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Exploring the representational basis of response-effect compatibility: Evidence from bilingual verbal response-effect mappings☆

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ABSTRACT

The ideomotor principle states that actions are represented by their anticipated sensory effects. This notion is often tested using the response-effect compatibility (REC) paradigm, where participants' responses are followed either by a compatible or incompatible response effect (e.g., an effect on the right side after a right-hand response is considered R-E compatible due to the spatial overlap, whereas an effect on the left side after the right-hand response is considered incompatible). Shorter reaction times are typically observed in the compatible condition compared to the incompatible condition (i.e., REC effect), suggesting that effect anticipation plays a role in action control. Previous evidence from verbal REC suggested that effect anticipation can be due to conceptual R-E overlap, but there was also phonological overlap (i.e., anticipated reading of a word preceded by the vocal response of saying that very word). To examine the representational basis of REC, in three experiments, we introduced a bilingual R-E mapping to exclude phonological R-E overlap (i.e., in the R-E compatible condition, the translation equivalent of the response word is presented as an effect word in a different language). Our findings show that the REC effect is obtained when presenting the effect word in the same language as the response (i.e., monolingual condition), but the compatibility effect was not found when the semantically same word is presented in a different language, suggesting no conceptually generalized REC in a bilingual setting. (232 words).

1. Introduction

According to the ideomotor principle, the cognitive basis of voluntary action control can be explained by anticipatory representations of the actions' sensory effects in the environment (e.g., Badets, Koch, & Philipp, 2016; Greenwald, 1970; Hommel, 2013; Koch, Keller, & Prinz, 2004; Shin, Proctor, & Capaldi, 2010, for reviews). For example, when talking to someone, one anticipates the perceptual effects of this action such as hearing one's own voice while speaking (i.e., auditory effect). Thus, the representation of actions effects is assumed to be the basis of voluntary action selection and initiation (e.g., Ansorge, 2002; Kunde, Elsner, & Kiesel, 2007).

Action (or response) effects are assumed to be learned throughout life. More specifically, voluntary action planning requires that we (1) observe and memorize the effects that derive from our actions, and once we (even incidentally) acquire these contingencies between specific actions and their effects, (2) we can voluntarily use the action to trigger the associated outcome (Elsner & Hommel, 2001; Hommel, Alonso, & Fuentes, 2003).

Some studies investigated effect acquisition using the response-effect (R-E) learning paradigm, where first participants' responses (e.g., keypresses) are followed by specific effects (e.g., tones), so that response-effect associations are created, and later tested these associations in a subsequent test phase, where these effects are used as stimuli. Reaction times (RTs) are shorter if the stimulus-response (S-R) mapping in the test phase corresponds to the R-E mapping from the learning phase, compared to when the two mappings are different (e.g., Badets & Pesenti, 2011; Elsner & Hommel, 2001; Herwig, Prinz, & Waszak, 2007; Herwig & Waszak, 2009; Hommel, 2013; Hommel et al., 2003; Janczyk, Heinemann, & Pfister, 2012; Pfister, Kiesel, & Hoffmann, 2011; Ziessler, Nattkemper, & Frensch, 2004).

1.1. Response-effect compatibility (REC)

In comparison to the R-E learning paradigm, the REC paradigm investigates the role of effect anticipation in action control by presenting either compatible or incompatible effects after the participants' response (e.g., Badets, Koch, & Toussaint, 2013; Földes, Philipp, Badets,

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& Koch, 2017; Koch & Kunde, 2002; Kunde, 2001; Kunde, Koch, & Hoffmann, 2004; Pfister, Kiesel, & Melcher, 2010). In these experimental settings, compatibility is defined based on preexisting associations that arise from dimensional overlap between responses and their predictable effects, unlike in the R-E learning paradigm, in which R-E associations need to be acquired first (Kornblum, Hasbroucq, & Osman, 1990). For example, in a study of Kunde (2001, Experiment 3), participants were instructed to press keys softly or forcefully in response to a visual go signal, and after each keypress a loud or quiet tone was displayed to them. Compatible trials (e.g., forceful keypresses followed by a loud tone, thus intensity of the effect matches the response's intensity) and incompatible trials (e.g., forceful keypresses followed by a quiet tone) were presented in a blocked design, so that effects could be anticipated. Kunde (2001) found shorter RTs in the R-E compatible condition compared to the R-E incompatible condition, demonstrating a REC effect. This REC effect suggests that the anticipated effect facilitated the corresponding response, since the keypress response had already been executed when the effect tone was presented.

1.2. Representational basis of REC

Compatibility in the REC paradigm is most often defined and investigated on a perceptual basis, for example sensory intensity (Kunde, 2001; Kunde et al., 2004), visual-spatial overlap (Müller, 2016 [Experiment 1 & 2]; Pfister, Dolk, Prinz, & Kunde, 2013; Pfister & Kunde, 2013; Yamaguchi & Proctor, 2011), spatial height-auditory pitch overlap (Keller & Koch, 2006, 2008) or duration (Kiesel & Hoffmann, 2004; Kunde, 2003; Müller, 2016 [Experiment 3]) In contrast, conceptual R-E overlap in the REC paradigm has received less attention so far.

