Acta Psychologica 159 (2015) 69–75

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy

From hands to feet: Abstract response representations in distractor–response bindings

Birte Moeller [a,*], Bernhard Hommel [b], Christian Frings [a]

[a] Trier University, Germany
[b] Leiden University, Netherlands

ARTICLE INFO

Article history:
Received 15 October 2014
Received in revised form 18 May 2015
Accepted 27 May 2015
Available online 2 June 2015

Keywords:
Action control
Event-file
Stimulus–response binding
Distractor–response binding
Effector

ABSTRACT

Evidence suggests that, when people respond to target stimuli, distractors that accompany the target become integrated with the response, and can thus subsequently serve as a retrieval cue of that response—an example of *distractor–response binding*. In two experiments, we investigated whether the response codes that become part of such distractor–response bindings are effector-specific or abstract. In a prime–probe design, participants gave left and right responses with their hands or their feet. The required effector set was systematically varied between prime and probe responses. If participants executed each response immediately, effects of distractor–response binding were only observed for effector repetitions but not for effector changes. However, distractor–response binding was observed in effector-change trials if participants were keeping the prime-action plan active during probe–response execution. These results indicate that it is rather abstract response codes that are integrated with distractor stimuli and retrieved upon distractor repetition.

1. Introduction

At any one moment, many objects in our environment are irrelevant for our current action goals and are thus better to be ignored. Interestingly, however, ignored stimuli have been shown to influence human actions by retrieving earlier responses (e.g., Frings & Rothermund, 2011; Hommel, 2005; Moeller & Frings, 2014). This influence can be accounted for in terms of the theory of event coding (TEC, Hommel, 2004; Hommel, Müsseler, Aschersleben, & Prinz, 2001). The TEC proposes that the formation of an action plan leads to an integration of stimulus- and response features into the same episodic memory trace or *event file* (Hommel, 2004). Repetition of any of these features reactivates the entire event file, including the stimulus and the previous response to it. Thus, if the same response is required again, responding is facilitated due to the repetition of the stimulus. In contrast, if another response is required, stimulus repetition impedes the action. Importantly, it has been shown that actions can be influenced by ignored stimuli in a similar way (e.g., Frings, Rothermund, & Wentura, 2007). This *distractor–response binding* effect can be demonstrated in prime–probe designs that require responses to prime and probe targets accompanied by distractors. If the response has to be repeated from prime to probe, a repetition of the same distractor facilitates responding on the probe as compared to different prime and probe distractors. In contrast, if the required response on the probe differs from that on the prime, distractor repetition hampers responding, leading to slow and/or inaccurate performance.

Response repetitions in previous studies of distractor-based stimulus–response retrieval involved a repetition of the exact motor response — e.g., pressing the same response key with the same finger as before (e.g., Frings & Moeller, 2010; Frings & Rothermund, 2011; Giesen & Rothermund, 2011, 2014; Moeller & Frings, 2011). However, under real-life conditions repeating an action does not necessarily involve the exact same muscle activations or involvement of the same effector: you may switch on the same light, and open the same door by using very different body parts. As actions have been defined in terms of both muscle activations (e.g., Barsalou, 2008) and more abstract codes such as the action goal (e.g., Prinz, 1997), it remains to be seen whether distractor-action bindings rely on the former or the latter.

On the one hand, it has been suggested that responses are represented in terms of their action goal rather than specific motor programs (e.g., Eder, Müsseler, & Hommel, 2012; Prinz, 1997; see also Rosenbaum, 1980; Schmidt, 1975; Stelmach, Mullins, & Teulings, 1984; Wright, 1990). It is therefore possible that it is relatively abstract action codes that become part of distractor–response bindings, and that such bindings are not overly sensitive to the particular effector used to execute an action. In line with this, several studies found that effects of stimulus–response compatibility are more or less insensitive to the anatomical status of the effector used to press a response key, so that a left stimulus, say, facilitates pressing a left key even if it is operated by the right hand (see, Simon, Hinrichs, & Craft, 1970; Wallace, 1971, 1972). Along the same lines, interference between concurrent action plans is equally pronounced

* Corresponding author at: Trier University, Department of Psychology, Universitätsring 15, D-54296 Trier, Germany.
E-mail address: moellerb@uni-trier.de (B. Moeller).

http://dx.doi.org/10.1016/j.actpsy.2015.05.012

between two plans involving the same hand and two plans with one involving a hand and another involving the ipsilateral foot (Stoet & Hommel, 1999). More specifically, regarding integration of distractor stimuli and responses, Frings, Bermeitinger, and Gibbons (2011) found that the repetition of the prime distractor as the probe target facilitated responses with the same hand as on the prime, even if the particular effector (i.e. the executing finger) changed. Even though alternative explanations (e.g., in terms of residual activation of the response hand) could not be ruled out entirely, this might be taken as a first indication that the response retrieved by distractor repetition is not restricted to exact muscle activation.

