kompromisa med eksperimentalnim nadzorom in zunanjo veljavnostjo je bila vsebina zaslona zmerno zapletena. Glede na vsebino spremembe smo uporabili različico v kateri je bila ena celotna postavka zamenjana z drugo.

Če vse, kar je bilo doslej podano, povzamemo, je pričujoča raziskava nastala zaradi razreševanja štirih vprašanj:

a) Katera čustvena komponenta vodi kognitivno predelavo obraznih čustvenih izrazov: grožnja, čustvenost ali negativnost?
b) Ali je hipoteza Williamsa in sod. (2005) pravilna? Ali ljudje odvračajo pozornost od prestrašenih obrazov, da bi poiskali vir njihovega strahu?
c) Ali so obrazni izrazi strahu in presenečenja diskretni čustveni izrazi ali ne?
d) Koliko obraznih čustvenih izrazov lahko hkrati obdržimo v vidnem delovnem spominu?

Ker teh težav niso razrešile različne raziskave, ki so uporabile različne metodološke pristope specijalizirane za eksperimentalno raziskovanje kognitivne predelave čustvenih obraznih izrazov, smo v pričujoči raziskavi na področju kognitivne predelave človeških čustvenih izrazov uporabili postopek, izdelan predvsem za raziskovanje pozornosti, vida, delovnega spomina in zavesti (paradigma odkritja spremembe).

7.3 Metoda

Udeleženci

V eksperimentu je sodelovalo štiriindvajset študentov psihologije (starostni razpon 20-26 let) z Univerze v Reki, Hrvaška. Število moških in ženskih udeležencev je bilo enako in vsi so poročali, da imajo normalno ali na normalno popravljeno ostrino vida.

Instrumenti

Dražljaji so bili prikazani na 17-palčnem zaslonu z ločljivostjo 1024x768 pikslov. Prikazovanje dražljajev in zbiranje podatkov je nadzoroval PC-računalnik. Odgovori so bili zbrani s pomočjo tipkovnice.

Dražljaji in postopek

Za pripravo gradiva smo uporabili Povprečeno Karolinsko podatkovno bazo usmerjenih čustvenih obrazov (AKDEF) (Lundqvist in Litton, 1998) in Calvo in Lundqvistjevo (2008) prilagoditev obraznih dražljajev iz Karolinske podatkovne baze usmerjenih čustvenih obrazov (KDEF) (Lundqvist in sod., 1998). Pripravili smo štiri sklope dražljajev, od katerih je vsak vseboval sedem slik čustvenih obraznih izrazov: strah, jeza, odpor, sreča, nevtralnost, žalost in presenečenje (slike 8-11).

Eksperiment je bil razdeljen na štiri dele. Vsakega je sestavljalo 260 poskusov (osem smo jih uporabili samo za vajo in niso bili upoštevani v analizi). Trajal je približno 30 minut. Vsak udeleženec je opravil 1008 poskusov. Da bi olajšali tako zahtevno dejavnost, so imeli udeleženec 7-dnevni odmor med dvema deloma eksperimenta. Vsi udeleženci so opravili eksperiment v laboratoriju pod enakimi pogoji. Hrup je bil minimiziran, osvetlitev in temperatura zraka pa sta bili konstantni. Udeleženci so sedeli tako, da so bile njihove oči 100 cm oddaljene od zaslona.

Vsak poskus se je začel z fiksacijskim znakom, prikazanim v sredini zaslona, v trajanju 250 ms, čemur je sledil prikaz začetnega zaslona dražljajev. Začetni zaslon dražljajev je sestavljalo šest različnih obraznih izrazov. Da bi ga generirali je bilo naključno izbranih šest slik iz množice sedmih slik z omejitvijo, da na istem zaslonu nikoli ne moreta biti prisotna dva ali več enakih izrazov. Ti obrazni izrazi so bili naključno postavljeni na šest prostorskih položajev (pod določenimi omejitvami, o katerih bomo govorili kasneje), kot je prikazano na sliki 12.

