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Visuomotor integration of relevant and irrelevant angry and fearful facial expressions☆

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ABSTRACT

Our brain codes the features of perceptual events in a distributed fashion, raising the question of how information belonging to one event is processed without any interference of features from other events. Hommel (1998) suggested the "event file" concept to elucidate these mechanisms: an episodic memory trace "binding" together perceptual features and actions related to an object. Using a similar paradigm, we designed a pilot experiment and four additional experiments to investigate whether emotion, similarly than perceptual features, could bind with a motor response when the emotion was relevant and irrelevant for the task. Few studies have revealed this to be the case. We investigated how angry and fearful faces expressed by avatars and humans might be subject to a binding phenomenon. Our results show that at least three degrees of visuomotor binding seem to coexist: one implicating the relevant feature of the task with a strong effect on behavior, another implicating the location with a smaller behavioral effect (even if not task related), and a third implicating non-task-related features with behavioral effects only under specific conditions in which emotion could play a role. Our adaptation of Hommel's paradigm showed that emotional percepts can be subject to visuomotor binding effects even if the emotion is not task related confirming the important role of emotional information for the central nervous system. These findings offer new perspective in the investigation of the emotion-action binding at the neuronal level.

1. Introduction

The primate brain codes the features of perceptual events in a distributed fashion (Hommel, 2004). Thus, color, shape, and location of a visual object are represented in different brain regions in the visual cortices (Hommel, 2004). The distribution of object features in several maps in the brain raises the binding problem (Treisman, 1996): How does the brain integrate the information belonging to one event without mixing it up with elements from other concurrently processed events? One hypothesis proposed by Kahneman, Treisman, and Gibbs (1992, cited by Hommel, 2004) involved the concept of an *object file*: "an episodic memory trace containing information about the relationship between object features, possibly enriched by object-related knowledge from long-term memory, and addressed via location codes" (pp. 494–495). In their experiment, two, four, or eight letters were presented in eight spatial locations. After a slight interval, a letter appeared in one of the locations. The aim was to designate the letter as quickly as possible. Kahneman et al. (1992) found that in some cases, but not all, participants were faster at naming the letter if it had been previously displayed. However, this effect was much stronger if the letter appeared in the same location. The authors concluded that the letter and location were bound in an object file in their first presentation and that reactivation of one automatically activated the other, facilitating the response.

The concept of an object file is interesting for describing the transient interactions occurring between, for example, the visual brain regions that construct a percept, but this assumption seems too narrow when the response action is also manipulated. In fact, Hommel (1998) showed that integration of distributed codes was not restricted to perception, but could apply to sensorimotor processing as well. In this study, the author designed the following experiments: a cue, represented by an arrow pointing in the right or left direction, was presented before a first stimulus (S1). The latter could be a circle or a cross, red or green, and located in the top or bottom part of the screen. Participants answered with a right or left key according to the direction of the cue and therefore independently of the stimulus. Another stimulus (S2) then appeared on the screen. This time, participants answered according to the shape of the stimulus for the first experiment and the color of the stimulus for the second. For example, in the first experiment, if the object was a circle, they pressed the left key, and if it was a cross, they pressed the right key. Hommel's assumptions were as follows: Participants would be faster at identifying the relevant feature of S2 if it remained the same in S1 and S2 and the answer was repeated. Indeed,

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according to Hommel, perceptual features bind with the motor response in S1. Thus, when one feature is repeated in S2, the other is automatically activated, facilitating the response in the case of a complete repetition. When a full alternation of the features and motor response from S1 to S2 occurred, Hommel assumed that the participant's response would also be favored. In fact, no previous association disrupted the answer in S2. In contrast, Hommel expected a greater reaction time when only one element was repeated. In this situation, Hommel predicted a partial repetition cost: The component that is repeated activates the previous association, disrupting the establishment of a new action scheme. This is exactly what Hommel found. Participants were faster when the relevant feature and the answer were both repeated and alternated than they were in the case of a partial repetition. It appears that binding exists between perceptual features and actions related to an object, which Hommel suggested calling an “event file” instead of an “object file”.

In consideration of evidence of a memory trace linking together perceptual features and actions related to an object, several investigators examined the impact of emotion on stimulus–response compatibility. For instance, Colzato, van Wouwe, and Hommel (2007) discovered, using the paradigm of Hommel (1998), that presentation of a positive picture between S1 and S2 increased visuomotor binding, whereas a negative picture decreased it. Indeed, the introduction of a picture between stimuli entailed a smaller partial repetition cost for positive than for negative images.

