Visual and linguistic cues to graspable objects.

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Abstract

Two experiments investigated (1) how activation of manual affordances is triggered by visual and linguistic cues to manipulable objects and (2) whether graspable object parts play a special role in this process. Participants pressed a key to categorize manipulable target objects co-presented with manipulable distractor objects on a computer screen. Three factors were varied in Experiment 1: (1) the target's and (2) the distractor's handles' orientation congruency with the lateral manual response and (3) the visual focus on one of the objects. In Experiment 2, a linguistic cue factor was added to these three factors – participants heard the name of one of the two objects prior to the target display onset.

Analysis of participants' motor and oculomotor behaviour confirmed that perceptual and linguistic cues potentiated activation of grasp affordances. Both target- and distractor-related affordance effects were modulated by the presence of visual and linguistic cues. However, a differential visual-attention mechanism subserved activation of compatibility effects associated with target and distractor objects. We also registered an independent implicit attention attraction effect from objects' handles suggesting that graspable parts automatically attract attention during object viewing. This effect was further amplified by visual but not linguistic cues, thus providing initial evidence for a recent hypothesis about differential roles of visual and linguistic information in potentiating stable and variable affordances (Borghi, 2012).
218 words.

Key words: grasp affordances, naming, visual attention, object categorization.

Visual and Linguistic Cues to Manual Grasp Affordances

Interacting with natural and man-made objects is an everyday routine task. Consider the following example. Your friend asks you to pass a cup that is on the table in front of you. After hearing the word "*cup",* you need to visually locate it, reach for it, seize it by its body or handle, pass it to your friend, and, finally, release the grip. This is a simple and effortless task; yet it requires well-orchestrated contributions from different perceptual, linguistic, and motor circuits of the brain that control the performance of the corresponding sensors and effectors. According to *vision-for-action* (e.g., Goodale, 2011, for a recent review) or *mental simulation* (e.g., Barsalou, 2008) theories, we are extremely efficient in these routine tasks because simply hearing a word related to a graspable object or seeing the object itself, even without an intent to use it, activates sensorimotor areas of the brain associated with the actual potential object manipulation (Martin, 2007). The specific focus of this paper is on *grasp affordances* – the object's features associated with how we typically interact with graspable objects, for example, *the cup* in our previous example (Gibson, 1979; Michaels, 1989; 1993).

Thill et al. (2013) provide a comprehensive review of the empirical evidence for the existence of affordance effects as well as a thorough discussion of the corresponding computational models. Hence, here we only review those findings most relevant to our experimental goals. Experimental findings documenting *stimulus-response compatibility effects* (Tucker and Ellis, 1998, 2001; Ellis and Tucker, 2000; Ellis, Tucker, Symes, and Vainio, 2007; Fischer and Dahl, 2007) provide good empirical support for the idea that simply perceiving a graspable object activates associated grasp affordances. For example, Tucker and Ellis (1998) demonstrated that when classifying with button-pressing responses whether a graspable object was upside or not, responses were easier (faster and more accurate) when the responding hand corresponded to the hand that would be optimal for grasping the depicted object. In contrast, when having to ignore an object in order to respond to the properties of another target object, responses were slower and less accurate when the optimal grasp associated with the ignored object was the same as that required as the response to the target (Ellis et al., 2007). These and similar findings suggest that perceptual representations of graspable objects encode the corresponding manual actions associated with it and that ignoring an object entails inhibiting these actions.

Linguistic information about a graspable object (e.g., objects' names and action related nouns) also has consequences for affordance processing, both by acting as top-down cues attracting attention to the named objects and by potentiating associated affordance components via the link between lexical and motor representational components. For example, Klatzky and colleagues (1989) showed that preparing for a grasp may influence understanding of the words associated with similarly grasped objects, and hearing grasp-related words may facilitate visual processing of graspable objects. In particular, they verbally instructed participants to adopt a hand shape (e.g., *pinch* or *clench*). Once participants adopted the hand shape, they had to decide whether a particular action description (e.g., *eat a carrot*) was sensible or not. Adopting hand shapes that were congruent with the object referred to in the action description facilitated these sensibility decisions. This finding was confirmed and extended in more recent studies. Tucker and Ellis (2004) demonstrated that showing a graspable object's name produced a congruency effect on manual responses similar to the one commonly registered in visual object categorization studies. Similar effects were reported in Bub, Masson, and Cree (2008) for both functional (grasping) and volumetric (lifting) actions (see also Lindemann et al., 2006). Interestingly, while elicitation of affordance effects from observing objects may be bound by the limits of reachable space, objects' names can act as activation cues to stimulus-response compatibility effects for objects within and outside of reachable space (Ferri et al., 2011). Furthermore, studies by Masson, Bub, and Newton-Taylor (2008), Masson, Bub, and Warren (2008), and Bub and Masson (2010) found that the linguistic elicitation of affordances is not limited to single-word processing. In their studies, functional gestures were produced faster after participants had read or listened to *sentences* referring to objects that afford similar grasps.

Affordance effects can be triggered not only by nouns but by verbs as well. A series of recent reports using a variant of the sentence-picture verification task showed that functional (*grasp*) and manipulation (*drink*) verbs related to graspable objects give rise to affordance effects in a fashion similar to nouns (Ambrosini et al., 2012; Borghi and Riggio, 2009; Constantini et al., 2011). In a typical setup, (Borghi and Riggio, 2009), participants first read imperative sentences (e.g., *"Verb" at the nail.*) with the verbs functionally related (e.g., *grasp*) or unrelated (e.g., *look*) to the object's affordance. In half of the trials, the noun in the sentence was the name of the target visual object displayed afterwards; in the other half, it was a different object. The objects themselves were either power- or precision-grip affording. Participants' task was to decide whether the object mentioned in the prime sentence was the same as the one they saw afterwards. Decision times were faster when the verbs in prime sentences were functional than when they were unrelated. Therefore, the verbs' functional semantics elicited an affordance effect similar to the effect of the objects' names that was documented in earlier studies. Put together, the studies reviewed thus far demonstrate that both seeing a graspable object and hearing its name or a verb related to manipulating the object leads to sensorimotor simulation of the associated grasp affordances.

As we noted above, typical manipulations with graspable objects seem to be highly automatic and effortless. Nevertheless, one important general question is how elicitation of affordance effects is related to attentional control. This question, in fact, has two independent components. One more specific question is whether attentional focus on a graspable object can modulate the corresponding affordance effect? The other question comes from the mere importance of common manipulable objects in every-day life (cups, handles, etc.) and the relative frequency of using them. This special role of manipulable objects may result in a specific increase in their own ability to automatically attract attention among other, equally salient but non-manipulable objects. Furthermore, grasp-related parts of manipulable objects may act as the specific object features that attract preferential attention. In part, these two questions motivate the current study.

The evidence about the role of attention in potentiating affordance effects is mixed. First of all, a seminal study by Hommel (1993) convincingly showed that the Simon effect, the ancestor of orientation affordance effects does not depend on the kind of attentional operations presumably performed to focus onto the stimulus. Similarly, a number of later *behavioural* studies indeed found that, regardless of whether the whole object or any of its parts is currently in the viewer's attentional focus, affordance effects are automatically evoked (e.g., Pappas and Mack, 2008; Phillips and Ward, 2002; Riggio et al., 2008; Vainio, Ellis and Tucker, 2007). Pappas and Mack (2008), for example, found that the affordance effect can be triggered outside of the viewer's conscious perception by co-present but undetected objects with similar affordances. Furthermore, Philips and Ward (2002) demonstrated that the graspable object's orientation facilitates corresponding hand responses in situations when the object itself is totally irrelevant to the task. Finally, Derbyshire et al. (2006) demonstrated the presence of affordance effects after an object was removed from the observer's view. Based on this evidence, one might conclude that object-directed attention is not a prerequisite for the emergence of the affordance effects.

Other reports suggest that affordance effects may be subject to attentional modulation. First, neurophysiological studies clearly demonstrated (1) the reduction in attentional ERP component related to attentional facilitation (Handy et al 2003) and (2) enhanced activation of attention-related areas for tools co-presented with non-tools (Handy et al 2005). Also, a study by di Pelegrino, Rafal, and Tipper (2005) showed that even in situations when the conscious access to this visual information is impaired, action-related information extracted by the visual system is modulated by object affordances via attentional selection and enhancing the competitive strength of manipulable object representation. Second, a number of behavioural studies provide both direct and indirect evidence for the reciprocal influence between attention and motor affordances. For example, Anderson, Yamagishi, and Karavia (2002) showed that affordance effects can be attributed to the attentional shift induced by perceiving asymmetrical targets. They presented participants with both affording and nonaffording objects (i.e., with or without handles) in their canonical (horizontal) and noncanonical (slightly tilted clock-wise or counter-clockwise) orientation. Participants judged the direction of orientation change by making left-hand or right-hand responses. Importantly, the pattern of results did not differ for affording and nonaffording objects, indicating that the object's salient feature but not the orientation of its graspable part was responsible for the facilitation of the lateralized response implicating a special role of *bottom-up* attention plays in potentiating affordance effects. Also in conflict with the notion of strictly automatic activation of affordances, attention to the semantic properties (e.g., goal-directed use) of the graspable objects was shown to reliably modulate the affordance effect. When the experimental task is relevant to the grasp-related potential of the perceived object, the resulting affordance effect is stronger (Creem and Proffitt, 2001; Shuch et al., 2010; Tipper, Paul, and Hayes, 2006).