Po 2000 ms trajajočem prikazovanju začetnega zaslona, je bil za 500 ms prikazan prazen zaslon, potem pa se je pojavil testni zaslon. V eksperimentu so bili uporabljeni posamezni testni zasloni - le en obrazni izraz je bil prikazan na testnem zaslonu; bil je nameščen na enem od šestih položajev, ki so bili prej zasedeni na začetnem zaslonu. Testni obraz je bil na vsakem položaju prikazan enakokrat (168-krat na položaju), z več omejitvami. V polovici vseh poskusov (vsi poskusi, ki niso vsebovali sprememb) je bil obrazni izraz testnega obraza enak izrazu obraza, ki je prej zasedal ta položaj na začetnem zaslonu, medtem ko je bil v drugi polovici poskusov (vsi poskusi, ki vsebujejo spremembe) izraz obraza prikazan na zaslonu izraz, ki ni bil prikazan na začetnem zaslonu.

Poglejmo si naslednji primer za razjasnitev (slika 13): na začetnem zaslonu je *položaj A* zaseden z jeznim obrazom, *položaj B* z prestrašenim obrazom, *položaj C* z žalostnim obrazom, *položaj D* z srečnim obrazom, *položaj E* s studljivim obrazom in *položaj F* z nevtralnim obrazom. Po retencijskem intervalu, je testni obraz prikazan na *položaju C*. V tem primeru bi lahko bil izraz testnega obraza bodisi žalosten (poskusi, ki ne vsebujejo spremembe) bodisi presenečen (poskusi, ki vsebujejo spremembo). Nobenega od preostalih petih izrazov ne bi bilo možno prikazati na *položaju C* na testnem zaslonu, ker so bili prikazani na začetnem zaslonu na katerem so zasedali nerelevantne položaje. (Izraz *nerelevanten položaj* se nanaša na katero koli mesto na začetnem zaslonu različnem od položaja obraznega izraza prikazanega na testnem zaslonu. Zato so irelevantni položaji v tej raziskavi *položaji* A, B, C, D, E in F. Izraz *ustrezen položaj* bomo uporabili pri obravnavi položaja na začetnem zaslonu, ki je enak položaju testnega izraza. V tem poskusu je *položaj C* ustrezen položaj).

Kot je bilo že omenjeno, je bil testni obraz je bil prikazan 168-krat na vsakem od šestih položajev. Vsak obrazni izraz je bil prikazan tudi enakokrat kot testni izraz na vsakem od položajev. Tako je bil vsak od sedmih izrazov prikazan 144-krat na testnem zaslonu: 24-krat na *položaju A*, 24-krat na *položaju B*, 24-krat na *položaju C*, 24-krat na *položaju D*, 24-krat na *položaju E* in 24-krat na *položaju F*. Zato je bil, ko upoštevamo samo testne zaslone, vsak izraz predstavljen na vsakem položaju v 24 poskusih z omejitvijo, da je v vsakem od teh 24 tehničnih pogojev izraz x položaj, 12 poskusov vedno vsebovalo spremembo, 12 pa ne.

Obstajala je še ena zelo pomembna zahteva glede 12 poskusov vsebujočih spremembo: vsak od preostalih šestih izrazov se je moral prikazati dvakrat na ustreznem položaju na začetnem zaslonu, medtem ko so bili drugi izrazi naključno dodeljeni irelevantnim položajem brez omejitev. V poskusih, ki niso vsebovali sprememb, je bil izraz prikazan na testu enak izrazu prikazanem na ustreznem položaju na začetnem zaslonu, kar pomeni, da je bilo treba enega od preostalih šestih izrazov izločiti iz začetnega zaslona. Izraz, ki je bil izločen v poskusih brez spremembe, vedno je bil vedno izbran naključno brez omejitev, preostalih pet izrazov pa je bilo razporejenih naključno brez omejitev na irelevantne položaje, podobno kot pri poskusih z spremembami.

