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The role of effect grouping in free-choice response selection

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ABSTRACT

Which motor actions are preferred to replace an initially planned but momentary not executable action? Previous research (Khan, Mourton, Buckolz, Adams, & Hayes, 2010, Acta Psychologica) suggests that anatomical constraints seem to be a major determinant for such choices: For example, participants more frequently chose to respond with the finger homologous to the prepared one. We argue that in this case finger homology is confounded with action effect similarity, and action effects have been ascribed a crucial role in action selection. We report two experiments. Experiment 1 replicated the results obtained by Khan et al. In Experiment 2, we introduced visual action effects in the paradigm. Results from this experiment clearly point to a role of effect similarity in addition to mere finger homology status for the choice frequency effect.

1. Introduction

Imagine you're preparing to hit the gas pedal of your car. While doing so, an unexpected event happens—a soccer ball is kicked on the road—and you must abort the initial plan and now hit the brake pedal instead. This is just one example of a situation demanding a change of an initial action plan in order to successfully accommodate to current environmental demands.

There is much evidence that knowledge about upcoming events improves performance because attention can be directed toward a particular location or item, both externally in the environment (e.g., Posner, 1980) and internally in memory (e.g., Griffin & Nobre, 2003; Janczyk & Berryhill, 2014). Pre-specifying characteristics of a to-be-produced movement also facilitates its initiation (e.g., Rosenbaum, 1980). It is further assumed that several possible responses are grouped together and that preparation for one element of such a subgroup brings about facilitated responding if another element of the same subgroup is to be executed eventually because otherwise the existing subgroup must be overcome (Adam, Hommel, & Umiltà, 2003; Miller, 1982). From such studies, it can be concluded that switching from one to another action benefits from pre-activation or subgroup membership. However, in many situations—such as in our introductory example—the new action is not prescribed but must rather be selected from several alternatives. The fictive driver may as well have turned the steering wheel appropriately to avoid hitting the soccer ball (instead of braking).

Tasks in which participants are to freely choose from several behavioral alternatives are technically termed *free-choice* tasks (Berlyne, 1957) in comparison to *forced-choice* tasks, where a stimulus entirely determines the one and only correct response (see also Janczyk, Dambacher, Bieleke, & Gollwitzer, 2014). Of crucial interest in such free-choice tasks is the question, "Which alternative is finally chosen?" There is evidence that subtle environmental events happen to influence the choice. For example, in one study, participants were to freely choose and articulate digits ranging from 1 to 9. Shortly preceding, they experienced short/long and quiet/loud tones, and in general, higher digits were chosen following intense tones (Heinemann, Pfister, & Janczyk, 2013). Even subliminally presented (arrow) cues seem to reliably influence participants' behavior in a free-choice task briefly after the cue (Kiesel et al., 2006; Schlaghecken & Eimer, 2004).

Further, the anatomical status of the relevant effector appears to influence choices. This was shown with an elegant paradigm by Khan, Mourton, Buckolz, Adam, and Hayes (2010), and their Experiment 1 is of particular relevance for the present purpose. In this experiment, four responses were possible. Thus, the right and left index and middle fingers were placed on the F, G, J, and K key of a computer keyboard. Four spatially corresponding rectangular visual boxes were presented in a row on a computer screen. A pre-cue (color change of one of the rectangles) indicated one particular response, which was to be prepared

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by the participants. Briefly thereafter, a left/right-pointing arrow appeared between the two central stimuli and pointed to either the two left or the two right boxes. This was the imperative stimulus, and two conditions were distinguished: If the arrow pointed toward the cued location, a forced-choice trial, the prepared response was to be executed. If the arrow pointed toward the opposite direction, participants were to choose freely from the two response alternatives on that side, thus a free-choice trial. The crucial finding was that participants more often chose to respond with the finger that was homologous to the prepared finger (i.e., if a response with the left index finger was prepared, a right index finger response was produced in a free-choice trial more likely than was a right middle finger response). This advantage was absent in other blocks, where participants were not to prepare the cued response but rather to prevent/inhibit execution of this particular response in a forced-choice trial. These results were interpreted in terms of the Grouping Model (Adam et al., 2003), which assumes that performance in response-cueing tasks is facilitated by processes of subgroup building in perceptual-motor representational space. Such subgroups are mostly specified by low-level operations based on, for example, Gestalt principles like symmetry or proximity. Accordingly, preparation of one response (automatically) resulted in the formation of subgroups, for example, that of homologous fingers (symmetry). Because the homologous finger was then a member of the same subgroup, the probability of its initiation was enhanced.