In addition, data on grasp-aperture priming clearly points to the existence of *a top-down* link between grasping and attention in that preparing to manipulate objects modulates attentional control. For example, preparing the hand for appropriate grasping action affects the response to graspable objects (Craighero et al., 1999) and hands (Craighero et al., 2002) while combining directional and aperture cues leads to the registration of aperture congruency effects for power grips (Tschentscher and Fischer 2008). Further evidence indicating the role of attention in affordance effects comes from Adamo and Ferber (2009) who demonstrated that presentation of manipulable tools (or their names) together with the objects these tools are usually used upon results in an action priming effect. Similarly, Symes et al. (2008) showed that grasp preparation improved participants' perception of grasp-congruent objects. This motor attention mechanism selectively inhibited competing motor programs associated with the same object that could potentiate erroneous actions (Loach et al., 2008). Finally, a recent report by Symes and colleagues (2010) suggested that the initial attentional state of the observer matters. Top-down motor attention in the latter study induced by grasp preparation improved visual detection of grasp-congruent targets. Probably the most direct evidence for the ability of attentional cues to modulate affordance effects comes from a recent report by Kostov and Janyan (2012) who demonstrated that lateral *auditory* spatial cues can facilitate the activation of affordance effects from targets with congruently oriented handles.

This wide range of seemingly contradicting findings about the interaction between attention and affordances suggests that the exact nature of this interaction is still unclear. On one hand, the fact that most manual-response studies using variants of a cueing paradigm failed to register attentional effects on affordance activation can simply indicate that the manual response mechanisms are not sensitive enough to register such effects. From this point of view, behavioural responses that are more sensitive to attentional manipulations, such as eye movements may prove to be a better window into the role of attention in affordance effects. This expectation is motivated by the electrophysiological studies discussed above that point to the existence of a two-way interplay between the attentional system and manipulation affordances. On the other hand, a recent theoretical proposal by Borghi and Riggio (2009) suggests that the exact dependence of affordance effects on the allocation of attention varies between *stable* and *variable* affordance types. Stable (stored or core) affordances are intrinsic properties of the affording objects such as, general graspability, size, or weight. These are hypothesized to be stored permanently as components of the object's off-line representation, elicited automatically (e.g., without spatial-attention prerequisites) and independent of specific visual context (e.g., spatial orientation). Variable (or situated) affordances, on the other hand, are contingent and context-specific object properties. Context dependent handle orientation is one example of such variable affordances. As such, they are not stored permanently, subject to the object's orientation, and short-lived (cf. Fischer and Dahl, 2007). Due to their contingent properties, variable affordances should require specific attention on the object or its graspable parts. To better understand this distinction think of *a cup*. Its stable affordances will result from its general graspability, both by means of wrapping one's hand around the cup's body and by using its canonical grasp-related part, i.e., the handle. This general graspability of a cup is expected to be encoded in its stored (or off-line) representation *independent* of how the cup is spatially presented at any given moment.

Further developing the proposed distinction, Borghi (2012) makes a series of valuable predictions with regard to the differential impact of linguistic (e.g., names) and visual cues on affordance effects. Because only stable affordances are expected to be stored permanently, top-down linguistic cues, which encompass general and symbolic relations to their referents, should only activate this type of affordance as it would be highly uneconomical to permanently store all possible orientations a cup can have. Bottom-up visual cues, on the other hand, reflect an object's current situation and should facilitate the extraction of variable affordances, such as well-documented compatibility (e.g., handle-orientation) effects. Compatibility effects resulting from handle orientation (leftward/rightward), in turn, reflect the cup's variable affordances as they will have to emerge within a given visual context. Because of their contingent nature, variable affordance effects should be dependent on visually directed attention and independent of linguistic cues.

The specified distinction between stable and variable affordances becomes crucially important for the predictions for the studies reported below. Importantly, in both studies we do not only use manual-response reaction time data as the affordance-specific evidence; we also analyse participants' oculomotor behaviour in order to further investigate the time-course and the early functional dynamics of the emergence of the affordance effects. In Experiment 1, we examine the availability of a target's affordances depending on its attentional status and the presence of another object with similar or opposite affordances. Experiment 2 replicates and extends this approach by adding linguistic cues. The presentation of the data from both studies is followed by general discussion about the nature of the distinct roles of and the interplay between the visual and the linguistic processing domains in their ability to evoke manual affordance effects.

Experiment 1

The main goal of Experiment 1 was to investigate how the affordance effect in two-object displays depends on the saliency of the target (being either visually unfocused or visually focused; Symes et al., 2001), on the orientation of the distractor (response inhibition; Ellis et al., 2007) and on attention to the target's graspable part. The last issue was addressed by recording eye movements as participants decided with lateralized buttons whether the target was a kitchen utensil or a tool.

Method

Design

Our three main questions and the corresponding analyses motivated our experimental design. For the purposes of evaluating the effects of visual focus and distractor orientation, three factors were independently manipulated: Target Congruency (Congruent/Incongruent), Distractor Congruency (Congruent/Incongruent), and Visual Focus (Target/Distractor). This resulted in a 2x2x2 within-subjects design. The target object was indicated to participants by means of changing its colour from natural to green. A target or a distractor was congruent when the direction of its handle (left/right) was concordant with the response hand (left/right) used to classify the object as a kitchen utensil or a tool. The utensil/tool categorization was performed with the left/right hand, counterbalanced, and the handle was pointing in one direction or the other. In half of the trials, the object in the visually focused position became the target; in the other half it was the distractor (see details of Visual Focus manipulation below).

While the majority of studies on affordances present single objects without any context, we presented target objects in a context of another, distracting object (cf. Ellis et al., 2007). This is an important feature because realistic object manipulations typically occur in co-presence of other manipulable objects whose role on modulating target object's affordance profile needs to be properly investigated. Following Ellis et al. (2007) we expected opposite effects from the response-congruent targets and the response-congruent distractors on *manual-response reaction times* (RT): Congruent targets should facilitate behavioural performance while congruent distractors should inhibit it. The Visual Focus manipulation should make one of the two objects more accessible for processing than the other, allowing us to test for possible attentional enhancement of both the target-bound and the distractor-bound congruency effects. The general hypothesis is that the more salient of the two co-presented objects would be processed faster, therefore enhancing the congruency effects from this salient object (Symes et al., 2010). This should result in the registration of interactions between Visual Focus and the two congruency effects.

For an evaluation of the role of the graspable object part we concentrated on the viewers' oculomotor behaviour specifically related to the activation of the affordance effects. As a result, we modelled an object-based rather than target-distractor based analysis with the data coded according to the following factors: Visual Focus (Focused/Unfocused), Object Status (Target/Distractor), and Object Part (Body/Handle). This design is crucial for the analysis of how visual interrogation of objects' manipulable parts (e.g., handles) changed when participants prepared and executed target responses in the presence of a distractor. The main hypothesis for this analysis was that viewers should attend proportionally more to manipulable parts of the objects (e.g., handles) than on their bodies.

One specific temporal interest period was used for both analyses. The interest period started with one of the two displayed objects turning green (target onset) and ended with the manual response (key press) to indicate the target's identity. The following manual and oculomotor behavioural measurements were treated as dependent factors: (1) manual response latencies to identify the target and (2) proportional Total Dwell Times (accumulated fixation durations divided by area in pixels, expressed as ms per interest area or MIA) on the objects and their graspable parts (i.e., handles).

Materials

Experimental materials consisted of 256 colour photographic displays portraying two manipulable objects – one was always a mechanical tool and the other was always a kitchen utensil (see example in Figure 1).

Fig. 1. Example of experimental materials. Target display includes two graspable objects; target identity is indicated by the eventual colour change.

All experimental materials were in landscape format with horizontal-to-vertical size dimensions of 1024x768 pixels. The “kitchen utensils” were *cup, pan, saucer,* and *strainer.* The “tools” were *brush, chisel, saw,* and *screwdriver.* We implemented all 16 possible tool-utensil combinations counterbalancing their presentation across the experimental conditions. The photographed objects were positioned on a flat surface against a light background. The objects were photographed so that one appeared farther from the viewer while the other appeared closer (see Figure 1). Both objects were presented with their bodies and handles perfectly visible. The objects were presented with their handles parallel to each other and always pointing either to the right or to the left side of the screen. Experimental materials were not controlled for size, luminance-related properties, or familiarity to the participants. This was due in part to the fact that we selected to use photographs of real objects that vary in size and luminance naturally. Also, we allowed such variation to prevent people from selecting any one feature dimension as a cue. Finally, any potential effect of these individual object features and/or their combinations was avoided by presenting objects in a balanced design. A random selection of 16 experimental trials (2 per experimental condition) was used in the practice session.

For the purposes of our eye-tracking analysis, we used SR Research Experiment Builder© to create original and mirror free-hand body-specific and handle-specific interest area sets for each of the objects used in the study. We implemented these interest area sets in each of the 256 pictures used in our studies (see example in Figure 2).

