The Lego hands: changing the affording location of graspable objects

Da Silva Fabrice (fabrice.da-silva@univ-montp3.fr) & Brunel Lionel (lionel.brunel@univ-montp3.fr)
Epsylon Laboratory, Paul Valéry University, Montpellier, 34190, France

Abstract

The present study examined throughout three experiments the nature of stimulus-response compatibility (SRC) effects related to affordance perception in situations wherein object affordances and response effectors are irrelevant to each other. In the first experiment, using a foot-press response dispositive, we found a SRC effect between the orientation of the graspable part of the presented object and the laterality of the response. In Experiment 2a, we showed that constraining the subject hands in a given position (i.e., a Lego hand shape) during the same task interfered with the SRC effect. In Experiment 2b, participants performed a short training phase with their hands constrained before performing the experiment. This resulted in an inversion of the direction of the SRC effect previously observed. We discuss these results and provide arguments in favor of a specific motor activation account.

Keywords: Visual Perception; affordances; categorization; motor constraints

Introduction

In stimulus-response compatibility (SRC) paradigms related to affordance perception (see Michaels, 1988), participants are usually faster and more accurate to categorize stimuli when the response hand and the presented objects are located on the same side (i.e., compatible) rather than on the lateral opposite side (i.e., incompatible). The present study aimed at disentangling between two alternatives explanations of this specific SRC effect.

The affordances

Stimulus-response compatibility paradigms were first designed to highlight affordance effects. These affordances were defined as what a given environment offers the animal, what it provides or furnishes in terms of action possibilities (Gibson, 1979). These action possibilities are properties of the subject-environment system and emerge from the relation between an object and a subject (Stoffregen, 2003). For instance, stairs can afford an action of climbing only when their size does not exceed a certain proportion of the riser leg height (Warren, 1984). In SRC paradigms, participants generally performe a perceptual categorization task using a specific motor response. The critical manipulation is the compatibility (or congruence) between the motor response setting and the perceptual configuration of this object. For instance, Tucker and Ellis (1998) showed that participants were faster and more accurate to categorize the orientation (i.e., upright or downright) of daily life graspable objects when object handles and motor responses referred to the same side (i.e., compatible) than when they referred to the opposite side (i.e., incompatible). These results were interpreted as evidences of the affordance effects. This interpretation was further supported by electrophysiological recording such as analyses of lateralized readiness potentials (LRP) during categorical judgments (Goslin, Dixon, Fischer, Cangelosi, & Ellis, 2012), or studies about the link between the affordance perception and the dorsal stream activation through transcranial mental stimulations (Buccino, Sato, Cattaneo, Rodà & Riggio, 2009).

Specific motor activation versus abstract space coding

Despite the multiplication of experimental works concerning affordance perception for about twenty years, the nature of affordance-related SRC effects is still debated. For Tucker and Ellis (1998), SRC effects were observed because interactions with an object involve a representation about the range of actions that we can perform with and thereby, potentiate them. The nature of these representations was discussed in later works by the same authors including through micro-affordances (e.g. Tucker & Ellis, 2001). However, other authors provided evidences that an alternative explanation of SRC effects might be considered. (Anderson, Yamagishi, & Karavia, 2002). These authors interpreted such effects as a consequence of an attentional bias induced by a stimuli perceptual asymmetry (i.e., attention might be oriented to the left or the right depending on the perceptual configuration of the stimulus). This attentional orientation could be responsible for spatial-related motor activations without requiring the potentiation of action-related properties of an object. This hypothesis is also in line with location-coding theories (e.g., Cho & Proctor, 2011). In order to disentangle between specific motor activations and abstract location coding as mechanisms responsible for affordance related SRC effects, Phillips and Ward (2002) developed a method wherein a prime graspable object and the orientation of its handle were irrelevant to the participants' task. In this study, the handle of the priming object was oriented to the left or to the right side. Furthermore, the object handle was presented with an apparent depth towards or away from the participant. Participants had to respond to a target that appeared in the center of a computer screen. Authors found a main effect of the handle orientation congruent with common SRC studies but no significant effects involving its apparent depth. Nevertheless, this result could be attributed to methodological issues. Indeed, such proximity-related effects have been reported since (see Fischer & Dahl, 2007). A more interesting point is that Phillips and Ward (2002) proposed another experiment in which participants had to respond to the same task pressing using foot switches with their left or their right foot. Like in the first experiment, authors found a significant main effect of correspondence. Therefore, participants were faster to categorize stimuli when both the foot and the handle of the object were localized on the same side. The authors concluded that response facilitation effects arise from an abstract location coding.

