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SHORT REPORT

Reversing the affordance effect: negative stimulus–response compatibility observed with images of graspable objects

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Abstract Responses are faster when the task-irrelevant orientation of a graspable object's handle corresponds to the location of the response hand. Over the past decade, research has focused on dissociating between two competing accounts of this effect: One rooted in motoric object affordances and the other resting on attentional mechanisms (i.e., Simon effect). Following this avenue of inquiry, we conducted three experiments, in which subjects had to respond bimanually to grayscale photographs of frying pans and saucepans. In addition to horizontal orientation (control/leftward/rightward handles), Experiments 1 and 2 also manipulated the direction of exogenous attentional shifts (left/right) using laterally placed, colored markers within the objects. Both experiments yielded regular Simon effects based on the location of the colored markers. However, in stark contrast to previous research, a negative stimulus–response compatibility effect was obtained with regard to the orientation of the graspable handles. This reversed affordance effect was also observed using the original, unedited grayscale photographs (Experiment 3), which suggested that its occurrence cannot be attributed to the use of colored markers. These unexpected findings appear to support the idea that Simon effects result from automatic and exogenous attentional orienting mechanisms, whereas affordances arise from controlled and endogenous attentional processes. Such a top-down attentional account of affordance can accommodate the observed reversal of the effect in the context of task characteristics.

Keywords Simon effect · Inverse affordance · Attention · Negative stimulus–response compatibility · Spatial coding

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Introduction

The Simon effect is an effect of irrelevant stimulus location, characterized by faster reaction times (RTs) when stimulus location corresponds to response location than when it does not (for a review, see Proctor and Vu 2006). It has been demonstrated that the Simon effect occurs relative to the direction of attentional shifts (Rubichi et al. 1997).

Tucker and Ellis (1998) demonstrated a similar stimulus–response compatibility (SRC) effect, in which responses were faster when the task-irrelevant orientation of the handle of a graspable object corresponded to the location of the response hand. They proposed that the handle of the object affords a grasping action for the hand toward which it is oriented, thereby facilitating responses with that hand. This hypothesis, hereafter referred to as the motor account of affordance, has received substantial theoretical and empirical support (for a review, see Thill et al. 2013).

A competing account of affordance was suggested by Anderson et al. (2002), who observed orientation effects for asymmetric object and non-object patterns, which afforded no grasping basis. They argued that asymmetric objects produce a shift in attention toward the visually salient cue within the object (i.e., the handle). This attentional account of affordance attributes the orientation effect to a directional shift of attention toward the handle, dismissing any relation to motor representations.

Given the possibility that the Simon and affordance effects may share the same underlying attentional mechanisms, a number of studies have attempted to dissociate between them. Symes et al. (2005) compared the two effects by simultaneously manipulating object location and object orientation. They advocated an independence between the two effects, whereas other studies have found evidence to the contrary (Iani et al. 2011).

It has also been suggested that affordance is merely a within-object Simon effect (Cho and Proctor 2010). However, such claims have recently come under criticism based on the types of stimuli that were used. Pappas (2014) demonstrated that silhouettes of graspable objects produce Simon effects, whereas photographs, which are rich in detail and environmental depth, give rise to affordance effects.

An important theoretical distinction has been drawn between stable and variable affordances (Borghi and Riggio 2009). It is hypothesized that stable object affordances such as graspability, size and weight are processed differently from variable and context-dependent properties such as handle orientation. Our present experimental focus, along with the findings we have outlined, is limited to variable affordances and their link to attentional processes.

In a previous study, we demonstrated that lateral auditory spatial cues exert a modulating effect on variable affordances (Kostov and Janyan 2012). In our current investigation, we placed colored markers on graspable objects, so as to study affordance effects while visually inducing exogenous shifts in attention.

Experiments

The apparatus, stimuli, design and procedure were almost identical across the three experiments. In the interest of brevity, aspects common to all experiments are presented together, whereas the differences are emphasized at the end of this section.

Participants

A total of 166 right-handed students (aged 19–51) from the New Bulgarian University volunteered to participate in the study (Exp.1: 57; Exp.2: 58; Exp.3: 51). All had normal or corrected-to-normal vision and were naïve as to the purpose of the study. Those with error rates exceeding 10 % were excluded from the analysis (Exp.1: 1; Exp.2: 5; Exp.3: 2).

Apparatus and stimuli

The experiments were conducted in a soundproof booth using E-prime 2.0 for the presentation of stimuli, and recording of accuracy and RTs.