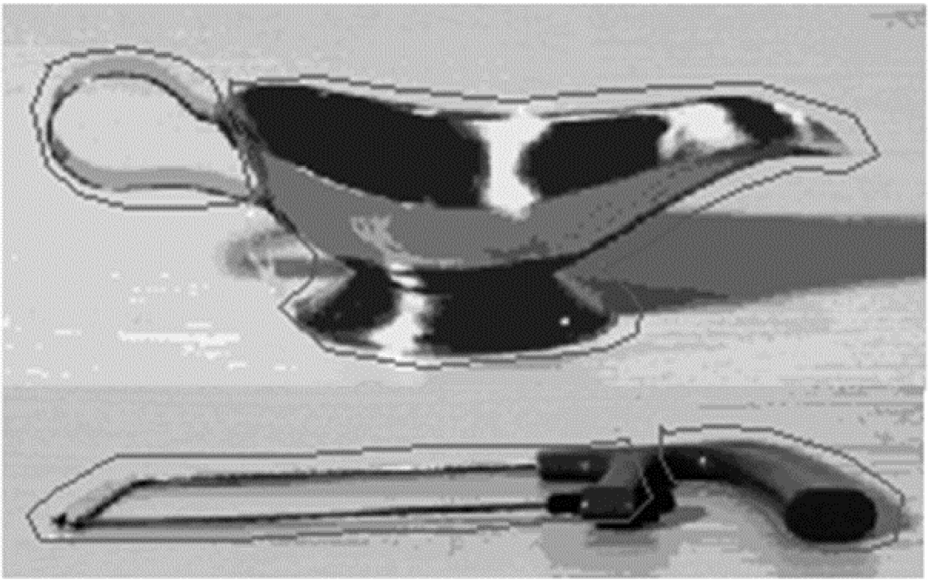

Fig. 2. Body-specific and handle-specific interest areas, indicated by the boundaries around each object's body and handle, respectively.

Apparatus

The experiment was implemented in *SR-Research Experiment Builder*© Version 1.5.201. An EyeLink© 1000 desk-mounted eye tracker with 1000 Hz sampling rate monitored participants' eye movements. The materials were presented on a 19' ViewSonic© G90fB monitor of a DELL© Optiplex 755 desktop computer running at a display refresh rate of 90 Hz. A chin rest restricted head movements. Manual response latencies were recorded time-locked to eye-tracking data with the help of the Microsoft© Sidewinder game-pad integrated with the EyeLink© eye-tracking system. The eye-tracking data were extracted and filtered using *SR-Research Data Viewer*© Version 1.91. Participants' handedness was assessed with a modified version of Annett's handedness questionnaire (Annett, 1970).

Participants

Twenty one native speakers of English (4 males) studying at Dundee University in Scotland participated for course credit or £6. Their mean age was 19.7 years and all had normal or corrected-to-normal vision. Their average handedness score was 34.3 (range 29-36), indicating they were all right-handed.

Procedure

Before each session, the experimenter collected the participant's written consent and administered the handedness questionnaire. Then the participant was positioned approximately 60 cm in front of the monitor. Viewing was binocular, but only the dominant eye was tracked (following the procedure of Roth, Lora, and Heilman, 2002). Before the main experiment each participant saw a randomized sequence of 16 practice trials – 2 from each of the experimental conditions. After that, the eye-tracking equipment was calibrated.

During the experimental session, each participant was presented with an individually randomized sequence of 256 trials, such that a maximum of two trials from the same experimental condition were presented in succession. A typical trial is portrayed in Figure 3.

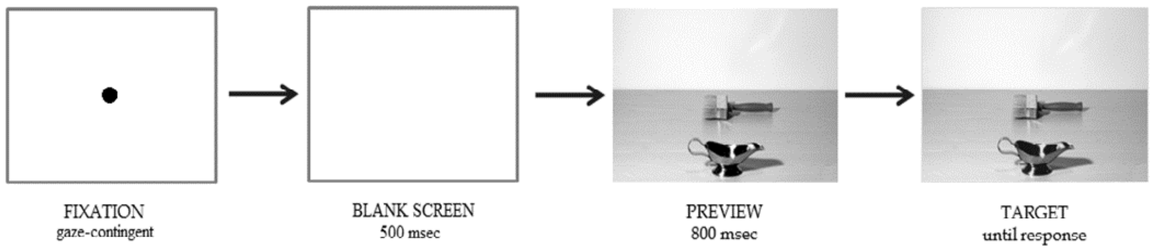

Fig. 3. Experimental trial sequence in Experiment 1.

Each experimental trial started with the presentation of a black central fixation dot (radius 20 pixels). The spatial position of the fixation dot always corresponded with the location of the backgrounded object in the subsequently presented target display putting this backgrounded object in the focus of visual attention when the preview display appeared on the screen. The participant had to fixate the dot for a minimum of 150 ms before it was replaced by a 500 ms blank screen, followed by the 800 ms preview display. The inclusion of a 500-ms blank screen facilitated the disengagement of attention (e.g., Fischer and Breitmeyer, 1987). After 800 ms preview, one of the objects would change its natural colour to green. This change signalled to the participant the identity of the target. Once that happened, the participant had to indicate whether this target was a utensil or a tool by pressing either the left or the right key on the game pad, according to the experimental instruction. The resulting manual reaction time (RT) was the time interval between the onset of the target (colour changing event) and the time the participant pressed the response key.

Participants were randomly assigned to one of the two *instruction* groups. Group 1 pressed the left key if the target was a kitchen utensil and the right key if it was a tool. Participants in Group 2 received the opposite response rule. Participants were told to look at the central fixation point at the beginning of each trial, to await the next display, to freely explore the preview display, and to press the correct response key as soon as they noticed the change of color. Each participant was debriefed after data collection to establish that the purposes of the study had remained unknown.

Results and discussion

Data from 2 participants were excluded due to high error rate (over 15%) and data from one more participant were excluded due to inflated RTs (over 2 standard deviations above the group mean). Analyses were performed on the data from the remaining 18 participants unless discussed separately. Response accuracy was high (98%). However, in order to confirm that there was no meaningful correspondence between the response accuracy and the RT data, we performed a correlation analysis across conditions. This analysis showed that there was no reliable correlation between error probability and the RT data (Pearson's r (8) = -.42, p = .301). There was no effect of Instruction Group on any dependent variables; therefore, we aggregated across this factor.

Manual response reaction time analysis

We eliminated trials with incorrect responses or RTs outside 240-1300 ms in order to exclude both anticipations and responses that were overly slow. We also trimmed the data to exclude RTs outside of 2 standard-deviations around an individual participant's mean. This left us with 90% of the data available for statistical analysis.

Average manual RT in Experiment 1 was 592 ms Although a 2x2x2 analysis of variance (ANOVA) did not reveal reliable main effects, it registered a reliable interaction between Visual Focus and Target Congruency ($F(1,17) = 6.489$, p <.05) (see Figure 4).

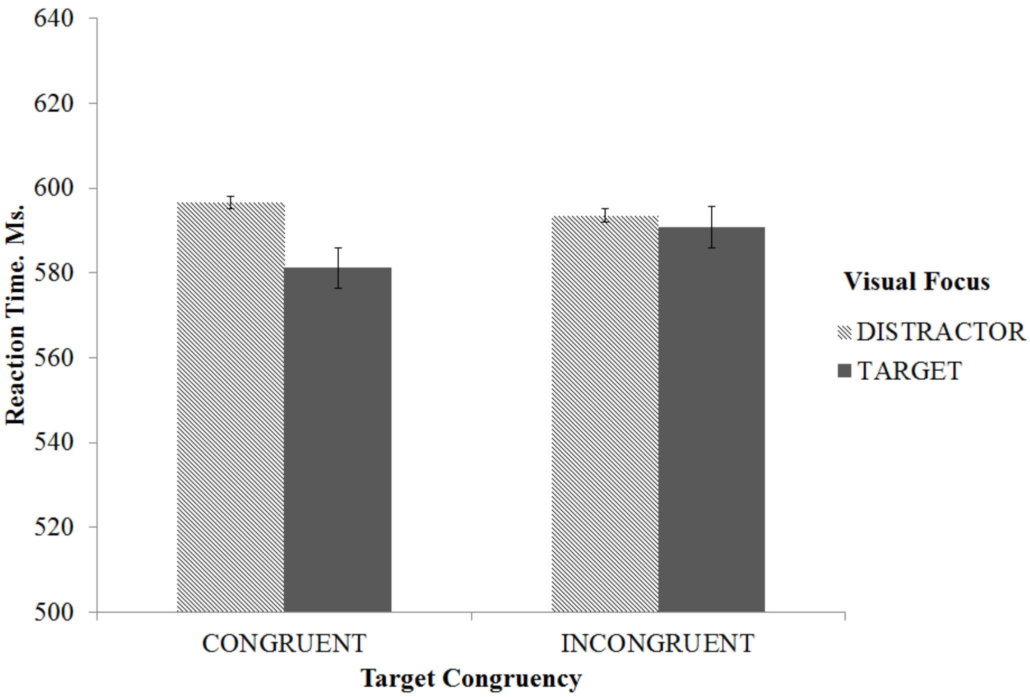

Fig. 4. Experiment 1. Manual reaction times for target detection. Target Position x Target Congruency interaction.

The strongest combined facilitation from the two factors was observed when the visually focused targets were presented as response-congruent. A more detailed examination of this interaction by means of pair-wise t-tests revealed that participants were

17 ms faster to detect the identity of congruent targets in the visually focused position (M = 584 ms) than when the distractor was in focus (M = 601 ms), $t(17) = -2.998$, $p = .008$. This confirms our post-hoc interpretation of the direction of the target position effect (see above): Given the design of our experimental materials, presenting an object in the visual focus corresponded with the location of the previously established attentional focus. It is possible that this correspondence resulted in a faster recognition of the visually focused objects via attentional facilitation. However, this conclusion cannot be unequivocal due to the fact that the eye position was not maintained by the fixation cross immediately before the target display. The fact that eye movement was necessary to respond to the target when the distractor was focused could, in principle, explain the facilitation effect observed when focussing on the target where no eye movement was required. The observed interaction pattern partially replicates previous findings by registering the significant difference in absolute RTs between the visually focused and the visually unfocused objects in case of congruency. It also reveals a positive compatibility effect for the visually focused targets and a negative compatibility effect for the visually focused distractors. The latter finding demonstrates that spatially guided visual attention gates target object recognition: Everything outside it is inhibited including the associated actions.