Gledano iz drugega kota, vsak obrazni izraz je zasedal ustrezen položaj v enakem številu poskusov (N = 144). V 72 poskusih je ostal med retencijskim intervalom obrazni izraz, ki je zasedal ustrezen položaj nespremenjen ter je bil ponovno prikazan na istem mestu na testnem zaslonu. V ostalih 72 poskusih se je med retencijskim intervalom spremenil točno 12 krat v vsakega od šestih preostalih izrazov (preglednici 1 in 2).

Po prikazu testnega zaslona so udeleženci prejeli navodilo da pritisnejo tipko «1», če je prišlo do spremembe (če se je čustvo na testnem zaslonu razlikovalo od čustva, ki je zasewdalo ustrezen položaj na začetnem zaslonu), ali da pritisnejo tipko «0», če do spremembe ni prišlo (če je bilo čustvo na testnem zaslonu isto kot čustvo prikazano na ustreznem mestu začetnega zaslona). Opozorjeni so bili naj se trudijo za točnost in ne za hitrost. V poskusih, v katerih so bili negotovi, ali je prišlo do spremembe ali ne, naj bi odgovorili naključno.

Takoj po odzivu so prejeli povratno informacijo. Če je bil odgovor pravilen se je pojavila beseda «pravilen» v modri barvi v sredini zaslona, če pa je bil odgovor napačen, se je pojavila beseda «napačen» v rdeči barvi.

Eksperiment je bil izveden na samouravnajoč način. Po prikazu povratne informacije, ki je trajal 500 ms, so morali udeleženci pritisniti tipko za «presledek», da bi začeli nov poskus.

7.4 Rezultati

Storitev udeležencev je bila analizirana preko odstotka pravilnih odgovorov. Odzivni časi so bili analizirani kot dodatna mera. Da bi odpravili vpliv skrajnih rezultatov, smo za vsakega udeleženca določili srednji odzivni čas za vsak eksperimentalni pogoj. Samo te srednje vrednosti smo uporabili v vseh naslednjih opisnih in inferencialnih obdelavah odzivnih časov.

V skladu z ugotovitvami drugih eksperimentov, ki so raziskovali učinke spola na predelavo obraznih izrazov (npr. Palermo in Coltheart, 2004; Calvo in Lundqvist, 2008), smo ugotovili, da spol udeležencev ni vplival na storitev ne glede na kriterijske spremenljivke. Ni vplival ne na točnost odzivov, ne na odzivni čas, ne na zmogljivost delovnega spomina za čustvene izraze. Prav tako spol ni bil v pomembni interakciji z drugimi neodvisnimi spremenljivkami. Ker so bili vzorci rezultatov podobni za moške in ženske udeležence, o njih, da bi se izognili nepotrebni zapletenosti, nismo bili poročali ločeno za moške in ženske.

Učinke modelnega spola nismo analizirali, ker bi bila zunanja veljavnost dobljenih sklepov slaba, saj sta bili po spolu le dve vrsti dražljajev.

Vse analize so dosledno pokazale prevlado veselega obraza v kognitivni predelavi (preglednice 3-7 in slike 14-23). Enak učinek smo opazili pri vseh analizah: storitev je bila najboljša in najhitrejša za poskuse, ki so vsebovali vesele izraze bodisi na testnem zaslonu ali na ustreznem položaju na začetnem zaslonu. To pomeni, da daje naš spoznavni sistem veliko prednost srečnim obraznim izrazom.

Analize osredotočene na problem odkrivanja sprememb v odvisnosti od njihove vsebine so pokazale, da je bilo spremembe iz presenečenega v prestrašen izraz in obratno bilo nekoliko težje odkriti kot nekatere druge vrste sprememb (preglednica 9 in slika 24). Obenem so bile spremembe iz presenečenega v prestrašen izraz odkrite enako hitro kot vse druge vrste sprememb (preglednica 10 in slika 25).

Po Pashlerjevi (1988) metodi si ljudje v vidnem delovnem spominu zapomnijo 3,07 čustvenih obraznih izrazov, medtem ko znaša po Švegarjevi (2008) formuli za izračun zmogljivost vidnega spomina 2,14 točk.