The stimulus set consisted of grayscale photographs of seven frying pans, seven saucepans and seven bowls/plates (see Fig. 1). Frying/saucepans feature pronounced handles and a high degree of visual asymmetry. Additionally, their everyday use relies almost exclusively on grasping interaction with their handles. Hence, we considered them as suitable stimuli under both the motor and the attentional accounts of affordance. Conversely, bowls/plates were selected as a control condition because of their vertical line symmetry and lack of handles. All photographs contained a high level of object detail, as in Pappas (2014).

Stimuli were presented at a distance of $\sim$60 cm, on a 17″ LCD display (1280 × 1024 @ 60 Hz). Each object (19.8° × 8.6°) was centered relative to its horizontal/vertical dimensions and appeared on a white background.

Design and procedure

All three experiments employed an identical procedure, consisting of 12 practice trials, followed by 180 experimental trials. Each trial began with a black fixation cross at the center of a white background. After 300 ms, the stimulus object appeared in place of the fixation cross and remained on screen until the participant made a response or up to a maximum of 1500 ms. Inter-trial interval was set to 1000 ms. Responses were executed on a standard QWERTY keyboard by pressing “Z” or “Num 3” with the left or right index finger, respectively. Response mapping was counterbalanced across participants. The trials were pseudorandomized so that no more than two consecutive responses were executed on the same side of space.

Experiment 1

In Exp.1, we placed a colored marker on either the left or right extremity of each grayscale object (Fig. 1). Color side (left/right), as well as handle side (control/left/right), was manipulated. Vertical orientation was upright in all trials. Participants had to respond bimanually based on the color of the marker (red/green).

Experiment 2

Experiment 2 was identical to Exp.1, except with regard to the task. Subjects had to respond bimanually depending on the vertical orientation of the object (upright/upside-down), as in Tucker and Ellis (1998). Therefore, in addition to

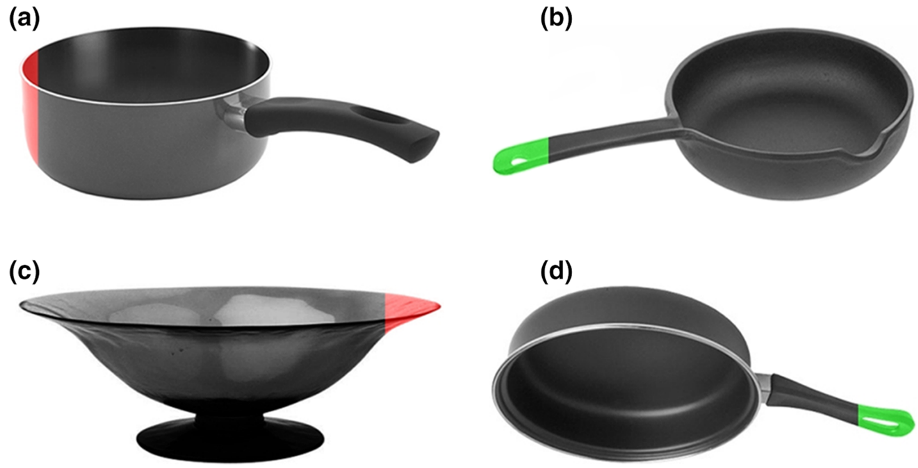

Fig. 1 Stimuli examples. The same set of 21 objects was used in all three experiments. In Exp.1, all objects featured left/right colored markers (*red/green*) and were presented in an upright orientation (e.g., **a–c**). Experiment 2 differed in that it presented the objects along two vertical orientations (upright/upside-down; **a–d**). Experiment 3 was the same as Exp.2, except that the colored markers were removed and the original grayscale images were used as stimuli. *Left/right horizontal* and *upright/upside-down vertical* orientations were generated for each object using image manipulation software (color figure online)

manipulating color side (left/right) and handle side (control/left/right), objects were also presented along two vertical orientations (upright/upside-down).

Experiment 3

Experiment 3 was a replication of Exp.2, without the use of colored markers. The original, unedited grayscale photographs were used as stimuli.

Results and discussion

Error trials (Exp.1: 2.46 %; Exp.2: 3.60 %; Exp.3: 4.01 %) were excluded from the analysis. Based on individual subject condition variances, RTs ± 2 SDs from their associated means were also removed (Exp.1: 5.00 %; Exp.2: 4.35 %; Exp.3: 4.92 %). The remaining correct RTs were averaged across subjects and were entered into a repeated-measures ANOVA. Experiment 1 had response hand (left/right), handle side (control/left/right) and color side (left/right) as within-subject factors. In Experiments 2 and 3, response hand (left/right) was taken as a between-subject factor because only upright vertical orientation trials were analyzed. Handle side (control/left/right) and color side (left/right) were within-subject factors (see Table 1 for associated means).