Eye-tracking analysis

In our eye-tracking analysis we were asking the two following general questions: (1) Do graspable parts implicitly attract special attention when people view and identify graspable objects and (2) does visual focusing amplify this potential effect. So, we implemented a 3-way model with the following factors: Visual Focus (Focused/Unfocused) X Object Status (Target/Distractor) X Object Part (Body/Handle). ANOVA on proportional Total Dwell Times (accumulated fixation durations divided by area in pixels, expressed as ms per interest area or MIA) confirmed reliable main effects of all three independent factors: Visual Focus ($F(1, 17) = 75.508$, $p<.001$), Object Status (F(1,

17) = 27.731, $p<.001$), and Object Part ($F(1, 17) = 127.755$, $p<.001$). Participants looked more at objects in focus than at those that were outside of focus (*Ms* = 9 MIA and 3 MIA, respectively). Participants also looked more at targets than distractors (*Ms* = 7 MIA and 6 MIA, respectively). Most importantly, participants looked proportionally longer at handles (M = 7 MIA) than at bodies (M = 5 MIA). Interaction between Visual Focus (focused/unfocused) and Object Part (body/handle) was also reliable, $F(1, 17) = 39.083$, $p<.001$ (see Figure 5) indicating a special role of the objects' graspable parts in comparison to the objects' bodies in attracting attention and potentiating variable affordances related to the differently oriented manipulable objects. Examination of the mean difference between between the proportional fixations to the objects' bodies and handles in the visually focused condition by means of a pairwise t-test confirmed that the objects' handles attracted relatively more attention when the objects were positionally focused than the objects' bodies ($t(17) = 8.315$, $p < .001$).

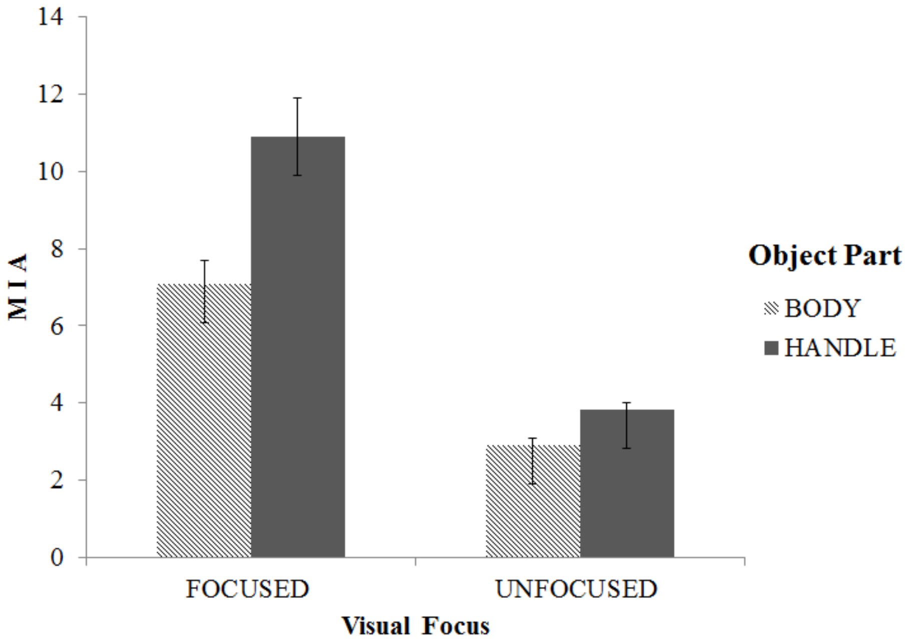

Fig. 5. Experiment 1. Proportional dwell times in milliseconds per Interest Area (MIA). Visual Focus x Object Part interaction.

The results of Experiment 1 confirmed a number of hypotheses and provided new important evidence. First, a reliable interaction between Target Congruency and Visual Focus revealed that viewers identified response-congruent targets faster when they appeared in the focus of the viewer's visual attention (i.e., in the background). Presenting distractors in visual focus and targets outside of it (i.e., in the foreground) resulted in a negative compatibility effect for the target. This finding provides evidence that affordance effects are modulated by the object's attentional status and that spatially guided visual attention activates relatively rich object representations that encode the object's action properties. Our data also demonstrate that directing spatial attention to an object results in inhibition of actions associated with targets outside of the fixated region. (cf. Symes et al., 2010).

One possible alternative explanation for the effect of positional cueing might be that the observed facilitation derives from the attentional shift alone. Because the fixation cue was always associated with the background object presented in the upper visual field, the spatial attention system was constantly primed for the upper location. Hence, responses were faster when the target appeared there. When it appeared in the lower visual field, attention had to be disengaged and switched to the new spatial location. This account, however, is not tenable due to a number of reasons. First, a study by Handy et al. (2005) demonstrated that action-specific attention to affording objects is distinct from purely orienting effects. Second, the attentional shift logic does not account for the *interaction* between the visual focus and the target *congruency*. If an attentional shift alone was responsible for generating the motor response (e.g., Anderson et al., 2002) then no interaction between orientation congruency and visual cue should be observed. Second, the attentional-shift account fails to fully explain the RTs in the two incongruent conditions. Finally, the attentional shift interpretation goes against recent reports about a special role of attention in potentiating of the affordance effect (e.g., Handy et al., 2003; Kostov and

Janyan, 2012). Handy et al. (2003), in fact, provide the most plausible explanation of the interaction pattern between the spatial orienting and the SRC congruency manipulations observed in our studies. Namely, spatial attention is enhanced for images of tools oriented with congruent handle positions. In the current study the potential effects were possibly somewhat mitigated because the upper visual field (not the lower) was always cued.

Our eye-tracking analysis provided novel evidence about the role of the objects' manipulable parts in potentiating affordance effects. Whilst identifying manipulable objects, viewers spent proportionally more time looking at the objects' handles than their bodies. This main effect of Object Part was accompanied by an important interaction with Object Focus: Viewers' attention for handles was further enhanced when the object was in visual focus. Together these results demonstrate that graspable objects' functional parts (i.e., their handles) automatically attract attention even when the experimental task is unrelated to manually manipulating these objects. Moreover, visually focusing the object further enhanced the handle-specific attention attraction effects. This novel finding provides initial support to the hypothesis outlined in Borghi (2012) – that visual cues to manipulable objects modulate variable affordances, such as the processing of handle orientation. By the same account linguistic cues (e.g., names or verbs) should not have this capacity. This should be true because linguistic information (e.g., the word *cup*) activates off-line or stable representational components, such as weight, general shape, and the general presence/availability of canonical graspable parts (i.e., handles), but not their variable orientations. This part of Borghi's claim was tested in Experiment 2.

Experiment 2

In order to test the ability of combined linguistic and visual cues to induce grasp affordance effects, we added a name cue manipulation in Experiment 2 to the positional cueing manipulation already used in Experiment 1.

Design

The implemented design was similar to Experiment 1 with the addition of the new linguistic cueing factor "Name Focus". Manipulating Target Congruency (Congruent/Incongruent), Distractor Congruency (Congruent/Incongruent), Visual Focus (Target/Distractor), and Name Focus (Target/Distractor) resulted in a 2x2x2x2 within-subjects design. Name Focus manipulation was operationalized via participants hearing the name of either the target or the distractor object during the presentation of the blank screen preceding the onset of the target display.

All names unambiguously related to one of the two objects. The names were singular nouns naming the object (i.e., *cup, pan, saucer, strainer, brush, chisel, saw, and screwdriver*). Otherwise, the analysis logic, the temporal interest period, and the interest areas for the eye-tracking analysis were the same as in Experiment 1.

Materials

We used the same visual displays as in Experiment 1. The eight object names were recorded by a male native speaker of English. The files' length was not controlled as the corresponding names differed in their syllabic structure. However, this did not present analysis-related problems as the names were always played within the 1000-ms blank screen event preceding object onset. Similarly to Experiment 1, a random selection of 16 experimental trials was used for practice.

Apparatus

The same apparatus as in Experiment 1 was used. The auditory stimuli were presented to the participants via Sennheiser© headphones.

Participants

Twenty native speakers of English (8 males) at Dundee University with normal or corrected-to-normal vision participated for credit or £6. Their mean age was 21.2 years and their average handedness score was 34.9 (range 29-36), confirming they were all right-handed.

Procedure

The same procedure as in Experiment 1 was followed, with the exception that an unpredictive object name was played during the blank screen interval preceding the target display. A typical experimental sequence is portrayed in Figure 6.

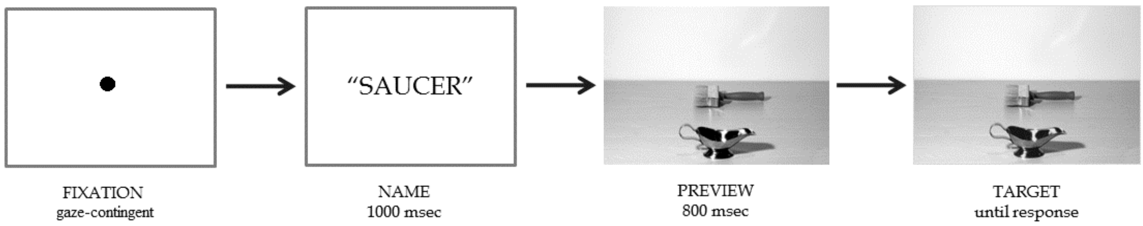

Fig. 6. Experimental trial sequence in Experiment 2.