7.5 Razprava

Grožnja nasproti negativnosti nasproti čustvenosti

V pričujoči raziskavi lahko v skladu s hipotezo grožnje pričakujemo, da bo točnost največja v poskusih v katerih je jezen obraz na začetnem zaslonu prikazan na ustreznem položaju. Vendar so analize pokazale, da storitev ni bila v teh popskusih nič boljša v primerjavi s katerokoli drugo vrsto poskusov. Storitev je bila v teh poskusih celo pomembno slabša v primerjavi s poskusi v katerih je bil na ustreznem položaju začetnega zaslona prikazan srečen obraz.

Če je veljavna hipoteza negativnosti potem lahko pričakujemo večjo točnost v poskusih, v katerih je testni dražljaj prikazan na položaju, ki so ga prvotno zasedali jezen, žalosten, studljiv in prestrašen obraz, v primerjavi s poskusi v katerih je testni dražljaj prikazan na položaju, ki sta ga prvotno zasedala nevtralen in še zlasti srečen obraz. Opazovani vzorec rezultatov je v celoti nasproten. Točnost v poskusih, v katerih so ustrezen položaj zasedali jezen, studljiv, prestrašen ali žalosten obraz, je bila bistveno manjša v primerjavi s poskusi v katerih je ustrezen položaj zasedal srečen obraz. Analize odzivnih časov se skladajo z analizami točnosti. Odzivi so bili najhitrejši v poskusih v katerih je ustrezen položaj v začetnem zaslonu zasedal srečen obraz.

Po hipotezi čustvenosti lahko pričakujemo najnižji delež pravilnih odgovorov pod pogojem, ko nevtralen obrazni izraz zaseda ustrezen položaj na začetnem zaslonu. Dobljeni rezultati ne podpirajo te hipoteze, saj noben od čustvenih obraznih izrazov (razen srečnega) ni imel prednosti pred nevtralnim izrazom v kognitivni predelavi – ne pri pregledu točnosti odgovorov, ne pri analizi hitrost odziva. Poleg tega, po hipotezi čustvenosti, ne moremo pričakovati razlik med čustvenimi izrazi. Zato tudi prednost srečnega izraza pred jeznim, prestrašenim, žalostnim, studljivim in presenečenim ne ustreza hipotezi čustvenosti.

Tako, ne hipoteza grožnje, ne hipoteza negativnosti, ne hipoteza čustvenosti niso uspele pojasniti rezultatov pričujoče raziskave. Dobljene ugotovitve niti delno ne ustrezajo kateri koli od teh treh hipotez.

Hipoteza Williamsa in sod. (2005)

V skladu s hipotezo Williamsa in sod. (2005) lahko pričakujemo, da bo storitev najslabša za poskuse v katerih prestrašen obraz zaseda ustrezen položaj na začetnem zaslonu, saj pričakujemo da bodo ti izrazi prejeli najmanj žariščne pozornosti in ker nima smisla zapravljati spoznavne vire za zapomnitev položaja prestrašenega izraza. Rezultati pričujoče raziskave nso pokazali nič posebnega o prestrašenih obrazih. Njihova predelava ni bila ne boljša, ne slabša od ostalih izrazov, z izjemo, da so imeli nižjo prednost v primerjavi s srečni obrazi. Torej, hipoteza Williamsa in sod. (2005) v pričujoči raziskavi ni bila podprta.

