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Updating schematic emotional facial expressions in working memory: Response bias and sensitivity

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ABSTRACT

It is unclear if positive, negative, or neutral emotional expressions have an advantage in short-term recognition. Moreover, it is unclear from previous studies of working memory for emotional faces whether effects of emotions comprise response bias or sensitivity. The aim of this study was to compare how schematic emotional expressions (sad, angry, scheming, happy, and neutral) are discriminated and recognized in an updating task (2-back recognition) in a representative sample of birth cohort of young adults. Schematic facial expressions allow control of identity processing, which is separate from expression processing, and have been used extensively in attention research but not much, until now, in working memory research. We found that expressions with a U-curved mouth (i.e., upwardly curved), namely happy and scheming expressions, favoured a bias towards recognition (i.e., towards indicating that the probe and the stimulus in working memory are the same). Other effects of emotional expression were considerably smaller (1–2% of the variance explained)) compared to a large proportion of variance that was explained by the physical similarity of items being compared. We suggest that the nature of the stimuli plays a role in this. The present application of signal detection methodology with emotional, schematic faces in a working memory procedure requiring fast comparisons helps to resolve important contradictions that have emerged in the emotional perception literature.

1. Introduction

Emotional facial expressions are relevant social signals that can reflect internal feelings, motives and intentions of a person. Different expressions that we encounter every day when walking on a street, shopping or talking to a friend alternate in a fast-paced manner. For example, when talking to a friend, one needs to monitor and keep in mind other persons' facial expressions during the interaction in order to understand the meaning of the information and to appropriately respond to it. Therefore, working memory is relevant for keeping the information in mind after it is no longer available for perception. Working memory can be viewed as an activated subset of long term representations (Cowan, 1993), such as facial expressions or objects, that fill one's current attention and awareness. When the same face changes expression, it can be important to detect that change through a comparison of the present expression and the previous ones in working memory.

In a normal population, subjects can easily label and distinguish basic facial emotions from each other (anger, happiness, sadness, fear, surprise, disgust). This ability is relatively constant in different cultures – it is a hereditary built-in mechanism that allows us to understand others (Ekman & Friesen, 1971). Even though emotional expressions might not be labelled the same way in different cultures, and emotion names can have different meanings in different languages (Russell, 1994), the majority of researchers agree that most humans can express and perceive different basic emotional expressions, such as sad, happy and angry. Despite the importance of the topic, current literature does not give a clear answer which emotional expressions, if any, gain an advantage in working memory. Moreover, specific processes of working memory, such as updating emotional expressions (not identity) in a fast-paced manner, to our knowledge have not been studied before.

1.1. Unresolved issues in the literature

There are related results in the literature but they are mixed. There are some gaps that should be investigated in order to have a better general theory of how emotional expressions are updated. First, response bias has not been in the focus of previous studies. Do emotions affect working memory or elicit a behavioural response bias? A bias change can look like a memory change if signal detection methods are not used.

Second, there is no consensus whether happy or angry faces gain an advantage in working memory. Previously, some studies have shown that schematic angry faces gain priority in attention (Öhman, Lundqvist, & Esteves, 2001; Fox, Russo, & Dutton, 2002), and angry real faces are better encoded and retrieved from working memory (Jackson, Wu, Linden, & Raymond, 2009; Jackson, Linden, & Raymond,

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2014). In contrast to this result, one recent study found that happy expressions prompt memory for face identity (Righi, Gronchi, Marzi, Rebai, & Viggiano, 2015). Some studies have found no effect of emotional content of visual stimuli on working memory (Kensinger & Corkin, 2003). Some have reported that happy faces gain priority in attention and recognition (Calvo & Nummenmaa, 2008; Nummenmaa & Calvo, 2015; Calvo, Nummenmaa, & Avero, 2010). Some argue that perceptual features not emotional content in schematic faces affect attention (Horstmann, Borgstedt, & Heumann, 2006). It has also been suggested that simple features carry an emotional meaning that is automatically detected (Tipples, Atkinson, & Young, 2002).

Third, there are only a couple of specific previous behavioural studies on face updating, such as Artuso, Palladino, and Ricciardelli (2012, 2015), which have examined face updating in working memory. Artuso et al. (2012) investigated how the strength of bindings of facial dimensions (emotion and gaze direction) affect the outcome of updating. They did not aim to show whether there are any differences between different emotional expressions (with a direct gaze) in updating, and whether it is due to the effect on working memory per se or because of behavioural response bias. We will return to this issue in the general discussion.

Unfortunately, previous studies do not provide a clear answer whether any of the emotional expressions (sad, angry, scheming, happy, neutral) have an advantage in working memory updating.

1.2. Examining sensitivity and bias

Our study complements previous literature, so that we examine different characteristics of updating (e.g. sensitivity, behavioural bias). The main goal was to examine how different emotional expressions, if any, affect working memory updating, and we aimed to separate sensitivity from response bias. If attentional focus is the gateway to working memory (Cowan, 2001), then both schematic and real faces (angry) could affect working memory updating, increasing sensitivity to whether there has been a change in expression.