However, if observing SRC effects with feet during the presentation of graspable objects seem to be inconsistent with the motor specific activations account, this is not sufficient to reject it. Indeed, grasping an object does not imply a single hand gesture but a more global engagement of the body. It is unclear in what extend the body is engaged during the perception of graspable objects and further investigations are necessary to question the implications of such generalized activations. Therefore, finding SRC effects while the response effector (i.e., the foot) and the action associated with the presented object (i.e., hand use) are seemly not directly related is not sufficient to conclude that no specific motor activations occurred.

The current study

In the present study, we aimed at showing that motor activations could constitute the core mechanism of SRC effects. For this purpose, we conducted three experiments in which subjects had to categorize a common graspable object with foot-press responses. The experimental design was similar to the one used by Tucker and Ellis (1998) and consisted in a classical SRC paradigm. In the three experiments, participants had to categorize with their feet the orientation (i.e., upright or inverted) of a common mug displayed on a computer screen. In the first experiment, they responded while keeping their hands placed on the table in front of them. In the second experiment, participants were wearing gloves during the task, constraining their hands in an opened position (i.e., such as the Lego hand shape). Finally, in a third experiment, a last group responded while wearing the same gloves but after performing a short training phase.

Experiment 1

The aim of this experiment was to replicate the SRC effects observed in Tucker and Ellis (1998) tasks using Phillips and Ward (2002) response setting.

Method

Participants Twenty undergraduates students (17 women) from Paul Valéry Montpellier University aged from 18 to 36 years old (M = 23.1, SD = 4.72) took part to this experiment and received course credits. All had normal or corrected to normal vision and were naïve to the purpose of the study. The experiment was realized in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Apparatus and materials The experiment was performed using E-Prime 2 software (Schneider, Eschman, & Zuccolotto, 2002). The visual material consisted of pictures of a common mug disposed sideway on a white background and centered on the display. The mug dimensions were 340 x 320 pixels. All pictures were realized using the software Maya 16.0 (Palamar, 2014). The orientation of the initial picture was manipulated to produce two horizontal and two vertical orientations of the mug. Additionally, a second filler picture was presented in order to increase the difficulty of the task. The two stimuli are depicted in Figure 1.

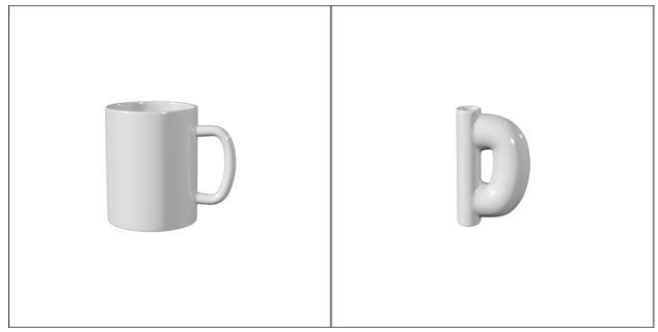

Figure 1: The two visual stimuli used in all our experiments (in one orientation condition). The right panel object acted as a filler object.

As with the realistic mug, we reoriented the original picture of the filler object to produce four final pictures. The depicted objects were presented with an apparent size similar to their real size which is about 11 cm high and 7.5 cm wide and the participants performed the task at a distance of 45 cm from the screen and a visual angle of about 15°. All results associated with the filler object were not included into the analyses. Each of the eight pictures was presented ten times in the experiment so that a participant responded to an overall of 80 trials presented randomly. Trials wherein the object was presented with its handle oriented on the same side that the response effector were considered as compatible and incompatible when it was the reverse situation.

