Combining motor and spatial affordance effects with the divided visual field paradigm

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Abstract

The affordance effect has been widely investigated employing various behavioral and brain-imaging techniques. Attempts to interpret the nature of the affordance effect led to two major views. Some researchers compare this kind of compatibility effect to the Simon effect, claiming abstract spatial association between the handle orientation of visually presented stimuli and the nearest response hand. Other authors advocate pure motor activation, during processing of visually presented tools without involvement of spatial information.
However, brain imaging studies seem to agree that no action can be computed in absence of spatial information. Taking the latter view into account, a divided visual field experiment was conducted, with the aim of crossing spatial and affordance correspondence effects. Overall, the results supported the view that motor and spatial information go hand in hand. Moreover, the data was in agreement with neuroimaging studies that show tool and affordance processing lateralization in the left hemisphere. The results are discussed in terms of neurophysiological data and brain mechanisms of perception and action.

Key words: Affordance, spatial correspondence, hemifield paradigm, RT.

Introduction

The affordance effect has been the center of a controversy for the past years. Behavioral data is interpreted either towards the theory that affordances activate specific motor programs in preparation of an action (Tucker & Ellis, 1998), or in support of shared abstract spatial codes between response position and visually salient object parts (Philips & Ward, 2002). Tucker and Ellis (1998) performed one of the first experiments whose results are taken in favor of the specific motor code theory. Subjects' responses were faster if the unattended-to orientation of the handle of the stimuli (household objects like pans) matched the response hand. Phillips and Ward (2002) observed similar correspondence effects between handle orientations and response button locations. However, these effects remained unchanged when participants responded with crossed hands or with their feet. This led Phillips and Ward (2002) to the conclusion that when action-affording stimuli are processed non-specific spatial codes are employed, enabling actions in any hand position or with any limb. Cho and Proctor (2010) varied handle salience and concluded that the affordance effect was simply due to higher visual salience. It acted as a within-stimulus Simon-like effect, which had nothing to do with grasping intentions or motor activation. Iani, Baroni, Pelicano & Nicoletti (2011)

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were the first to investigate the possible interaction between spatial and motor activation, and finding an affordance effect only when non-corresponding spatial codes were induced.

Thus, behavioral data on affordance seem to put spatial and motor activation athwart, attributing the affordance effect to either one or the other (Tucker and Ellis, 1998; Phillips and Ward, 2002; Cho and Proctor, 2010), and rarely allowing for a combination of both (Iani et al., 2011).

Brain-imaging studies of affordances (Buccino, Sato, Cattaneo, Rodá, Riggio, 2009; Proverbio, Adorni, D'Aniello, 2011) and tool-use (Grafton, Fadiga, Arbib & Rizzolatti, 1997; Chao & Martin, 2000; Creem-Regehr & Lee, 2005) do not endorse this distinction between motor and spatial activation, but find data in support of both. Activation of affordance and tool use processing was mostly found in the left hemisphere, in premotor and parietal areas (e.g., Buccino et al., 2009; Creem-Regehr & Lee, 2005). Much of these results were explained by the premotor theory of Rizzolatti, Riggio & Sheliga (1994), which integrates spatial and motor processing in the dorsal visual stream. In an attempt to reconcile the dispute between these views on affordance, we adapted the original Tucker and Ellis (1998) task to the divided visual field paradigm. This paradigm allows for non-invasive exploration of the processing difference between the two brain hemispheres. Moreover, the paradigm can be more sensitive to the differences between spatial and motor activation. The method may be less reliable than brain imaging, but it still offers differentiation between mere spatial proximity of response hand and stimulus site of presentation (spatial correspondence) and motor activation of affordances. This is possible because of the separate visual field presentation (a stimulus can appear in two locations and have two types of affordances, factors that do not always converge), and because of the motor control of each contralateral hemisphere over each hand. Based on the premotor theory of Rizzolatti et al. (1994) that spatial activation is needed for any motor program to be activated, we expected an interaction between the spatial and affordance correspondence factors. Also, in light of brain imaging studies of tool use and affordances, we expected a left hemispheric lateralization of both spatial and affordance correspondence.