Results

Data from two participants were excluded from analysis due to high error rates (over 15% of their total responses). The data from the remaining 18 participants were subjected to statistical analyses. There was again no effect of response to category mapping on any dependent variables; therefore we aggregated across this factor.

Manual reaction time analysis

Response accuracy in Experiment 2 was 97%. Similarly to Experiment 1, we performed a correlation analysis on error rates across conditions. This analysis showed that there was no reliable correlation between error probability and the RT data (Pearson's r (16) = .399, p = .125). The same data trimming as in Experiment 1 left us with 94% of the correct RT data for statistical analysis. Average manual RT in Experiment 2 was 598 ms A 2x2x2x2 ANOVA revealed a reliable effect of Name Focus ($F(1,17) = 31.800$, $p<.001$) with the named targets identified 41 ms faster (M = 578 ms) than when the distractor was named (M = 619 ms). There were no other main effects on the manual RT performance. However, RT data analysis revealed a reliable two-way interaction between Visual Focus and Name Focus ($F(1,17) = 5.722$, $p = .029$) (see Figure 7).

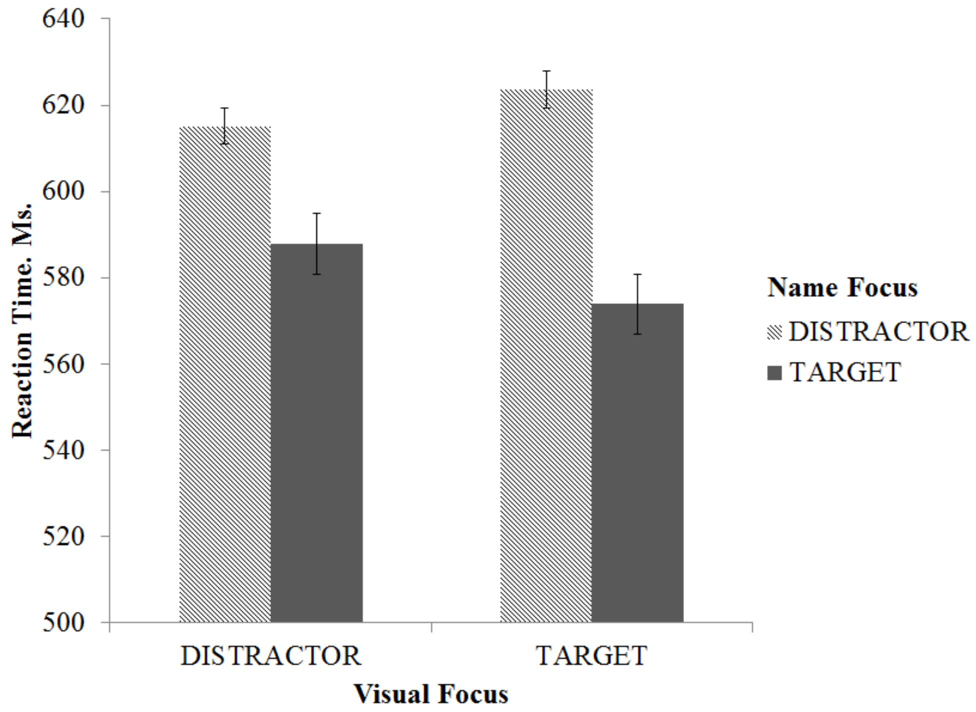

Fig. 7. Experiment 2. Manual reaction times for target detection. Visual Focus x Name Focus interaction.

Planned comparisons confirmed that participants were 56 ms faster to identify named and visually focused targets (M = 566 ms) than named and focused distractors (M = 622 ms), $t(17) = 5.487$, $p<.001$. The 26 ms advantage for named and unfocused targets (M = 589 ms) over named and unfocused distractors (M = 615 ms) was also reliable ($t(17) = 3.208$, $p = .005$). Manual RTs to targets were also 23 ms shorter when the named targets were unfocused than when they were focused ($t(17) = -2.722$, $p = .014$). The 33 ms facilitation in the target unfocused/target named condition as compared to the target focused/distractor named condition was also reliable ($t(17) = 4.001$, $p = .001$). Overall, the interaction pattern demonstrates a combined effect from linguistic (naming) and visual (positioning) cueing of targets. Conversely, when the name participants received before the target display referred to the subsequent focused distractor this cueing combination resulted in a combined inhibition effect. The observed interaction between linguistic and positional cueing effects provides evidence about the presence of a combined effect on target categorization from top-down linguistic and bottom-up visual cues.

We also registered two important reliable three-way interactions. One of such interactions was between Visual Focus, Target Congruency, and Distractor Congruency ($F(1,17) = 8.164$, $p = .011$). In order to graphically illustrate this interaction, we separated the RT data into two two-way interactions along the Visual Focus variable (target/distractor) (see Figures 8 and 9).

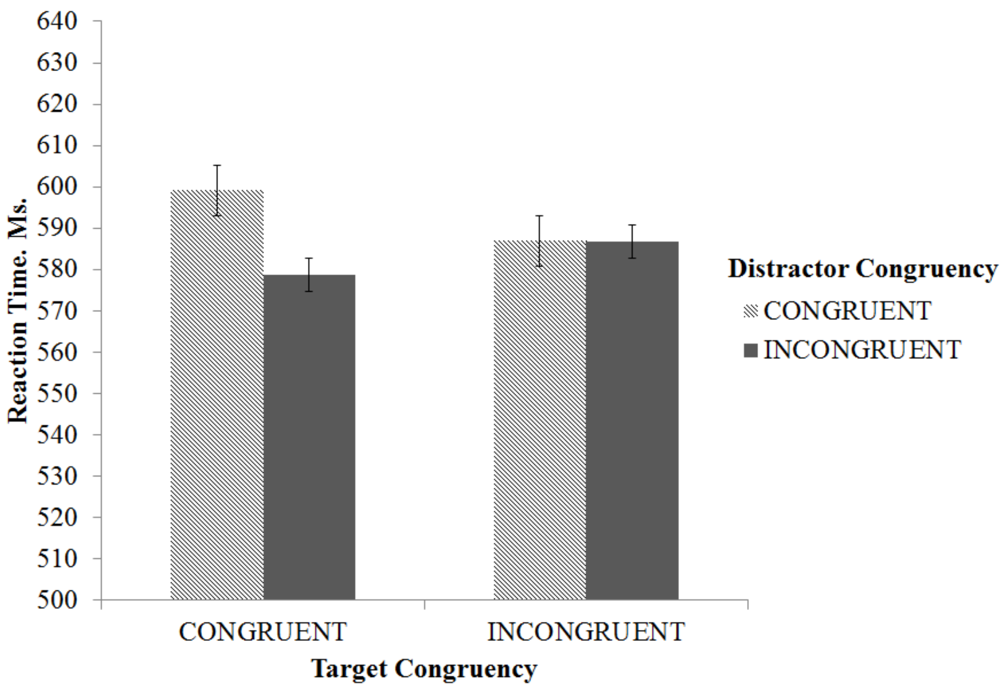

Fig. 8. Experiment 2. Manual reaction times for target detection: Target Congruency x Distractor Congruency interaction in “Visual Focus: Target” condition.

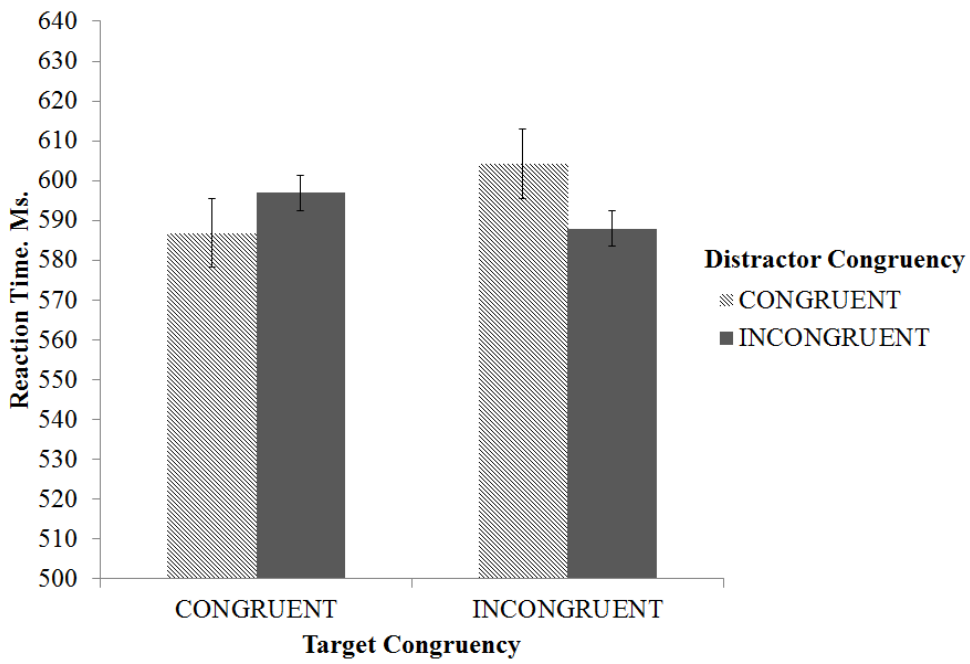

Fig. 9. Experiment 2. Manual reaction times for target detection: Target Congruency x Distractor Congruency interaction in "Visual Focus: Distractor" condition.