Procedure After filling out a consent form, participants sat in front of a computer and were asked to rest their hands on the table in front of them and their foots above the pedals. Then, they were asked to perform a forced choice categorization task on a computer by pressing a left or a right switch of a pedalboard. They had to determine as fast as possible if the displayed objects were disposed upright or inverted. Each pedal was attributed to a response category. This attribution was counterbalanced for the half of the sample. Each picture was displayed until the response and preceded by a fixation point which remained on the screen during 200 milliseconds.

Results

First, we observed that participants have accurately performed the categorization task (less than 5% of error rate). Thus, we only considered latencies for analysis. We excluded RTs above 1250 milliseconds (This cut-off led to the exclusion of 11.37% of trials). Thus, We performed a RT analysis between Compatible and Incompatible situations for responses exclusively related to the realistic mug pictures. Mean response times for the Compatible situations (M = 713 ms, SD = 76.77 ms) were faster than mean response times for the Incompatible situations (M = 750 ms, SD = 93 ms). Using a bilateral paired t-test, we found that this difference was significant, $t(19) = 2.55$, $p < .05$, $d = .43$.

Discussion

The results clearly demonstrated a SRC effect. Indeed the participants were faster to categorize objects when their graspable part was oriented on the same side as the response effector rather than the opposite side. With the same pattern of results, Phillips and Ward (2002) concluded that such facilitation effects had to be consecutive to an attentional shift and could not be associated with premotor activations. This conclusion is congruent with the fact that the graspable part of objects like the mug we used constitutes a visual protrusion that could capture the subject attention. Furthermore, a foot-press response seems to be not related to the perception of the affordance of the mug. However, to conclude that facilitation effects emerging from unsuited limb responses are not related to specific motor activations, this experimental design is insufficient. Indeed, contrary to the experimental context, the tool use in daily life implies a more global generation of movements and might involve that perception of graspable objects potentiate a higher range of muscles that the hand or even the arm. If the affordance theory is unclear to specify such implications, it is necessary to control the hand disposition during this kind of tasks for rejecting this motor hypothesis. If such of a hand constraint results in an alteration of facilitation effects as those observed in the experiment 1, this would constitute evidence that such response facilitations are dependent on the subject action possibilities.

Experiment 2a

In this experiment, we aimed at constraining subject hands to a certain position which is incompatible with the usual grasp of the object used in Experiment 1. The gloves used in this experiment were conceived to induce a large grasping position incompatible with the handle of the mug. If SRC effects such as the ones revealed by Tucker and Ellis (1998, 2001) or Phillips and Ward (2002) arise well from an abstract representational coding, this manipulation should not impact the effect. On the contrary, if the previous effect is a consequence of perceived affordances traduced by more general potentiations, wearing gloves inducing a particular grasp should invert the stimulus-response compatibility effect in the direction of the tank of the mug. This is precisely our hypothesis: considering that a large hand position is fitter with the manipulation of the tank of the mug and not anymore with its handle, the effects will be inverted regarding Experiment 1 and the incompatible situation should be facilitating for the subjects.

Method

Participants Twenty undergraduate students (19 women) from Paul Valéry Montpellier University aged from 18 to 41 years old (M = 22.45, SD = 6.15) took part to this experiment and received course credits. All had normal or corrected to normal vision and were naïve to the purpose of the study. Among them, four left-handed were distributed into the two groups.

Apparatus and Materials The experimental setup and the materials remained the same as Experiment 1. The only change in the experimental design was that participants had this time to wear specific gloves. We constructed these gloves with Plaster bands in such a way that the participant's hands adopt the form of a large grasping position (i.e., a necessary position to grasp a mug by its tank).

Procedure The instructions were the same as Experiment 1. Nevertheless, participants were asked to wear the gloves and to place their hands on the table in front of them before beginning the experiment. Their hands were placed shoulder-width apart and with palms facing inward. Once the participants felt comfortable with the gloves and the pedalboard, they could begin the experiment.