Methods

Participants

Thirty-six right-handed students (12 male) participated in the experiment for partial course credit. The average age was 26 years (7.5 SD). All subjects had normal or corrected to normal vision.

Stimuli and Design

The stimuli were 18 black-and-white pictures from the Hemera Photo-Objects collection of various pans with handles protruding sideways. Each pan picture was rotated in two axes: once to provide an upside-down or proper view of the pan and once to provide a left or right orientation of the handle. Each stimulus appeared in each of the sixteen conditions: hand position of the participant (crossed/uncrossed), visual field of presentation of the stimulus (LVF/RVF), affordance correspondence between handle orientation and response hand (corresponding/non-corresponding), and spatial correspondence between VF and response location (corresponding/non-corresponding).

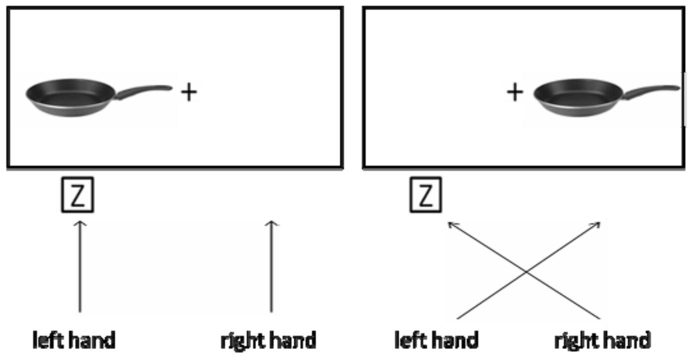


Figure 1. A sample stimulus in uncrossed hands LVF, affordance non-corresponding, spatial corresponding condition (left) and a sample stimulus in crossed hands RVF, affordance corresponding, spatial non-corresponding condition (right). In both conditions participants had to press button Z, on the left side of the keyboard.

Procedure

Each trial started with a 500 ms presentation of a fixation cross. The stimuli (inner edge) were shown 2.5 degrees left or right of the fixation cross (the picture's overall span was no more than 4 degrees) for 100 ms, and were then covered by a mask for 100 ms. After the mask disappeared participants had a 2000 ms response window to press the corresponding button (see Fig. 2 for timeline of the experiment). Participants had to decide whether the pan on the picture was presented in its proper orientation (right side-up) or was inverted (upside-down). Button position was counterbalanced so that each button corresponded equally often to proper and inverted orientation. Participants responded to the task at hand by pressing either with crossed or uncrossed hands, buttons Z and 1 (from the numeric pad) of a standard keyboard. Both speed and accuracy were emphasized with instructions. Subjects performed 32 practice trials before each condition. E-prime software (Schneider, Eschman, & Zuccolotto, 2002) controlled stimulus presentation and recorded response accuracy and time.

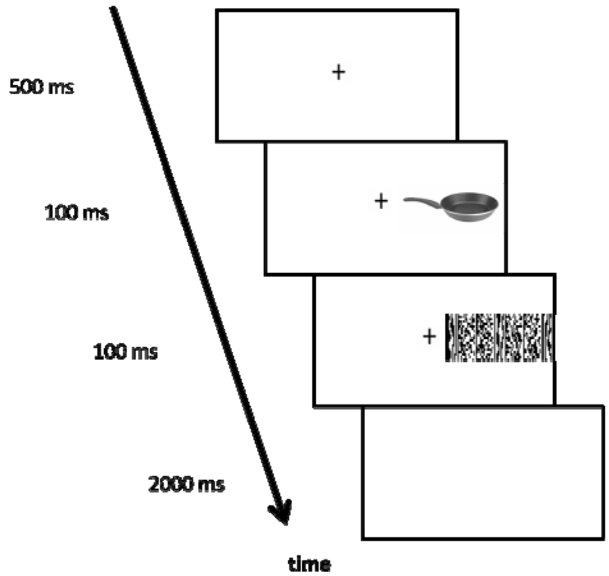


Figure 2. Timeline of the experiment.