Other experiments even showed that an emotion-action integration was probable by interfering with approach- and avoidance-related responses to emotions. These experiments mainly used an approach-avoidance protocol (see Phaf, Mohr, Rotteveel, & Wicherts, 2014). For example, Lavender and Hommel (2007) presented right- and left-oriented positive and negative pictures to participants and asked some of them to move a doll toward the positive pictures and away from the negative pictures. Other participants received the opposite instructions. Results showed that participants with the former instructions were faster than were those with the opposite instructions. According to authors, this phenomenon occurred because in everyday life, people are used to approaching positive events and avoiding or withdrawing from negative events. Therefore, they integrate the “approach” action with a positive valence and the “avoid” action with a negative one. Thus, when valence is reactivated, people automatically activate the action related to it, affecting the reaction time. This observation is in accordance with the concept of action tendencies (Frijda, 1986, 2007), emotion embodiment (Niedenthal, 2007), or motivational theory (Lang & Bradley, 2010) and is integrated in theories of emotion (e.g., Grandjean, Sander, & Scherer, 2008; Scherer, 2001).

1.1. Purpose of the Study

Several studies have investigated the impact of emotion and integration on sensorimotor interactions. Emotions, like perceptual features, are likely related to the concept of action tendencies (Frijda, 1986, 2007) and are part of the event files suggested by Hommel (1998). In the present studies, our first aim was not to investigate consequences of the general valence-action binding phenomenon, as previously studied (e.g., Eder & Klauer, 2009; Eder, Musseler, & Hommel, 2012; Lavender & Hommel, 2007), but to examine how emotional information could be the subject of visuomotor binding. In the five studies described below, we used angry, fearful, and neutral facial expressions as emotional information. To our knowledge, only one study has used emotional faces in Hommel's paradigm, but only as task-irrelevant background stimuli behind S1 and S2. Trubutschek and Egner (2012) discovered then that anger did not affect the integration between perceptual features and motor response when it was irrelevant for the task. However, Trubutschek and Egner did not specifically test the emotion-action integration, as faces remained the same in S1 and S2.

Our second aim was to study how task relevance can affect emotion-action binding, with the hypothesis that an automatic and accurate behavioral response to emotional stimuli in our environment is an important aspect of our survival developed during our ontogenetic and phylogenetic history. Discrepant results have been shown in the literature concerning an influence of emotional stimuli when irrelevant for the task. For instance, Lavender and Hommel (2007), who, as mentioned earlier, interfered with approach- and avoidance-related responses to emotions, did not observe an approach-positive/avoidance-negative facilitation effect when realizing a spatial task with their emotional stimuli. However, Giesen and Rothermund (2011), using unaccustomed left and right responses to emotion, showed that emotion can bind with motor responses when the task is not about the emotion. They presented an emotional noun and adjective at the same time. Participants had to indicate whether the noun designated a person or an object. The emotional aspect of the words was irrelevant for the task and their valence varied. After a delay, a new noun-adjective pair awaiting the same response appeared on the screen. Results showed that distractor and response integration, as well as recall, was modulated by affective congruence: If the target and the distractor had the same valence, the distractor's repetition facilitated the response when it was also repeated. These effects occurred, according to the authors, because the distractor, when it had the same valence as the target, bound with the motor response during the presentation of the first noun-adjective pair. Repetition of the distractor then reactivated the previous association, facilitating the answer when it was the same.

In the present studies, we designed one pilot experiment and four additional experiments to investigate the foundations of emotion-action binding with unfamiliar responses to emotions (left and right responses) and emotion as a relevant or irrelevant feature of the task in S2. The pilot experiment was a gender task with angry and neutral facial expressions of human avatars, as in the first, second, and fourth studies. The first experiment was an emotional task. The precise design of this experiment was developed on the basis of the results of the pilot study. The second experiment was a location task. The third experiment was a location task with fearful and neutral facial expressions of real humans (photographs). The fourth study was a color task in which participants had to categorize the color of the eyes of the previous angry and neutral facial expressions. Therefore, in four experiments, the task was not about the emotion (emotion task-irrelevant: pilot study, study 2, study 3 and study 4), whereas in one experiment, the task was about the emotion (emotion task-relevant: study 1). Three effects were expected for the five experiments. First, we predicted binding to occur between perceptual features, as predicted by the object file assumption of Kahneman et al. (1992). We expected participants to be faster for the repetition and alternation of the perceptual features than in the situation of a partial repetition of one or some of these features. Second, we predicted an event file binding between perceptual features and motor actions, in particular an emotion-action integration. As in the object file hypothesis, we predicted our participants to be faster for a repetition and alternation of the perceptual features and the motor response than in the situation of a partial repetition. Finally, we predicted that, if emotion and motor response were in fact bound, this integration would be more important for emotional than for neutral faces. Indeed, numerous studies have shown emotional relevance in various cognitive abilities, such as perception, attention, or memory (e.g., Hodsoll, Viding, & Lavie, 2011; Ohman, Lundqvist, & Esteves, 2001; Talarico & Rubin, 2003). For instance, Ledoux (1994) revealed a specific cerebral pathway for threat detection: a direct path from the visual pathways to the amygdala, without accessing the visual cortex. This circuit would be implicated in the automatic detection of environmental hazards (Ledoux, 1994). Moreover, other authors, such as Talarico and Rubin (2003), revealed that emotional events, particularly negative events, would be more rooted in memory and then better recalled than neutral events. Motivated by these studies and the potential role played by binding in anxiety disorders such as phobia, obsessive–compulsive disorders or post-