Results

Response errors accounted for 4.62% of the total of trials. There were no significant differences between error rates in compatible and incompatible situations. As in experiment 1, all response times exceeding 1250 milliseconds were removed from the analysis. Theses exclusions represented 17% of trials. The response time analysis between Compatible and Incompatible situations showed not statistically significant differences ($p > .05$).

Discussion

Apart from the fact that participants were wearing constraining gloves inducing a large grasp shape during the task, the second experiment was identical to experiment 1. This single difference has seemly altered the results in the way that there was no significant SRC effect anymore. However, contrary to our hypothesis, the hand constraint did not reverse the result's pattern but seemed to have interfered with the previous effect. This interference could represent an argument which is not in favor of the abstract coding. Indeed, if facilitation effects arise from an abstract spatial coding, there is no rational that a change applied to subject hands during foot-press responses impacts the facilitation effect. Nevertheless, this null result cannot be fully interpreted as it stands and there is a doubt as to whether the gloves acted on subjects. While the purpose of the gloves was to potentiate a large grasping position and thus promote a facilitation effect directed toward the location of the mug tank, they may have been perceived by the subjects as a simple immobilization.

Experiment 2b

Experiment 2a showed that a constraint applied to subject hands during a categorization task with foot-press responses seems to have significantly altered the facilitation effect previously observed in Experiment 1. It is unclear that this was due to a simple interference or to a conflict between a specific motor activation of the feet on one side and of another activation of hands on the other side. This could stem for an insufficient subject integration of the gloves possibilities. Indeed, in Experiment 2a, no rationales about the glove shaped were given to participants. Thus, in the present experiment, we proposed to new participants to perform a five minutes training in which they had to move a real mug along several drawn points on a sheet while wearing the gloves. The purpose of this training was to strengthen the potential disposition to grasp the mug tank with hands during the task. Our hypothesis is that a better integration of the grasping possibility of the gloves will produce a facilitation effect in favor of the side of the mug tank and thus, will facilitate incompatible responses regarding the handle location.

Method

Participants A new sample of twenty undergraduate students (12 women) from Paul Valéry Montpellier University aged from 17 to 29 years old (*M* = 21.5, *SD* = 4.32) took part to this experiment and received course credits. All had normal or corrected to normal vision and were naïve to the purpose of the study. Among them, two left-handed were distributed into the two groups.

Apparatus and materials The experiment itself remained unchanged. The participants were preforming the same task while wearing the same gloves that in Experiment 2a. The difference was that they had to perform a training phase during which they had to move a real mug (with the same appearance that the one modelised for the experiment) on a sheet plotted course. The plotted course consisted in nine drawn circles. These circles were numbered from 1 to 9. To ensure that participants remain focused during this phase, the mug was filled with water.

Procedure To perform the training phase, participants manipulated the mug while wearing the gloves (see Figure 2). They were told to move the filled mug circles by circles in the ascending and then in the descending order on the sheet with the left hand and after that, with the right hand. They had to put down the mug on each circle before moving on the next one. This course was repeated two times. Regarding the shape of the gloves, the participants were obliged to grasp the mug by its tank. No instructions were given concerning the better way to grasp the mug in this situation. The participants spontaneously grasped it by the tank and performed the training without dropping the mug. After this training phase, they performed the same categorization task than the one proposed in the two previous experiments.

Figure 2: Plotted course for the training phase

Results

Response errors accounted for 6.25% of the total of trials. There were no significant differences between error rates in compatible and incompatible situations. Response times exceeding 1250 milliseconds were excluded and represented also 6.25% of trials. Regarding the compatibility between response feet and handle locations, mean responses for the Incompatible situations (*M* = 686 ms.14, *SD* = 111.44 ms) were faster than mean responses for the Compatible situations (*M* = 713.66 ms, *SD* = 126.76 ms). A dependent t test revealed that the difference was statistically significant, $t(19) = 2.64$, $p < .02$, $d = .23$. This pattern was therefore the reverse than the one observed in Experiment 1 (see Table 1).