Results and discussion

Filler trials (responses to inverted stimuli) were discarded from reaction time (RT) analyses, as well as erroneous trials (5.6%). Responses lying below or above 2 standard deviations (SD) per condition were excluded. A 2x2x2x2 repeated measures ANOVA on item means were performed (see Table 1 for means and SDs for each condition). The four factors were hand position (crossed or uncrossed), visual field of presentation of the stimuli (RVF/LVF), affordance correspondence (corresponding/non-corresponding), and spatial correspondence (corresponding/non-corresponding).

	Uncrossed hands				**Crossed hands**			
	LVF		**RVF**		**LVF**		**RVF**	
	Spatial C	**Spatial NC**	**Spatial C**	**Spatial NC**	**Spatial C**	**Spatial NC**	**Spatial C**	**Spatial NC**
Affordance C	431 (35)	442 (34)	388 (55)	461 (38)	449 (30)	559 (59)	479 (73)	481 (53)
Affordance NC	459 (50)	453 (44)	397 (54)	455 (61)	425 (40)	581 (59)	529 (93)	487 (42)

Table 1. Mean reaction times (standard deviations) per condition, ms. Item means. C denotes corresponding conditions, NC denotes non-corresponding conditions.

A significant effect of hand position ($F(1, 17)=213.93$, $p<0,001$; $\eta_p^2=0.93$) was obtained. Subjects responded faster with their hands uncrossed than crossed, probably due to the awkward hand position. There was a 12 ms effect of affordance correspondence ($F(1, 17)=4.48$, $p<0,05$; $\eta_p^2=0.21$). This effect was better interpreted in light of later interactions with spatial correspondence. A 45 ms effect of spatial correspondence was observed ($F(1, 17)=71.13$, $p<0,001$; $\eta_p^2=0.81$). The effect, in accordance with the literature, was much larger than the affordance correspondence effect (e.g., Iani et al., 2011). Again, interpretation of spatial correspondence was more informative when later interactions were looked upon.

The interaction between hand position and spatial correspondence was marginally significant ($F(1, 17)=4$, $p=0,06$; $\eta_p^2=0.19$). A significant interaction between visual field of presentation and spatial correspondence ($F(1, 17)=13.49$, $p<0.01$; $\eta_p^2=0.44$) showed a spatial correspondence effect only in the LVF. This can be interpreted as a right hemispheric specialization in spatial correspondence.

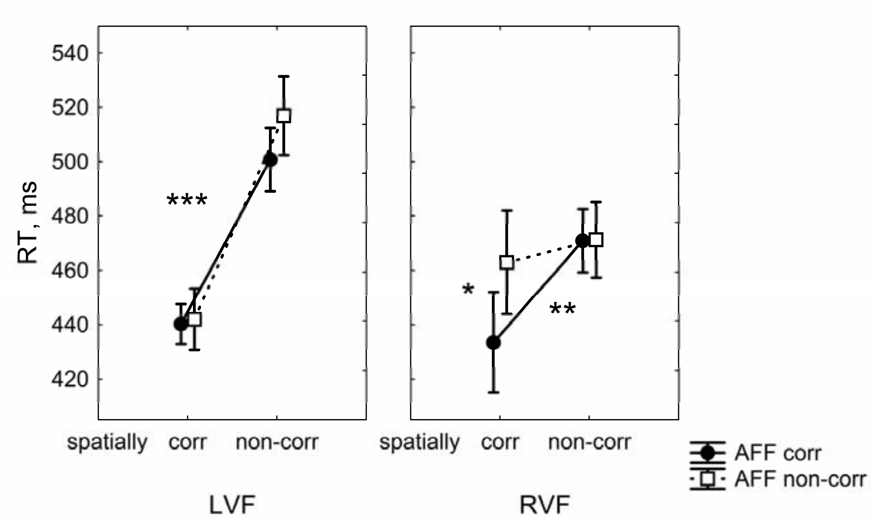
The three way affordance correspondence by visual field of presentation by hand position interaction ($F(1, 17)=8.32$, $p<0,05$; $\eta_p^2=0.33$) showed affordance correspondence effects in the RVF when participants responded with their hands crossed, as well as in the LVF when participants responded with their hands uncrossed (cf. Table 1).