Both Experiments 1 and 2 revealed a significant interaction between response hand and color side ($F_{\mathrm{EXP1}}(1,55) = 201.35$, $p < .001$, $\eta_p^2 = .79$; $F_{\mathrm{EXP2}}(1,51) = 6.20$, $p < .05$, $\eta_p^2 = .11$), with responses being faster when corresponding to the location of the color. This Simon effect was more pronounced in Exp.1 (45 ms), where subjects had to attend to the color, compared to Exp.2 (18 ms), where it was task-irrelevant. It is worth noting that in both of the experiments the Simon effect was greater on the right side of space (see Fig. 2). This observed asymmetry, coupled with our right-handed pool of subjects, falls in line with previous research indicating that the Simon effect is larger on the side of space, in which the dominant hand is operating (Rubichi and Nicoletti 2006).

The critical finding of this study was the observed interaction between response hand and handle side in Exp.2 ($F(2,102) = 8.91$, $p < .001$, $\eta_p^2 = .15$) (Fig. 2). Contrary to our expectations, RTs for corresponding trials were significantly slower compared to non-corresponding trials (see Table 1). Post hoc comparisons using the Newman–Keuls method revealed that this negative correspondence effect was primarily derived from left-hand responses, which were slower when the graspable handle was oriented to the left than to the right (572 vs. 539 ms; $p < .001$). Right-handed corresponding trials failed to reach significance compared to non-corresponding (530 vs. 520 ms; $p = .11$). The same pattern of negative stimulus–response compatibility was obtained in Exp.3, using the original, unedited grayscale photographs ($F(2,94) = 6.16$, $p < .01$, $\eta_p^2 = .12$), which suggested that its occurrence cannot be attributed to an effect produced by the colored markers. Again, left-handed corresponding trials were slower than non-corresponding (574 vs. 550 ms; $p < .01$), whereas right-handed corresponding trials did not quite reach significance compared to non-corresponding (514 vs. 496 ms; $p = .1$).

The observed reversal of the orientation effect runs contrary to both the motor (Tucker and Ellis 1998) and the

Table 1 Means (ms) and (SDs) of RTs as a function of stimulus–response type, collapsed into corresponding and non-corresponding trials

	Stimulus–response	Corresponding (ms)	Non-corresponding (ms)	Correspondence Effect (ms)
Experiment 1	Handle hand	492 (75)	492 (77)	0
	Color hand	470 (76)	515 (74)	45***
Experiment 2	Handle hand	551 (88)	529 (87)	−22**
	Color hand	530 (78)	548 (89)	18*
Experiment 3	Handle hand	544 (97)	523 (97)	−21**