Table 1: Summary of the chronometric results in milliseconds (with the standard deviations in parentheses) and associated p-values for the three experiments

	Compatible	Incompatible	*p*
Experiment 1	713 (76.77)	749.96 (93)	.02
Experiment 2a	766.41 (105.80)	786.73 (127.22)	n.s.
Experiment 2b	713.66 (126.76)	686.14 (111.44)	.01

Complementary analysis We calculated the mean effect size differences between Compatible and Incompatible situations by subtracting the mean response times related to the Incompatible situation from the ones related to the Compatible situation for each subject and for each experiment. This allowed us to produce a value for each subject (i.e. positive if he was faster to respond in Compatible situations and negative if he was slower) and the size of this difference (see Figure 3). Regrouping those values for each experimental condition, we conducted a one-way between subjects ANOVA to compare the effect of

Experiments 1, 2a and 2b on mean effect size differences. There was a significant effect of the Experimental Conditions on subject Response times for the three conditions, $F(2, 57) = 7.42$, $p < .002$, $\eta^2_p = .21$.

Post hoc comparisons using the Tukey HSD test indicated that the mean effect size for the Experiment 1 condition ($M = 36.93$, $SD = 64.62$) was significantly different than the one of the Experiment 2b condition ($M = -27.51$, $SD = 46.54$). The test indicated too that the mean effect size of the Experiment 2a condition ($M = 20.32$, $SD = 52.07$) was significantly different than the one of the Experiment 2b condition. However, the mean effect size of the Experiment 1 condition did not significantly differ from the one of the Experiment 2a.

Finally, considering that in the three experiments, our samples were quite inhomogeneous with respect to age, we performed the same analysis while excluding subjects older than 30 years. The results stayed unchanged.

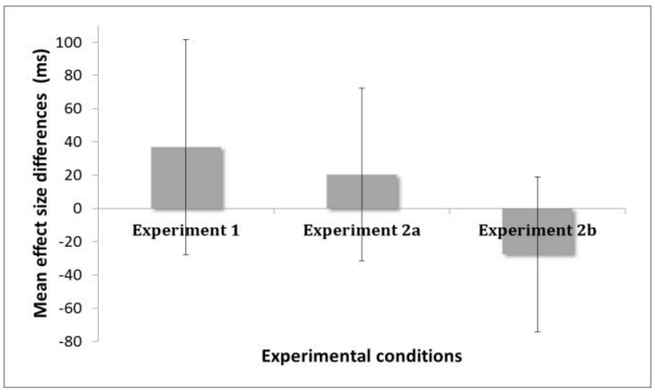

Figure 3: Mean effect size differences (in milliseconds) as a function of the experimental conditions. Errors bars depict standard deviations.

General Discussion

In Experiment 2b, subjects manipulated a real mug with constraining gloves before performing the categorization task. The only way to proceed was to grasp the mug by its tank and not by its handle which is in accordance with the purpose of the shape applied to the gloves. Results showed that a facilitation effect emerged from the incompatible situation regarding the classic stimulus-response compatibility paradigms. Thus, the training seems to have strengthened a potential reach to grasp gesture oriented to the mug tank and facilitated subsequent categorizations in situations wherein the responses and the mug tank were on the same side.

Taken together, the results suggest that facilitation effects observed in stimulus-response compatibility paradigms could well arise from specific motor activations instead of abstract coding like Philipps and Ward (2002) suggested it. Indeed, if the results observed in Experiment 1 were due to a representational abstract coding, no differences would be found applying a hand constraint during foot-press responses. Yet, in experiment 2a, the effect was still in the right direction but this time, it was not significant suggesting an interference in the subject disposition to respond. Furthermore, a real manipulation of a mug with a specific constraint inverted the location of the effect in Experiment 2b. This implies that the manipulation seems to have led to a sensorimotor integration changing the location of the potentiating part of the object. This result is also particularly interesting because it seems that no rationales can be found in the attentional shift hypothesis. Indeed, in all of our experiments, the stimulus stayed unchanged and hence, the perceptual asymmetry cannot be taken as the origin of these results.