Strah in presenečenje – enaka ali različna izraza

Rezultati te raziskave kažejo, da je bilo spremembe iz presenečenih v prestrašene izraze in obratno nekoliko težje odkriti kot nekatere druge vrste sprememb (slika 24). Tukeyjeve HSD post-hoc primerjave so pokazale, da so udeleženci odkrili spremembe pomembno manj točno v poskusih, ki so vsebovali izmenjavo prestrašenih in presenečenih izrazov v primerjavi s poskusi, ki so vsebovali druge izmenjave: prestrašen in srečen, jezen in srečen, jezen in presenečen, studljiv in srečen, studljiv in nevtralen, studljiv in presenečen, srečen in nevtralen, srečen in presenečen ter žalosten in presenečen (preglednica 9). Tukeyjeve HSD post-hoc primerjave so tudi pokazale, da se točnost udeležencev v odkrivanju izmenjav med prestrašenim in presenečenim izrazom ni bistveno razlikovala od naslednjih vrst sprememb: prestrašen in jezen, prestrašen in studljiv, prestrašen in nevtralen, prestrašen in presenečen, jezen in studljiv, jezen in nevtralen, jezen in žalosten, studljiv in žalosten, nevtralen in žalosten ter nevtralen in presenečen (preglednica 9). Analiza reakcijskih časov je pokazala, da hitrost odziva v poskusih, ki vsebujejo izmenjavo med presenečenim in prestrašenim obrazom, ni bila hitrejša kot v ostalih poskusih (slika 25). Tukeyjev HSD je pokazal, da je bil odziv pri odkrivanju sprememb med presenečenimi in prestrašenimi izrazi enako hiter kot pri odkrivanju sprememb katerih koli drugih izrazov, z izjemo poskusov, v katerih so se izmenjevali srečni in nevtralni izrazi obraza.

Če upoštevamo vse, ni trdnih dokazov zoper Ekmanovo (1982, 2003) teorijo po kateri so čustva strahu in presenečenja diskretna. Ta dva izraza se včasih zamenjujeta, verjetno zato, ker ju je zaznavno težko razlikovati, saj imata več skupnih značilnosti: široko odprte oči, dvignjene obrvi, odprta usta (slika 27).

Ocena zmogljivosti vidnega delovnega spomina za obrazne izraze

Po Pashlerjevem postopku (1988) lahko hkrati shranimo 3.07 čustvenih izrazov v vidnem delovnem spominu. Švegar (2008) je pokazal, da je Pashlerjev (1988) postopek zelo odvisen od kriterija odziva in teži k precenjevanju zmogljivosti vidnega delovnega spomina. V nizu simulacij je Švegar (2008) ugotovil, da je odnos med resnično zmogljivostjo vidnega delovnega spomina in odstotkom pravilnih odgovorov v nalogah odkrivanja sprememb linearen. Zato je postavil novo formulo za ocenjevanje zmogljivosti vidnega delovnega spomina, ki izračuna zmogljivost spomina preko odstotka pravilnih odgovorov, ne pa preko deleža zadetkov in zmotnih alarmov, kot po Pashlerjevi (1988) metodi. Po Švegarjevi (2008) formuli lahko ohranimo v vidnem delovnem spominu le 2,14 izraza. Toda, čeprav Pashlerjev postopek precenjuje resnično zmogljivost vidnega delovnega spomina, je bila pričujoča raziskava specifična, ker je bila zelo naporna za udeležence (vsebovala je 252 poskusov na srečanje), zato je možno, da je utrujenost negativno vplivala na uspešnost udeležencev. Če upoštevamo vsa našteta dejstva, je možno sklepati, da ljudje lahko shranijo v svojem vidnem delovnem spominu od dva do tri obrazne izraze.

Prednostni učinek srečnega obraza

Čeprav so številni raznovrstni poskusi odkrili prednost jeznih ali negativnih dražljajev, obstaja nekaj zanimivih ugotovitev, ki kažejo na prednostni učinek srečnega obraza. Srečni obrazi niso bili v ospredju te raziskave in smo zato v uvodu omenili le nekaj eksperimentov, ki kažejo na prednost kognitivne predelave srečnih izrazov.

Rezultati pričujoče raziskave se skladajo z ugotovitvami raziskav o hitrosti prepoznavanja. V več tovrstnih raziskavah je bilo ugotovljeno, da so srečni obrazni izrazi prepoznani hitreje od ostalih obraznih izrazov. V nekaterih od teh raziskav, so udeležencem prikazali slike izrazov, njihova naloga pa je bila, da jih razvrstijo glede na čustveno stanje (ali čustveno valenco), ki jo prikazujejo. Merili so odzivni čas, potreben za pravilno prepoznavo vsakega čustvenega stanja. Pri ostalih poskusih so spreminjali čas prikazovanja, da bi določili prage prepoznave različnih čustvenih obraznih izrazov. V nekaterih eksperimentih so spreminjali čas prikazovanja, da bi določili prag prepoznavanja čuvstvene obrazne izraze. V nekaterih eksperimentih so bili čustveni obrazni izraszi maskirani. V vseh raziskavah so analizirali točnost odgovorov.