* $p < .05$; ** $p < .01$; *** $p < .001$

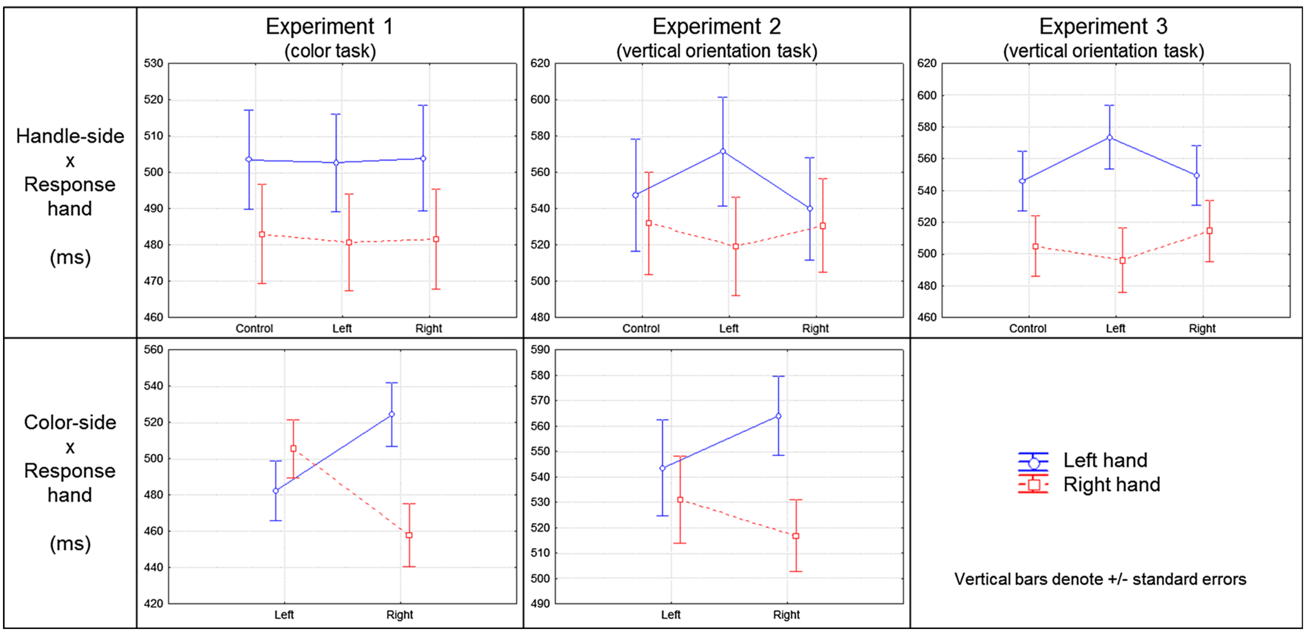

Fig. 2 Interactions between response hand and handle side, as well as response hand and color side across the three experiments

attentional accounts of variable affordances (Anderson et al. 2002; Cho and Proctor 2010). Regardless of whether object location (Symes et al. 2005; Riggio et al. 2008) or object detail (Pappas 2014) has been manipulated, the orientation effect has occurred relative to the handles and not the bodies of graspable objects.

One possible interpretation of our results rests on the resemblance obtained between the orientation and Simon effects. Both effects exhibited similar asymmetric patterns (see Fig. 2). The Simon effect in Experiments 1 and 2 was much stronger when the colored marker was located on the right side of space. On the other hand, the negative orientation effect appeared to originate when object handles were to the left side of space (i.e., object bodies were to the right). Therefore, an argument could be made in favor of the existence of a disguised Simon effect toward object bodies, possibly as a result of horizontal object positioning. When it comes to centralizing an asymmetric object such as a frying pan, there are two main approaches, which can be equally problematic. Some researchers (e.g., Pappas 2014) have positioned objects based on "mass," so that there are an equal number of object pixels on either side of the center. The larger an object's body is relative to its handle, the more this technique will shift the object in the direction of the handle. As a result, the handle would become the most lateralized part of the object during presentation. The alternative approach, which we have employed, centers the object based on its length. However, this produces an uneven distribution of pixels, with the object occupying a larger area on the side of space containing the body. There exists an alarming possibility that the former approach produces spatial compatibility effects with regard to the handle, while the latter favors the body. Such a scenario could potentially cast a shadow of doubt on more than a decade of research on variable affordances using centralized stimuli. In fact, recent findings have increasingly emphasized the role of object location in producing object-based correspondence effects (Lien et al. 2014; Proctor and Miles 2014).

If the horizontal positioning of our stimuli was indeed responsible for producing a spatial compatibility effect toward the object bodies, it is difficult to understand why Exp.1 fails to produce any trace of this compatibility ($F(2,110) = .10$, $p = .9$, $\eta_p^2 = 0$). Instead, the lack of an orientation effect falls in line with Symes et al. (2005), who argued that color processing tasks are insufficient in forming detailed object representations necessary to elicit affordance. Moreover, the lack of a second-order interaction between response hand, handle side and color side in Exp.2 ($F(2,102) = .72$, $p = .49$, $\eta_p^2 = .01$) suggests that the color and the orientation effects are independent and additive, rather than being two Simon effects (Sternberg 1969). Nevertheless, we have already begun an investigation into the exact nature of the relationship between horizontal object positioning and orientation effects. However, on the basis of our current findings, we are more inclined to refer to another interpretation of the observed reversal of the affordance effect, which rests on different attentional mechanisms.

Riggio et al. (2008) proposed that the Simon effect be attributed to automatic and exogenous attentional orienting mechanisms, whereas affordances arise from a controlled and endogenous deployment of attention, which is goal-oriented and processes object characteristics with respect to task requirements. Such a perspective on variable affordance has been recently supported by Yu et al. (2014), who also obtained instances of negative compatibility effects in the course of their investigation. With regard to the present study, an exogenous account of the Simon effect could explain the color location effects we observed in Exp.2, despite their irrelevance to the task. At the same time, an endogenous view of affordance could justify the apparent independence between the two effects, as well as the reversal of the orientation effect. Compared to the handles, the bodies of our stimuli contained much more information, useful in discerning vertical object orientation and completing the task. Therefore, it is plausible that the reversed orientation effect resulted from participants inhibiting an exogenous orientation of attention toward the handles, in favor of an endogenous shift toward the bodies, so as to fulfill the task requirements. However, it still remains unclear why inverse orientation effects are not more widespread in the literature, considering the sheer number of previous studies that have employed the same task along with a similar experimental design.

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