When the target was visually focused (Figure 8), participants were 21 ms faster to identify congruent targets co-presented with incongruent distractors (M = 585 ms) compared to the average of 606 ms when both objects were congruent ($t(17) = 2.032$, p = .058). When the distractor was visually focused (Figure 9), participants were faster to identify incongruent targets alongside incongruent distractors (M = 596 ms) than in the situation when incongruent targets appeared alongside congruent distractors (M = 611 ms) ($t(17) = 1.917$, p = .072). The general interaction pattern suggests the presence of a negative compatibility effect between target's and distractor's congruency profiles when the target is in focus and a positive compatibility effect, when the distractor is in focus. We will provide a full examination of this novel finding in the General Discussion.

Another reliable three-way interaction observed in manual RT data was between the factors of Target Congruency, Visual Focus, and Name Focus ($F(1,17) = 7.490$, p = .014). Figures 10 and 11 illustrate this interaction along the Target Congruency factor.

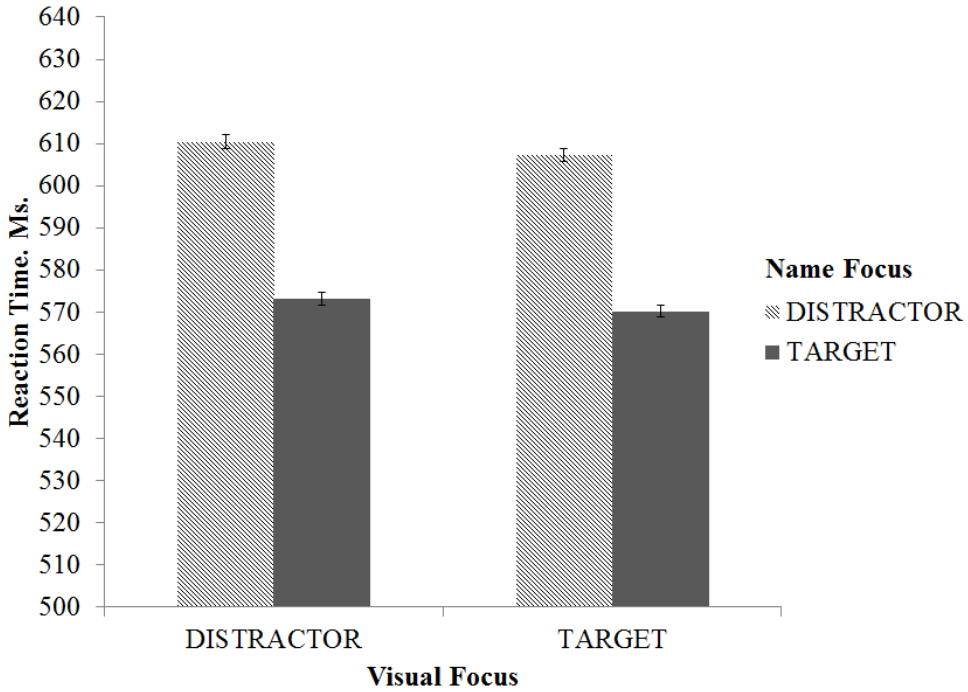

Fig. 10. Experiment 2. Manual reaction times for target detection: Visual Focus x Name Focus interaction in "Congruent Target" condition.

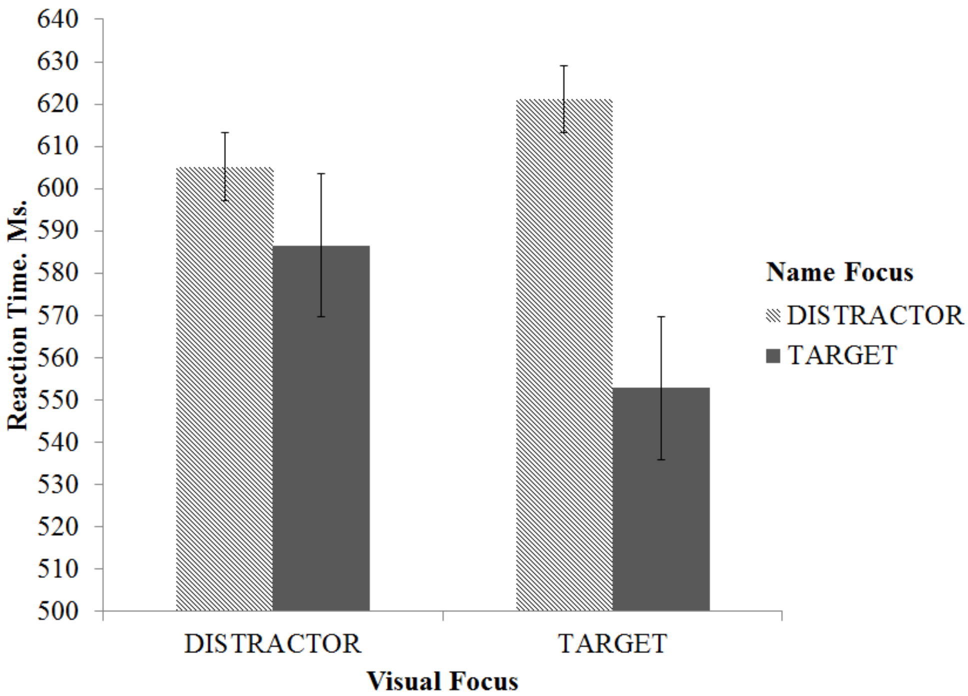

Fig. 11. Manual reaction times for target detection: Visual Focus x Name Focus interaction in "Incongruent Target" condition.

Figure 10 illustrates the RT pattern for congruent-target trials. Figure 11 illustrates the interaction pattern for incongruent-target condition. Examination of Figure 10 confirms that the pattern is carried primarily by the main effect of Name Cue with named congruent targets identified faster than when the distractor was named. It also shows an additional minimal facilitation for congruent targets when they were simultaneously visually and linguistically focused. Figure 11 provides further details to the overall interaction pattern. When the targets appeared response-incongruent, a combined facilitation from visually and linguistically cueing the target was even stronger than in the congruent-target condition. Examination of the interaction by means of pair-wise t-tests confirmed that participants' responses were reliably facilitated when the targets were cued by both the positional cueing and their names compared to when the distractor was named in both the target cueing Visual Focus condition ($t(17) = 5.003$, $p < .001$) and the distractor cueing Visual Focus condition ($t(17) = 3.972$, $p = .001$). Therefore, incongruent targets also enjoyed a combined facilitating effect from focusing via linguistic and visual cues. This was only true, however, when the distractor was out of visual focus. Putting the distractor in the visually focused position slowed down target categorization.

Eye-tracking analysis.

Our eye-tracking analysis of the proportional dwell times followed the same logic already discussed for Experiment 1. However, we now also added a new factor, Name Focus. So, we implemented a 4-way design with the following factors: Visual Focus (Focused/Unfocused) X Name Focus (Focused/Unfocused) X Object Status (Target/Distractor) X Object Part (Body/Handle). A 4-way ANOVA performed on revealed reliable main effects of all four independent factors: Visual Focus ($F(1, 17) = 136.541$, $p < .001$), Name Focus ($F(1, 17) = 7.899$, $p = .012$), Object Status ($F(1, 17) = 21.123$, $p < .001$), and Object Part ($F(1, 17) = 168.423$, $p < .001$). All effects followed the same direction as in Experiment 1: Participants looked more at visually focused than unfocused objects (*Ms* = 10 MIA and 4 MIA, respectively), they looked more at named objects than not-named (*Ms* = 7 MIA and 6 MIA, respectively), they looked more at targets than distractors (*Ms* = 7 MIA and 6 MIA, respectively), and they looked more at handles ($M = 8$ MIA) than at bodies ($M = 5$ MIA). Hence, our data from Experiment 2 largely replicated the findings from Experiment 1 and also provided new evidence, namely, that linguistic cues to objects also implicitly attract viewer's attention.

Importantly, we also replicated the interaction between Visual Focus and Object Part registered in Experiment 1 ($F(1, 17) = 31.846$, $p < .001$) with the interaction pattern mirroring the one observed in Experiment 1 (see Figure 12) while the interaction between Name Focus and Object part was unreliable (p =.75). Further analysis of the mean difference between the proportional fixations to the objects' bodies and handles in the visually focused condition confirmed the finding in Experiment 1 that the objects' handles attracted relatively more attention when the objects were positionally focused than the objects' bodies ($t(17) = 10.422$, $p < .001$).