Rezultati teh raziskav, so pokazali, da obrazno mimika sreče hitreje in/ali točneje prepoznajo kot izražanje jeze (Harrison in sod., 1990, Billings in sod., 1993; Harrison in Alden, 1993; Hugdahl in sod., 1993; Palermo in Coltheart, 2004; Goren in Wilson, 2006; Montagne in sod., 2007; Calvo in Lundqvist, 2008; Milders in sod., 2008), studljivosti (Stalans in Wedding, 2985; Leppanen in Hietanen, 2004; Palermo in Coltheart, 2004; Montagne in sod., 2007; Calvo in Lundqvist, 2008), straha (Palermo in Coltheart, 2004; Goren in Wilson, 2006; Montagne in sod., 2007; Calvo in Lundqvist, 2007; Milders in sod., 2008), žalosti (Stranners in sod., 1985, Feyereisen in sod., 1986; Crews in Harrison, 1994; Palermo in Coltheart, 2004; Goren in Wilson, 2006; Motnagne in sod., 2007; Calvo in Lundqvist, 2008) in nevtralnosti (Esteves in Ohman, 1993; Hugdahl in sod., 1993; Leppanen in Hietanen, 2004; Palermo in Coltheart, 2004; Milders in sod., 2008). Tudi v drugih medkulturnih raziskavah, so bili najvišji dosežki prepopznavanja najvišji za srečen obrazni izraz (npr. Ekman in

Friesen, 1976; Ekman, 1982; Russell, 1994). Leppanen in Hietanen (2004) sta pokazala, da odkrite prednosti srečnega obraza v raziskavah hitrosti prepoznavanja ni možno pripisati nizki ravni fizičnih razlik med srečnim obrazom in ostalimi obraznimi izrazi (npr. vidnost zob).

Dodatno sta Goren in Wilson (2006) odkrila, da je obrobna prepoznava obraznih izrazov bistveno slabša kot z fovealnim vidom. Vendar ta ugotovitev ne velja le za srečne obrazne izraze. Z drugimi besedami, tudi če pogled ni usmerjen neposredno v srečen obraz, je ta uspešno prepoznan. V skladu so ugotovitvami Gorena in Wilsona (2006) sta Mack in Rock (1998) so odkrila, da so srečni obrazi prepoznani tudi, če so prikazani nepričakovano v množici drugih dražljajev. Medtem, ko so ostali obrazni izrazi ostali neopaženi, so bili srečni obrazi prepoznani na podoben način kot lastno ime v «pojavu koktelske zabave» (Mack in Rock, 1998).

Čeprav v drugih paradigmah prednosti srečnega obraza niso skoraj nikoli opazili (z nekaterimi izjemami kot je Juth in sod., 2005), ki so uporabili naloge vidnega iskanja ali Leppanen in sod., (2003), ki so uporabili paradigmo izbirnega odzivnega časa), skoraj vsi eksperimenti prepoznavanja vodijo k istem sklepu, da daje spoznavni sistem prednost srečnemu obraznemu izrazu. Vendar je bil prednostni učinek srečnega obraznega izraza v spoznavni predelavi deležen zelo majhne pozornosti. Avtorji, ki so odkrili ta učinek, so bili osredotočeni na nekatere druge raziskovalne probleme, tako da se niso osredotočali na teoretično razlago za nepričakovane prednostne učinke srečnih obraznih izrazov.

Čisti učinek prednosti srečnega obraza, ki je bil odkrit v tej raziskavi, se dobro ujema z evolucijskim okvirom. Pri ne-človeških primatih, je tihi obrazni izraz, ki pokaže zobe, signal brez sovražne namere. Nasmeh pri ljudeh je sodobna oblika tihega kazanja zob pri primatih (Mehu in sod., 2007). Človeški nasmeh lahko smatramo za vedenje, ki se je osamosvojilo od tihega kazanja zob, in je zelo pomembno pri vzpostavljanju socialnih stikov pri ljudeh (Mehu in sod., 2007).