In the following, we suggest that mere finger homology, although certainly important, was not the sole reason for this observation. According to ideomotor approaches to action control (e.g., Harleß, 1861; James, 1890; see Pfister & Janczyk, 2012, and Stock & Stock, 2004, for historical remarks) and its modern descendants such as the Theory of Event Coding (TEC; Hommel, Müsseler, Aschersleben, & Prinz, 2001), individual motor actions cannot be accessed directly, but only by retrieving memories of their sensorial consequences: their action effects. Action effects can be either environment-related (such as a light or a tone) or body-related (such as the proprioceptive feedback from bending a finger and feeling the touch of the response key).[1] Evidence for this assumption comes from response–effect compatibility experiments. For example, left/right responses are produced faster if predictably followed by spatially compatible left/right visual effects than when predictably followed by spatially incompatible right/left visual effects (Kunde, 2001). This basic principle does not only hold for simple key press responses but also for continuous left/right movements (Janczyk, Pfister, & Kunde, 2012; Kunde, Pfister & Janczyk, 2012), wheel rotations (Janczyk, Pfister, Crognale, & Kunde, 2012), scrolling directions in human–computer interaction (Chen & Proctor, 2013), and also for rather abstract relations such as the verbal production of a number that is followed by the visual presentation of the same or another number (Badet, Koch, & Toussaint, 2013; for a recent review, see Shin, Proctor, & Capaldi, 2010). The problem is that it is conceivably hard to experimentally manipulate body-related action effects. One recent study with tactile action effects reported the same result patterns as was previously observed for environment-related action effects (Pfister, Janczyk, Gressmann, Fournier, & Kunde, 2014). Nonetheless, the employed manipulation was at best an approximation of "true" body-related action effects. The typical way to disentangle the role of responses/anatomical features and action effects is thus to add (visual) environment-related action effects to the responses and to vary their compatibility (see also Janczyk, Pfister, Hommel, & Kunde, 2014).

One study applied this logic to bimanual key pressing (Janczyk, Skirde, Weigelt, & Kunde, 2009). It was argued that the well-known advantage of responding with two homologous fingers simultaneously (e.g., Cohen, 1971) does not only imply the use of homologous fingers (thus an anatomical constraint) but also comes with perceptual symmetry as a result. Perceptual symmetry, in turn, is known to improve performance (e.g., Mechsner, Kerzel, Knoblich, & Prinz, 2001; Mechsner & Knoblich, 2004). Also, pressing keys simultaneously with homologous fingers requires anticipation of two rather similar body-related action effects to bring about the overt movement (as compared to non-homologous fingers requiring anticipation of rather distinct body-related effects). Thus, Janczyk et al. (Experiment 1) coupled visual effects (growing columns) with four response keys operated with the left and right index and middle fingers. For one group, using homologous fingers resulted in similar visual effects (and thus non-homologous fingers resulted in different visual effects). This group showed the typical advantage of homologous fingers (that was confounded with the production of similar visual effects). In another group, the relationship between finger homology and effect-similarity was reversed, and this yielded faster responses with non-homologous fingers (that resulted in similar visual effects) than with homologous fingers (resulting in different visual effects). Thus, important in this experiment was the production of similar effects that led to faster responses, regardless of the finger homology status. In sum, it can be argued that participants in the Khan et al. (2010) study did not actually choose the homologous finger but rather that particular response that gives rise to a similar (body-related) action effect as the cued and prepared response does.

There is indeed evidence for a role of action effects when a switch from a prepared to another action is required (Kunde, Hoffmann, & Zellmann, 2002). Participants can switch more quickly from an initially cued to an actually required motor action, if prepared and actually required action would predictably produce the same rather than different auditory effects. This observation suggests a crucial role of the similarity of action effects for response re-programming. Whether this observation extends to choice frequency in a free-choice task remains unknown but certainly possible against the background of the above reviewed studies.

We report two experiments. Experiment 1 was closely modeled after the first experiment in the Khan et al. (2010) study and—to anticipate—we were successful in replicating the higher frequency of homologous finger choices when participants were instructed to prepare a particular response at the outset of a trial. Experiment 2 built upon these results and tested an impact of action effects beyond mere finger homology status. To this end, each response key was coupled with visual action effects (growing columns as used by Janczyk et al., 2009).

2. Experiment 1

This experiment was a close replication of Khan et al.'s (2010) Experiment 1. Participants were presented with a cue signaling a to-be-prepared response. Upon presentation of an arrow stimulus, a forced- or a free-choice situation arose. Our focus was on the free-choice situation, where participants were to choose and press one of the two possible response keys of the other hand. Against the background of the Khan et al. study, we expected a higher frequency of homologous finger choices.

2.1. Methods

2.1.1. Participants

Sixteen undergraduate students participated for course credit (12 females; mean age = 23.5 years). All participants gave consent prior to experimentation and were naïve regarding the hypotheses of the experiment. One participant exclusively chose the homologous finger in free-choice trials and was thus excluded from analyses.

2.1.2. Apparatus, stimuli, and procedure

Experimental protocols were controlled by a standard PC. Stimuli were presented on a 17-in. CRT screen, and responses were collected via a QWERTZ keyboard using the keys F, G, J, and K. Each trial began with the presentation of four black squares with white outline (2000

[1] James (1890) used the terms "remote" and "resident" effects to refer to these different types of effects.