Another significant three-way interaction between spatial correspondence, visual field of presentation, and hand position ($F(1, 17)=8.58$, $p<0,01$; $\eta_p^2=0.34$) was revealed. There were spatial correspondence effects in uncrossed hands RVF condition, as well as in crossed hands LVF condition (cf. Table 1).

Finally, a significant three-way interaction between visual field of presentation, affordance correspondence, and spatial correspondence was obtained ($F(1, 17)=6.85$, $p<0,05$; $\eta_p^2=0.29$). When stimuli were presented to the LVF, no affordance correspondence effect was present, but there was a strong spatial correspondence effect (Fig. 3). When stimuli were presented to the RVF, an affordance correspondence effect was obtained only for spatially corresponding stimuli.

All other interactions failed to reach the significance level ($p_s>.1$)

Figure 3. VF by spatial correspondence by motor correspondence interaction. Vertical bars denote standard errors. *Note*. AFF -- affordance; corr/non-corr -- corresponding/non-corresponding; *** -- $p<.001$; ** -- $p<.01$; * -- $p<.05$



The three-way interaction allowed for the most comprehensive differentiation between the spatial and motor processes at play. These data supported Iani et al. (2011) in their conclusion that the affordance and spatial correspondence effects modified each other, however, they seemed to do so in an opposite way. Iani et al. (2011) obtain affordance correspondence results in Simon (spatial) non-corresponding conditions. The current results are also in concord with Rizzolatti et al. (1994) premotor theory, which claims that spatial relations information and motor affordance information need to be processed together for an individual to be efficient in their environment.

No support of Phillips & Ward (2002) or Cho & Proctor (2010; 2011) was found in that there is lack of motor activation during the processing of affordances. This did not mean that the data "spoke in favor of" Tucker and Ellis (1998), either. Rather, the results showed a complex interplay between spatial and affordance correspondence, modulated by visual field, much like what would have been predicted by Rizzolatti et al. (1994).

The results diverge from Iani et al.'s (2011) findings that the affordance effect was present only in the spatially non-corresponding condition. Other than that, the current experiment, somewhat similarly to Iani et al. (2011) did find a more robust spatial correspondence effect, compared to affordance correspondence.

Conclusion

Using the divided visual field paradigm in the present study, we had the opportunity to pull apart all the different influencing factors (spatial and motor) on the ever-disputed affordance effect.

The experiment provided data that there really was no need to support one way of visual processing and deny the other. Rather, it seemed that the left hemisphere used both kinds of information in the visual processing of graspable objects which was in accord with the premotor theory (Rizzolatti et al., 1994). Further, the divided visual field paradigm provided results that were not obtained in previous studies with crossed hands conditions (Phillips & Ward, 2002; Symes et al., 2005), namely, the affordance effect. Participants processed corresponding affordances faster even when the presented stimulus was not in the VF right next to their hand.

The results of the experiment showed a strong spatial correspondence effect in the right hemisphere for both affordance correspondence conditions, in accord with most literature about hemispheric differences (Jeannerod & Jacob, 2005; Kosslyn, 2010). Moreover, the spatial correspondence effect in the left hemisphere was modified by affordance correspondence, so that there were matching correspondence effects. It can be even further speculated that spatial correspondence activated dorsal streams bilaterally (Jeannerod & Jacob, 2005; Kosslyn, 2010) whereas motor correspondence was calculated only in the dorsal stream of the left hemisphere.

In a nutshell, the divided visual field paradigm proved to be extremely fruitful in the explorations of the affordance and spatial correspondence effects, providing a comparatively easy way to investigate already established neuroimaging and neurophysiological results in light of RT.

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