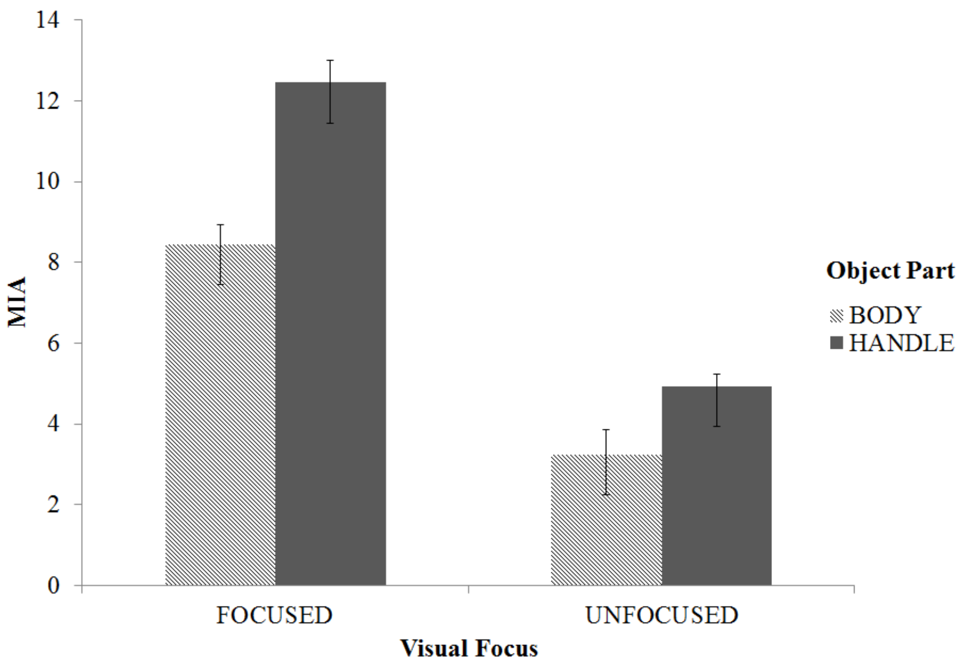

Fig. 12. Experiment 2. Proportional Dwell Times. Object Position x Object Part interaction.

General Discussion

In two experiments, we analysed how perceptual and linguistic cues to the manipulable objects influence manual and oculomotor behaviour during categorization of graspable objects. Object identification in a real-world scenario often involves the availability of both visual and linguistic information about the objects. Hence, it is important to understand how the perceptual and the linguistic information are simultaneously integrated in simulating action components of manipulable objects during their identification.

One important general finding in both Experiments was that, albeit traced in different main effects and interactions, both target-bound and distractor-bound response-congruency effects were registered in the manual reaction time data and in the *eye-tracking* data likewise. First, our analysis of the manual reaction-time data partially replicated the previously reported opposite-direction effects from target congruency and distractor congruency. Specifically, response-congruent orientation of the target object's manipulable part generally facilitated the categorization of this object while the response-congruent orientation of the manipulable part of a co-present distractor led to the establishment of an inhibition effect on the speed of this process. However, our main focus was in understanding of how the availability of visual (bottom-up) and linguistic (top-down) *cues* to the objects affects the affordance effect, both generally and in relation to specific response-congruency factors. Both types of cues were previously investigated for their potential to modulate affordance activation with mixed results. The novelty of our investigation was two-fold. First, there is no comparable analysis of the combined effect the top-down and the bottom-up cues exert on affordance effects in general and, specifically, the orientation compatibility effects. Second, our novel approach to analysing viewers' oculomotor behaviour documented a fine-grained record of implicit attentional processes underlying activation of affordance effects, especially in relation to the two implemented cueing manipulations.

In Experiment 1, we documented a general positional focusing facilitatory effect on object categorization both in manual reaction time data and in eye behaviour. In particular, we were able to confirm that putting the object in the visual focus amplifies the observed congruency effect. This was revealed in the interaction between Visual Focus and Target Congruency in Experiment 1: Participants were faster to identify targets when their orientation was response-congruent and when they were in the attentional focus. This confirms previous findings about the special role of attention in potentiating affordance effects (e.g., Handy et al., 2005; Kostov and Janyan, 2012). The three-way interaction between target and distractor congruency effects, on one hand, and the positional cueing effect, on the other, observed in Experiment 2 revealed a more complex pattern. Categorization of the visually focused targets was faster when they were presented alongside an incongruent distractor. This facilitation effect reinforces previous findings about the negative compatibility effect from congruent distractors on graspable target's categorization (Ellis et al. (2007). However, when the visually focused object was the distractor instead of the typical negative compatibility effect from co-present distractors we observed a positive compatibility effect: Viewers' benefitted in cases when targets and distractor had *the same* handle orientation; when objects were differently oriented target response was slowed down. When the distractor was focused, the pattern was reversed: Viewers were almost equally fast to detect congruent targets alongside congruent distractors and incongruent targets alongside incongruent distractors. Hence, instead of inhibition from simultaneously congruent or simultaneously incongruent distractors, target categorization was *facilitated* in both cases. We suggest that in order to understand this complex pattern one needs to consider the identity of the object (target vs distractor) in the visual focus and the associated necessity to switch attention in the cases when this object is a distractor.

Imagine the case when the focused object is the target. The viewer's attention is already on this object before its target status is revealed. So, the observer temporarily considers both objects as potential targets while waiting for the colour change. Although attentional resources are "stretched" between the two objects, the primary focus is maintained on the fixated object when it becomes the target. In this case, once the target identity is confirmed for the focused object, the information about the other object (i.e., the distractor) needs to be inhibited similarly to the inhibition of return (IOR) effect (Posner and Cohen, 1984) or a negative priming effect (Neumann and DeSchepper, 1992; Tipper et al., 1991). This interpretation is supported by some previous findings. For example, Riggio et al. (2006) found affordance-related IOR effects when participants had to detect targets (ungraspable or graspable object parts) after whole objects were presented as cues in the same location. Importantly, presentation of a corresponding graspable object as the cue led to slower RTs when graspable parts were later presented as targets but not when the target was the ungraspable object part, confirming the presence of an IOR effect. Our situation of simultaneously congruent targets and distractors with target in the cued location is similar in that temporarily considering both objects as potential targets led to the eventual necessity to inhibit the affordance effect from the co-present distractor (Ellis et al., 2007).

Having a distractor in the visual focus initially follows the same scenario. However, when the target is revealed attention needs to be switched from the focused distractor toward the unfocused target. In this case shared handle direction between distractor and target facilitates identification. This happens because the distractor's identity can be discarded when the observer realizes that the focused object is not the target. As a result, the distractor's identity does not need to be actively inhibited, leaving resources to accommodate both congruency profiles in a "boost" or "priming" fashion. This is a novel finding that suggests that affordance effects are activated differently in the situations when attention needs to be directed away from distractor objects in order to identify target objects. In general, our new findings about the role of visual attention in affordance effects provides initial evidence about the existence of a differential attentional mechanism for the combined effect of the target- and distractor-related affordances in cases when targets or distractors are in visual focus.

However, in Experiment 2 we aimed to investigate activation of grasp affordance effects in a mixed-cue scenario where both the top-down linguistic cues and the bottom-up visual cues are available to the perceiver. Hence, participants had two types of cues simultaneously available to them as both objects could be linguistically and visually cued before one them appeared as the target. Unsurprisingly, providing participants with an object's name facilitated object categorization. Combining naming with positional cueing further accelerated this facilitation. Our primary interest, however, was in understanding how these cues together influence the extent of affordance effects. Two notable findings reflected a degree of this influence. First, name focus interacted with visual focus and the target congruency effect. Response-incongruent targets were also processed faster when they were named but only when the distractor was out of visual focus. Putting distractor in the visually focused position slowed down target categorization relative to the situation when the target was in focus. This suggests that integration of linguistic and visual cues during object identification is limited to the objects that need to be identified, that is, target objects. When different cues direct attention to the co-present distractors, such an effect is not observed. This novel evidence about the effect of attentional facilitation on the objects' response congruency puts specific constraints on the degree and the scope of interactions between competing cues that can potentially lead to the attribution of affordance effects.

It has to be noted that the insertion of the word prior to the picture presentation and subsequent target display may have also led to a situation typically observed in a number of dual-task studies examining the role of shared resources in cross-modal tasks using auditory and visual sensory modalities (Glover and Dixon, 2002; Glover et al., 2004; Singhal et al., 2007). These and similar studies typically register interference effects from different modality cues in a situation when the cues are presented in a sequence as the processor attempts to make a selection in a situation when both cues compete for the same resource. Similarly in our Experiment 2, slow-down in target detection after the presentation of distractor's name compared to detection compared to when the target was named may reflect interference between name and visual cues especially when the target was visually focused. In fact a similar, although a weaker, pattern is observed when the target is presented outside of the focused. The latter may be due to the fact that attention shift necessary for target identification in this case requires allocating resources to this shift reducing the resulting interference between name focus and visual focus.

Another important finding (or the lack of thereof) comes from our novel eye movement analysis implemented in both experiments. We analysed proportional viewing dwell times on targets and distractors with specific focus on the proportional dwell times spent on the non-manipulable parts of the objects (i.e., their bodies) and the manipulable parts of the objects (e.g., handles). Our reasoning was that in order to utilize affordance profiles projected by the visual object, viewers may have to pay specific attention to its *manipulable* part. Our analysis confirmed this expectation: Participants visually interrogated handles as affordance-related object parts more than the objects' bodies. This handle-specific attention attraction was accompanied with a reliable interaction with visual but not with name cue manipulation: Activation of grasp-related affordances (based on implicit preferential attention to handles) was amplified in both studies by directing visual attention to the perceived object; the same amplification was not observed in the name cue condition. This new evidence reveals for the first time differential effects of visual and linguistic cues on implicit attraction of attention by graspable parts. This finding is important as it confirms the idea that top-down linguistic information activates off-line (stable) memory object representations and that these representations do not encode the object's temporary or variable parameters, such as handle orientations. Bottom-up visual cues, on the other hand, have a potential to modulate variable affordances, such as compatibility effects obtained from handle orientations (Borghi, 2012).[1]

The results of our study are intriguing and thought provoking as they are compatible both with the view according to which object representations encode blueprint instructions about potential afforded actions (e.g., main effect of object part) and with the more flexible views of object representations suggesting that the specific information encoded in these representations may be more flexible and variable (e.g., interaction object part / object focus). Put together, our data cast new light on the complex perceptual and linguistic attentional mechanisms underlying the activation of grasp-related affordance effects. These are the early days and more experiments are necessary, but we are moving towards understanding the role of manipulation affordances in "naturalistic" situations where both visual and linguistic information can influence potentiation of affordance effects. Further experiments will address these and other issues.