Smehljanje je učinkovito pri spreminjanju odnosa opazovalca do pošiljatelja. Z nasmehom ljudje signalizirajo svojo pripravljenost na sodelovanje z opazovalcem svojega smehljaja (Mehu in sod., 2007). Poleg signaliziranja pripravljenosti na sodelovanje z obraznimi izrazi, ljudje z nasmehom oglašajo tudi svojo privlačnost in zdravje. Nasmeh v smislu oglaševanja lastne privlačnosti in zdravlja je značilen zlasti za ženske, ki pogosto uporabljajo prevare, da bi izboljšale svoj fizični videz (Buss, 1992). Poleg tega se nasmejani ljudje zdijo bolj velikodušni, tekmovalni, prijetni in odprti (Mehu in sod., 2008). Nasmeh povečuje tudi zaupanje med tujci (Scharlemann in sod., 2001) in ima pozitiven učinek na odpuščanje pri kriminalcih (LaFrance in Hecht, 1995). Nasmeh se uporablja na prožno prilagodljiv način – poleg oglaševanja privlačnosti, zdravlja, velikodušnosti in drugih pozitivnih lastnosti, skupaj z odražanjem pripravljenosti ljudi za sodelovanje, nasmeh istočasno povzroča pozitivna čuvstva pri opazovalcih (Surakka in Heitanen., 1998; Mehu in sod., 2007).

Zato je nasmeh prilagojevalno obnašanje za pošiljatelja in prejemnika, ki ima posledično pozitivne učinke, še posebej na socialne odnose (Scharlemann in sod., 2001; Mehu in sod., 2007), v skladu s pristopom vedenjske ekologije.

Torej, na koga se lahko zanesemo, s kom se lahko družimo, komu lahko verjamemo, koga se ne smemo izogibati, v skladu z vsemi prej zapisanimi dejstvi? Na **ljudi z nasmehom!** Zato je logično, da so nasmejani obrazi prednostno kognitivno predelani. Opazovalci imajo nedvomno korist od odkrivanja, prepoznavanja in zapomnitve položaja srečnega obraza v množici, zato ker je to položaj njihovega potencialnega delovnega ali romantičnega partnerja. Zato, da ne izpustimo dobre priložnosti za sodelovanje, romantičen odnos ali drugo obliko socialnega stika, ima srečen obraz prednost v kognitivni predelavi na račun drugih čustvenih izrazov. Na ta način je naša evolucijska ustreznost optimizirana.

7.6 Sklep

Ne hipoteza grožnje, ne hipoteza negativnosti, ne hipoteza čustvenosti niso prejele podpore. Tudi hipoteza Williamsa in sod., (2005) ni bila potrjena. Nobenih trdnih dokazov ni bilo proti teoriji po kateri sta presenečenje in strah diskretni čustvi. Namesto tega je bilo ugotovljeno, da kognitivni sestav daje prednost predelavi srečnih obrazov. Pokazali smo, da prednostni učinek srečnega obraza ni zgolj artefakt metodoloških nepopolnosti, kot je vidljivost zob (ki se najbolj vidijo na srečnem obrazu) ali poznanost (zaradi prejšnjih izkušenj udeležencev) srečnega obraza.

Poleg tega smo izračunali, da ljudje lahko shranijo in obnovijo 2-3 čustvene obrazne izraze v vidnem delovnem spominu.

Dobljeni rezultati so bili razloženi v evolucijskem okviru. Pojasnjeno je bilo, da je nasmeh evolucijsko razvito vedenje, ki je prilagojevalno za prejemnika in pošiljatelja in ima pozitivni učinek na družbene odnose. Srečni obrazi imajo prednost v našem kognitivnem sistemu, saj imajo opazovalci nedvomno korist od odkrivanja, prepoznavanja in spominskega shranjevanja položaja srečnega obraza v množici – tj. položaja njihovega potencialnega poslovnega ali romantičnega partnerja.