Nevertheless, an alternative explanation could be as well proposed. Indeed, due to the manipulation phase, participants may have learnt to pay attention to the tank of the mug which could conduct to an attentional shift in the direction of this one. For further investigations, it would be interesting to expound on this by proposing a new experiment in which participants would realize the training but then, take off the gloves for the SRC experiment. This design should allow knowing if the results of the Experiment 2a and 2b are due to the wearing of the gloves or by sensorimotor integrations.

Regarding this possibility and considering that only a short training impacted the SRC effect directions. It is nevertheless possible that such attention-related effects be rooted in a sensorimotor process. For instance, a possible explanation could emerge if we replace our results within the framework of the premotor theory of attention (see Craighero, Fadiga, Rizzolatti & Umiltà, 1999). According to this theory, orienting of attention implies an activation of basic circuits associated with the action goal. Therefore, the results of the Experiments 2a and 2b could arise from an attentional effect determined by the motor preparation induced by the training phase. This interpretation is in phase with both the specific motor activation account and the general ecological approach to perception. In this context, attentional shifts could be consecutive to premotor activations and be constitutive parts of the action-perception coupling.

In conclusion, the present study represents a further argument in favor of specific motor activations during perception of graspable objects. Nevertheless, it carries also some questions about its results and further works will be necessary to investigate such SRC modulation effects. More broadly, it underscores some imprecisions about the original propositions made by Gibson (1979). For instance, how a specific affordance can be perceived instead of another and how much the physical disposition to act in a given time impacts the subject's tendency to perceive them.

Acknowledgments

Authors want to thank Jean-François Loisel for his help to design the visual stimuli used in this study.

References

Anderson, S. J., Yamagishi, N., & Karavia, V. (2002). Attentional processes link perception and action. *Proceedings. Biological Sciences / The Royal Society*, *269*(1497), 1225–32.

Buccino, G., Sato, M., Cattaneo, L., Rodà, F., & Riggio, L. (2009). Broken affordances, broken objects: A TMS study. *Neuropsychologia*, *47*(14), 3074–3078.

Cho, D. T., & Proctor, R. W. (2011). Correspondence effects for objects with opposing left and right protrusions. *Journal of Experimental Psychology. Human Perception and Performance*, *37*(3), 737–49.

Craighero, L., Fadiga, L., Rizzolatti, G., &Umiltá, C. (1999). Action for perception: A motor-visual attentional effect.*Journal of Experimental Psychology: Human Perception & Performance*,25, 1673–1692.

Fischer, M. H., & Dahl, C. D. (2007). The time course of visuo-motor affordances. *Experimental Brain Research. Experimentelle Hirnforschung. Expérimentation Cérébrale*, *176*(3), 519–24.

Gibson, J.J. (1979). *The ecological approach to visual perception*. Boston: Houghton Mifflin.

Goslin, J., Dixon, T., Fischer, M. H., Cangelosi, A., & Ellis, R. (2012). Electrophysiological examination of embodiment in vision and action. *Psychological Science*, *23*(2), 152–7.

Michaels, C. (1988). SR compatibility between response position and destination of apparent motion: evidence of the detection of affordances. *Journal of Experimental Psychology: Human Perception and Performance*, *14*(2), 231–40

Palamar, T. (2014). *Mastering Autodesk Maya 2015 : Autodesk Official Press*. Indianapolis, Indiana: John Wiley & Sons, Inc.

Phillips, J. C., & Ward, R. (2002). S-R correspondence effects of irrelevant visual affordance: Time course and specificity of response activation. *Visual Cognition*, *9*(4–5), 540–558.

Stoffregen, T. A. (2003). Affordances as properties of the animal – environment system. *Ecological Psychology*.

Tucker, M., & Ellis, R. (1998). On the relations between seen objects and components of potential actions. *Journal of Experimental Psychology. Human Perception and Performance*, *24*(3), 830–46.

Tucker, M., & Ellis, R. (2001). The potentiation of grasp types during visual object categorization. *Visual Cognition*, *8*(6), 769–800.

Warren, W. H. (1984). Perceiving affordances: visual guidance of stair climbing. *Journal of Experimental Psychology. Human Perception and Performance*, *10*(5), 683–703.