On the other hand, there are reasons to consider that distractor–response bindings might involve effector-specific representations. Theories of cognitive embodiment claim that actions are represented through mental *simulations*, suggesting that action representation is body based (e.g., Barsalou, 2008; Wilson, 2002). If we assume an integration of such response representations, a distractor that has been bound to a left response with a hand would not retrieve a left response with a foot at repeated presentation. Consequently, changing the executing extremity from prime to probe should modulate the effect of distractor–response bindings. In fact, Eimer, Schubö, and Schlaghecken (2002) found response inhibition due to masked priming both for hand responses and for foot responses but no such inhibition if the effector pairs (hands or feet), associated with the prime and target, were different. In addition, Braem, Verguts, and Notebaert (2011) found better discrimination between tasks if participants used their hands to respond to one task and their feet to respond to the other, as compared to when participants used hand responses in both tasks to respond. These results also support a notion of action discrimination by extremities. Finally, manual probe responses were not influenced by retrieval of verbal prime responses when an auditory prime distractor was repeated as the probe target (Mayr & Buchner, 2010), further supporting the notion of effector specific bindings.

Taken together, different theories and past findings provide no clear picture as to what kind of response representation is likely to become integrated with a distractor stimulus. Particularly, in the one extreme, specific muscle activations might be integrated in distractor–response binding, resulting in the facilitation of very specific responses by repeated distractors. In the other extreme, it might be an abstract response code that is integrated with a distractor stimulus, resulting in the modulation of a range of responses by distractor repetition.

The present study was designed to pit these notions against each other. We used a prime–probe design and asked participants to categorize prime and probe targets by means of right and left responses, while ignoring flanking distractor stimuli. Left and right responses could be carried out with the hands or with the feet and the required effector pair (i.e., hands or feet) could repeat or change from prime to probe response. If distractor–response binding takes place at an abstract level of response coding the effect of distractor–response binding should survive changes of the effector set and thus be equally significant with effector-set repetitions and effector-set changes. For example, a left response executed with a hand on the prime should be integrated with the distractor and the repetition of this distractor should facilitate a left foot response on the probe. In contrast, if distractor–response binding is specific to the effector used to execute the response, we should only find a significant effect of distractor–response binding on trials with responses executed with the same effector set on the prime and the probe (i.e., either both with the hands or both with the feet). In two experiments we varied the effector-set relation (repetition vs. change) between prime and probe responses and measured effects of distractor–response binding on probe responses. In Experiment 1, we used a sequential distractor-priming paradigm that required participants to respond to the prime and the probe targets immediately. In Experiment 2, participants were required to delay the prime response and execute it only after completion of the probe response. The rationale of this requirement was that it would assure that the action plan of the prime response was kept active during probe response execution (see Stoet & Hommel, 1999).

2. Experiment 1

2.1. Method

2.1.1. Participants

A total of 30 students (21 female) from the University of Trier took part in the experiment. The median age was 20 years with a range from 19 to 28 years. Two additional participants were replaced because of an extreme number of slow or incorrect responses (their error rates or mean response times were more than three interquartile ranges above the third quartile of the remaining sample; Tukey, 1977). All participants took part in exchange for partial course credit and had normal or corrected to normal vision.

2.1.2. Design

The design essentially comprised three within-subjects factors, namely response relation (repetition vs. change), distractor relation (repetition vs. change) and effector set relation (repeated vs. changed).

2.1.3. Materials

The experiment was conducted using the E-prime software (E-prime 2.0). Instructions and the fixation mark were shown in white on black background on a standard TFT screen. Target stimuli were colored ellipses that could be presented in red, yellow, green, or blue. Distractor stimuli were the white outlines of the shapes rectangle, triangle, ellipsis, and star. All stimuli had a horizontal visual angle of 1.5° and a vertical visual angle of 1.1°. A constant viewing distance of 50 cm was provided by asking participants to place their heads on a chin rest.

2.1.4. Procedure

Participants were tested individually in sound proof chambers. Instructions were given on the screen and summarized by the experimenter. Two foot pedals (Psychology Software Tools, Inc., Sharpsburg, USA) were placed in a comfortable position on the floor in front of the participants. The foot pedals were connected to the computer via a serial response box (PST, Inc., Sharpsburg, USA), providing a zero ms debounce period. Participants were instructed to place the index fingers of their hands on the far left and the far right key on a serial response box, respectively, and to place their feet on the foot pedals. Each participant worked through four blocks of the experiment: in one block they responded with their hands to both prime and probe, in one with their hands to the prime and with their feet to the probe, in one with their feet to the prime and with their hands to the probe, and in one with their feet to both the prime and the probe. In addition, before each prime and each probe display, a picture of a hand or a foot was presented in white on black background to indicate whether participants had to respond via hands or via feet to the next display. In each prime and each probe display a colored ellipsis was presented in the center of the screen and was flanked by two identical shapes. Participants' task was always to identify the color of the centered ellipse by pressing a key with the index finger on the side corresponding to the color or by pressing a foot pedal on the corresponding side with the left or right foot. To be able to vary response repetition independent of target repetition, each response could be indicated by two different target colors. Red and green stimuli were mapped to the right, and blue and yellow stimuli were mapped to the left responses. Participants were instructed to react as quickly and as correctly as possible.

A single prime–probe sequence consisted of the following sequence of events (see Fig. 1): at the beginning of each trial, a plus sign was presented as a fixation mark for 1000 ms in the center of the screen and was followed by a blank screen that was presented for 200 ms. Then the cue (i.e., a picture of a hand or a foot) was presented for