Some studies have reported that emotional words (negative or positive) in general (compared to neutral words) elicit a subjective feeling of recollection, and that negative words lead to a response bias towards more liberal responses (more likely to agree that the stimulus was the previously presented) (Dougal & Rotello, 2007). Work done with schematic emotional stimuli suggests that positive facial expressions are recognized more efficiently (Leppänen & Hietanen, 2004), but estimates of bias and sensitivity have not been obtained in the procedures that have been used. We expected that if a response bias is present, it should be most clearly seen in smiling faces (happy and scheming) towards "same" responses because positive emotions (a smiling mouth) may prime an attitude of agreeability (e.g. Johnson & Fredrickson, 2005).

1.3. Experimental control factors

Our study is different from previous work in the literature. These differences are also the main strong points that support the novelty and explain the rationale of our study:

First, we carefully *controlled facial features* and identity in stimuli that we selected for the 2-back task (Fig. 1). Schematic stimuli allow better control than real faces in photographs. It has been shown that identity recognition and emotional expression recognition can be separated (Bruce & Young, 1986). These two processes activate separate brain regions (Neta & Whalen, 2011). However, the systems are not entirely independent, which means that perception of facial features, and emotional content are partially based on the same mechanism (Calder & Young, 2005). Majority of literature in behavioural sciences supports the idea of using different types of stimuli in order to control for specific aspects of processing. Four different schematic faces were chosen for three reasons. First, (1) schematic sad, angry, scheming and happy can be combined into pairs so that the effects of eyebrows and mouth can be separated (e.g. angry and sad have the same mouth curvature, but angry and scheming have the same eyebrows). Also, (2) previous studies have mostly used 3 expressions (angry or sad, happy, neutral, e.g. Leppänen & Hietanen, 2004; Öhman et al., 2001), so we decided to broaden the scope of different expressions used, but still be able to categorize them into positive and negative valence groups (either according to eyebrows or mouth). (3) Controlling perceptual similarity by making use of the schematic nature of the stimuli, each emotional expression differs from the neutral face and objects by the same number of features (2 features different from neutral, at least 3 features different from objects).

When using schematic faces instead of photos, ecological validity can be questioned. However, when taking into account technological advances it can be argued that ecological validity of schematic faces is as high as in real faces; especially in a modern world, where internet-based communication takes place. People easily grasp the meaning of facial expressions of animated characters in movies, and emoticons or emojis in e-mails. Brain imaging studies support this: amygdala activation is relevant for emotion recognition in real life (Cristinzio, Sander, & Vuilleumier, 2007). Schematic faces activate amygdala in a similar way as real emotional faces do (Wright, Martis, Shin, Fischer, & Rauch, 2002). Wright et al. (2002) have stated that, "/… / schematic faces may be useful for studying brain responses to emotional stimuli because of their simplicity relative to human faces". In the Results section we also show that the combination of valence and arousal was unique for each schematic face. The main strength of these stimuli is that they can be very easily controlled (colours, identity, features etc).

A second way that our procedure is different from previous work is that we used a *well-known updating task* that is calibrated to avoid ceiling and floor effects (2-back: Neta & Whalen, 2011; Owen, McMillan, Laird, & Bullmore, 2005). Memory load effects were not of interest in this study, as we were interested instead in updating of emotional expression information in a situation known to impose a moderate load. By 2015, only one previous study that we could find had explicitly used the n-back task with schematic emotional expressions in brain imaging (Beneventi, Barndon, Ersland, & Hugdahl, 2007), but they did not use signal detection analysis, nor studied differences between updating emotional expressions.

Third, we applied *signal detection theory and separated sensitivity from response bias* (see Stanislaw & Todorov, 1999), which is necessary in order to understand which process is affected by the emotional content. In an emotional 2-back task, the effect of emotional content can be retrieved by comparing responses to same target-probe in different emotion conditions (e.g. sad in memory –vs sad probe condition can be compared to neutral in memory vs neutral probe condition etc). That requires using the signal detection measure – correct rejections, i.e. rejection of a difference. We calculated hits (detection of a new signal, i.e. difference) and correct rejections (detection of the same signal,

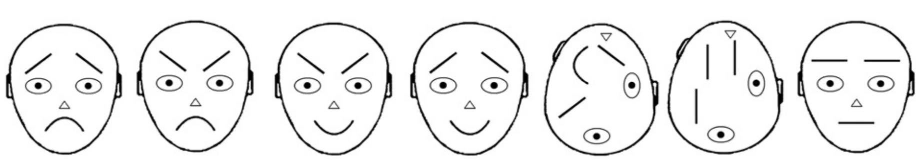

Fig. 1. The stimuli used in the experiment were similar to stimuli used in Öhman et al. (2001), except the two objects. The labels for the objects (from left): sad, angry, scheming, happy, object1, object2, neutral.