First evidence for conceptually generalized response effects in the REC paradigm was reported by Koch and Kunde (2002). In Experiment 2, participants' vocal color word responses (i.e., *blue*) were followed by a written color word effect in neutral color, that was, predictably, either the same color word (R-E compatible) as the response word or a different color word (R-E incompatible). The authors found a REC effect, suggesting that beyond merely physical features (i.e., the visible color of an effect word), there might be a conceptual basis for effect anticipation in the REC paradigm – in this case the semantic meaning (i.e., color) implied by the written color word (see also Badets et al., 2013; Földes et al., 2017; Paelecke & Kunde, 2007).

However, Koch and Kunde (2002) discuss in their paper the possibility that their REC effect was actually phonologically mediated based on phonological recoding of the anticipated visual effect word, therefore, a stronger demonstration of conceptual verbal REC would include conditions that exclude any perceptual, phonological R-E overlap. The aim of the present study was to examine conceptual R-E overlap in the REC paradigm using bilingual R-E mappings by excluding phonological similarity of conceptually related responses and effects.

Besides first evidence by Koch and Kunde (2002), there is an additional reason to assume that response effects can be conceptually generalized. Our assumption is based on findings from studies investigating S-R relations, and we argue that these relations should work based on the same mechanism in R-E relations (Keller & Koch, 2006; see also Badets & Pesenti, 2011; Badets et al., 2016; Elsner & Hommel, 2001; Fitts & Deininger, 1954).

Conceptual S-R compatibility has been shown in studies using the Stroop-task (Stroop, 1935), where participants have to respond by saying either the physical color in which the word is written, ignoring the meaning of the stimulus word (color naming), or reversed (word naming). Performance is worse if the physical color and the meaning of the word are incongruent compared to when they are congruent, both in the color naming and in the word naming version of the task (MacLeod, 1991). This finding suggests, that the conceptual content of the word is processed together with the physical color of the stimulus word, even though participants are instructed to ignore the first one.

Conceptual S-R compatibility can be explained in terms of the theory of event coding (TEC; Hommel, 2009) which states that "perception, attention, intention, and action share, or operate on, a common representational domain" (Hommel, Müsseler, Aschersleben, & Prinz, 2001, p. 859). Accordingly, compatibility between stimulus and response can be described by the degree to which these two share their representational codes. For example, it should be easier responding *red* to the stimulus word *tomato* than giving the same response to the stimulus word *sky* (which is expected to activate the word *blue*), investigating S-R compatibility defined based on perceptual characteristics. However, the TEC does not limit codes to perceptual ones, instead, it should be also easier to respond *fruit* to the first than to the latter stimulus word, as well as depending on the task, the previous stimulus word *tomato* can fill up with conceptual content such as "left hand response", "frequently presented word", etc. (Hommel, 2009).

Studies investigating action control with the R-E learning paradigm suggest that compatibility between stimulus and response and between response and effect can work bidirectionally (Elsner & Hommel, 2001), thus, in the light of previous preliminary evidence for conceptual S-R compatibility, we assume that response effects should also be conceptually generalized, but this still needed to be demonstrated in a way that excludes perceptual, phonological overlap between the verbal codes for response and effect.

1.3. Present experiments

The present study investigates conceptual generalization of anticipated response effects in three experiments, using monolingual and bilingual settings in the REC paradigm. In the monolingual setting, participants are presented with the same effect word as their response word in the R-E compatible condition (e.g., response: *Hund* [German for *dog*] ➔ effect: *Hund*) and with a semantically different word in the R-E incompatible condition (e.g., response: *Hund* ➔ effect: *Schwein* [German for *pig*]). Thus, this is a setting similar to the one used by Koch and Kunde (2002), and therefore both conceptual and phonological overlap is present between the given response word and the presented effect word in the R-E compatible condition. However, in the bilingual setting, participants are presented with an effect word that is the translation-equivalent of the response word, presented in English (i.e., response: *Hund* ➔ effect: *dog*). Therefore, conceptually R-E compatible and incompatible conditions in this kind of bilingual setting were created in a way that any effect of phonological overlap between response word and effect word could be excluded.

In the present experiments, unbalanced bilinguals[1] responded vocally to visual stimuli according to the instruction. After their response, participants received either an R-E compatible or incompatible auditory effect to their headphones. Note that Koch and Kunde (2002) used visually presented effects, but Földes et al. (2017) demonstrated similar REC effects using auditory effects of vocal responses.

In Experiment 1, participants responded by saying animal names (e.g. *Hund*, *Schwein*, German for *dog* and *pig*). Each participant performed the R-E task in an R-E compatible and incompatible condition, while bilingual transfer was varied between-subjects (i.e., monolingual vs. bilingual). In Experiment 2, participants executed a similar task as in Experiment 1; however, here a single group was tested only in the bilingual conditions to replicate the findings of Experiment 1 with larger statistical power. In Experiment 3, a similar task was used as in Experiment 1, aiming to confirm and complement findings of Experiments 1 and 2 using a within-subjects design for the transfer condition (monolingual vs. bilingual).

[1] German native speakers with L2 English who learned English at school at an early age or acquired English knowledge at early adulthood, and who continue to use English in their everyday life, for example, in their studies or through the media. (Duyck & Brysbaert, 2004; Lemhöfer & Broersma, 2012; Vega-Mendoza, West, Sorace, & Bak, 2015).