[1] Of course, upon hearing *cup* one would not only represent its typical shape and weight but also assume that a typical cup has a handle. However, what would not be available from hearing *cup* is how this handle is oriented because the semantic information in *cup* does not cue a particular handle orientation and/or location. A richer linguistic cue (e.g., *cup with a handle on the left*) should, in principle, activate both stable and variable affordances.

References

Adamo M, Ferber S (2009) A picture says more than a thousand words: Behavioural and ERP evidence for attentional enhancements due to action affordances. Neuropsychologia 47:1600-1608

Ambrosini E, Scorolli C, Borghi AM, Costantini M (2012) Which body for embodied cognition? Affordance and language within actual and perceived reaching space. Consciousness and Cognition 21:1551-1557

Anderson SJ, Yamagishi N, Karavia V (2002) Attentional processes link perception and action. Proceedings of the Royal Society Series B 269:1225-1232

Annett M (1970) A classification of hand preference by association analysis. British Journal of Psychology 61: 303-321

Barsalou LW (2008) Grounded Cognition. Annual Review of Psychology 59:617-645

Borghi AM (2012) Action language comprehension affordances and goals. In Coello Y, Bartolo A (eds) Language and action in cognitive neuroscience. Psychology Press, pp 531-556

Borghi AM, Riggio L (2009) Sentence comprehension and simulation of object temporary canonical and stable affordances. Brain Research 1253:117-128

Bub DN, Masson MEJ, Cree GS (2008) Evocation of functional and volumetric gestural knowledge by objects and words. Cognition 106:27-58

Bub DN, Masson MEJ (2010) Grasping beer mugs: On the dynamics of alignment effects induced by handled objects. Journal of Experimental Psychology: Human Perception and Performance 36:341-358

Costantini M, Ambrosini E, Scorolli C, Borghi AM (2011) When objects are close to me: affordances in the peripersonal space. Psychonomic Bulletin And Review 18:32-38

Craighero L, Fadiga L, Rizzolatti G, Umiltà C (1999) Action for perception: a motor-visual attentional effect. Journal of Experimental Psychology: Human Perception and Performance. 25:1673-1692

Craighero L, Bello A, Fadiga L, Rizzolatti G (2002) Hand action preparation influences the responses to hand pictures. Neuropsychologia 40:492-502

Creem SH, Proffitt DR (2001) Grasping objects by their handles: A necessary interaction between cognition and action. Journal of Experimental Psychology: Human Perception and Performance 27:218-228

Derbyshire N, Ellis R, Tucker M (2006) The potentiation of two components of the reach-to-grasp action during object categorisation in visual memory. Acta Psychologica 122(1):74-98 di Pellegrino G, Rafal R, Tipper SP (2005) Implicitly evoked actions modulate visual selection: Evidence from parietal extinction. Current Biology 15(16):469-1472

Ellis R, Tucker M (2000) Micro-affordance: The potentiation of actions by seen objects. British Journal of Psychology 91:451-471

Ellis R, Tucker M, Symes E, Vainio L (2007) Does selecting one visual object from several require inhibition of the actions associated with non-selected objects? Journal of Experimental Psychology: Human Perception and Performance, 33: 670-691

Ferri F, Riggio L, Gallese V, Costantini M (2011) Objects and their nouns in peripersonal space. Neuropsychologia 49:3519-3524

Fischer B, Breitmeyer B (1987) Mechanisms of visual attention revealed by saccadic eye movements. Neuropsychologia 25:73-83.

Fischer MH, Dahl C (2007) The time course of visuo-motor affordances. Experimental Brain Research 176(3):519-524

Gibson JJ (1979) The Ecological Approach to Visual Perception. Boston, Houghton Mifflin

Glover S, Dixon, P (2002) Semantics affect the planning but not control of grasping. Experimental Brain Research 146: 383-387

Glover S, Rosenbaum DA, Graham J, Dixon P (2004) Grasping the meaning of words. Experimental Brain Research 154:103–108

Goodale MA (2011) Transforming vision into action. Vision Research, 51:1567-1587

Handy TC, Grafton ST, Shroff NM, Ketay S, Gazzaniga MS (2003). Graspable objects grasp attention when the potential for action is recognized. Nature Neuroscience, 6: 421-427

Handy TC, Borg JS, Turk DJ, Tipper CM, Grafton ST, Gazzaniga MS (2005) Placing a tool in the spotlight: Spatial attention modulates visuomotor responses in cortex. NeuroImage, 26:266-276

Humphreys GW, Yoon EY, Kumar S, Lestou V, Kitadono K, Roberts KL, Riddoch MJ (2010) The interaction of attention and action: From seeing action to acting on perception. British Journal of Psychology, 101:185-206

Klatzky RL, Pellegrino JW, McCloskey BP, Doherty S (1989) Can you squeeze a tomato? The role of motor representations in semantic sensibility judgments. Journal of Memory and Language 28:56-77

Kostov K, Janyan A (2012) The role of attention in the affordance effect: Can we afford to ignore it? Cognitive Processing, 13: S215-S218

Lindemann O, Stenneken P, van Schie H, Bekkering H (2006) Semantic activation in action planning. Journal of Experimental Psychology: Human Perception and Performance 32(3):633-643

Loach D, Bruce N, Tsotsos JK (2008) An attentional mechanism for selecting appropriate actions afforded by graspable objects. Psychological Science 19:1253-1257

Martin A (2007) The representation of object concepts in the brain. Annual Review of Psychology 58:25-45

Masson MEJ, Bub DN, Newton-Taylor M (2008) Language-based access to gestural components of conceptual knowledge. Quarterly Journal of Experimental Psychology 71:869-882

Masson MEJ, Bub DN, Warren CM (2008) Kicking calculators: Contribution of embodied representations to sentence comprehension. Journal of Memory and Language 59:256-265

Michaels CF (1989) S-R compatibilities depend on eccentricity of responding hand. Quarterly Journal of Experimental Psychology 41(2):263-272

Michaels CF (1993) Destination compatibility affordances and coding rules – a reply. Journal of Experimental Psychology–Human Perception and Performance 19(5):1121-1127

Neumann E, DeSchepper BG (1992) An inhibition-based fan effect: Evidence for an active suppression mechanism in selective attention. Canadian Journal of Psychology 46:1-40

Pappas Z, Mack A (2008) Potentiation of action by undetected affordant objects. Visual Cognition 16(7):892-915

Phillips JC, 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

Posner MI, Cohen Y (1984) Components of visual orienting. In Bouma H, Bowhui DG (eds) Attention and Performance, Vol X. Hillsdale NJ, Erlbaum, pp 531-556

Riggio L, Patteri I, Oppo A, Buccino G, Umilta C. (2006). The role of affordances in inhibition of return. Psychonomic Bulletin and Review 13: 1085-1090

Riggio C, Iani E, Gherri F, Benatti S, Rubichi R, Nicoletti R (2008) The role of attention in the occurrence of the affordance effect. Acta Psychologica 127:449-458

Roth HL, Lora AN, Heilman KM (2002) Effects of monocular viewing and eye dominance on spatial attention. Brain 125: 2023-2035

Schuch S, Bayliss AP, Klein C, Tipper SP (2010) Attention modulates motor system activation during action observation: Evidence for inhibitory rebound. Experimental Brain Research 205:235-249

Singhal A, Culham J C, Chinellato E, Goodale MA (2007) Dual-task interference is greater in delayed grasping than in visually guided grasping. Journal of Vision 7(5): 1-12

Symes E, Tucker M, Ellis R, Vainio L, Ottoboni G (2008) Grasp preparation improves change detection for congruent objects. Journal of Experimental Psychology: Human Perception and Performance 34(4):854-871

Symes E, Ottoboni G, Tucker M, Ellis R, Tessari A (2010) When motor attention improves selective attention: the dissociating role of saliency. Quarterly Journal of Experimental Psychology 63 (7):1387-1397

Thill, S., Caligiore, D., Borghi, A.M., Ziemke, T., Baldassarre, G. (2013). Theories and computational models of affordance and mirror systems: An integrative review. Neuroscience and Biobehavioral Reviews 37: 491-521

Tipper SP, Weaver B, Cameron S, Brehaut JC, Bastedo J (1991) Inhibitory mechanisms of attention in identification and localization tasks: Time course and disruption. Journal of Experimental Psychology. Learning Memory and Cognition 17(4):681-692

Tipper SP, Paul MA, Hayes AE (2006) Vision for action: the effects of object property discrimination and action state on affordance compatibility effects. Psychonomic Bulletin and Review 13(3):493-498

Tucker M, Ellis R (1998) On the relations between seen objects and components of potential actions. Journal of Experimental Psychology: Human Perception and Performance 24:830-846

Tucker M, Ellis R (2001) The potentiation of grasp types during visual object categorization. Visual Cognition 8:769-800

Tucker M, Ellis R (2004) Action priming by briefly presented objects. Acta Psychologica 116:185-203

Tschentscher N, Fischer MH (2008) Grasp cueing and joint attention. Experimental Brain Research. Experimentelle Hirnforschung. Expérimentation cérébrale 190(4):493-498

Vainio L, Ellis R, Tucker M (2007) The role of visual attention in action priming. The Quarterly Journal of Experimental Psychology 60:241-261