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Is that graspable? Let your right hand be the judge

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ABSTRACT

A right-hand preference for visually-guided grasping has been shown on numerous accounts. Grasping an object requires the integration of both visual and motor components of visuomotor processing. It has been suggested that the left hemisphere plays an integral role in visuomotor functions. The present study serves to investigate whether the visual processing of graspable objects, without any actual reaching or grasping movements, yields a right-hand (left-hemisphere) advantage. Further, we aim to address whether such an advantage is automatically evoked by motor affordances. Two groups of right-handed participants were asked to categorize objects presented on a computer monitor by responding on a keypad. The first group was asked to categorize visual stimuli as graspable (e.g. apple) or non-graspable (e.g. car). A second group categorized the same stimuli but as nature-made (e.g. apple) or man-made (e.g. car). Reaction times were measured in response to the visually presented stimuli. Results showed a right-hand advantage for graspable objects only when participants were asked to respond to the graspable/non-graspable categorization. When participants were asked to categorize objects as nature-made or man-made, a right-hand advantage for graspable objects did not emerge. The results suggest that motor affordances may not always be automatic and might require conscious representations that are appropriate for object interaction.

1. Introduction

Behavioral studies have demonstrated that humans generally prefer to use their right hand for grasping. Using unimanual and bimanual tasks, an overall right-hand preference in the majority of right-handed individuals has been shown for picking up various types of objects: geometric 3D shapes (Gabbard, Tapia, & Helbig, 2003), cards (Bishop, Ross, Daniels, & Bright, 1996; Calvert & Bishop, 1998; Carlier, Doyen, & Lamard, 2006), toys (Bryden & Roy, 2006; Sacrey, Karl, & Whishaw, 2012), tools (Mamolo, Roy, Bryden, & Rohr, 2004; Mamolo, Roy, Bryden, & Rohr, 2005; Mamolo, Roy, Rohr, & Bryden, 2006), and blocks (Gonzalez, Whitwell, Morrissey, Ganel, & Goodale, 2007; Stone, Bryant, & Gonzalez, 2013), for example. This preference extends beyond handedness as several of these studies have also found similar results in subgroups of left-handed individuals (Gonzalez & Goodale, 2009; Gonzalez et al., 2007; Stone et al., 2013). In addition, psychophysical studies have shown that in both left- and right-handers, right hand reach-to-grasp movements are less susceptible to the influence of visual illusions and visual context (Adam, Müskens, Hoonhorst, Pratt, & Fischer, 2010; Gonzalez, Ganel, & Goodale, 2006) when compared to those performed by the left hand. For instance, when participants were asked to grasp an object embedded in the Ebbinghaus or Ponzo illusion, the grip apertures of the right hand were accurately scaled to the real size of the object. Grip apertures of the left hand, however, reflected a perceived (illusory) state rather than the actual size of the target (Gonzalez et al., 2006). In harmony with the aforementioned behavioral studies, functional studies examining right-handers have shown a left-hemisphere dominance for motor behavior (Civardi, Cavalli, Naldi, Varrasi, & Cantello, 2000; Volkmann, Schnitzler, Witte, & Freund, 1998). Together these results suggest that the left hemisphere, which controls the right hand, plays a special role in the control of visually-guided grasping.

But what aspects of visuomotor processing are more specialized to the left hemisphere? Visually-guided actions like reaching and grasping require the integration of visual and motor information. Is there a left-hemisphere advantage in the processing of visual information relevant to grasping? This was the question addressed in the current investigation. Behavioral and neuroimaging research has shown that the visual representation of an object not only includes a description of its visual properties but also encodes actions relevant to that object (Ellis & Tucker, 2000; Gibson, 1979; Grèzes & Decety, 2002; Grèzes, Tucker, Armony, Ellis, &

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Passingham, 2003; Tucker & Ellis, 1998). In other words, the viewing of manipulable objects has been shown to potentiate motor affordances of possible actions toward those objects. For instance, a cup handle might afford grasping and a door knob might afford turning. In a classic experiment investigating motor affordances, Tucker and Ellis (1998) presented participants with photographs of graspable objects. The objects were presented in two horizontal orientations (one compatible with a right-hand grasp, and the other with a left-hand grasp) and two vertical orientations (upright or inverted). Participants were asked to make keypad responses as quickly and accurately as possible according to whether an object was upright or inverted. The results showed a 'stimulus response compatibility (SRC) effect'; when an object's horizontal orientation was compatible with the hand of response (handle oriented to the right when responding with the right hand and viceversa for the left hand), participants responded quicker even though the object's horizontal orientation was irrelevant to the task at hand (as participants were responding to the vertical orientation). This result led the authors to suggest that the perception of an object induces a range of object-action associations irrespective of the viewer's intention. Extensive behavioral data have shown similar results in that the perception of an object automatically elicits motor affordances (Ellis & Tucker, 2000; Grèzes et al., 2003; Phillips & Ward, 2002; Tucker & Ellis, 1998, 2001).

To this day, a focus on motor affordances continues to remain in the spotlight of empirical research. By far and large, the SRC effect has been shown to play a prevailing role in the actualization of motor affordances and has been ascribed to automatic mapping of compatible stimulus-response coding (Kornblum, Hasbroucq, & Osman, 1990). For example, studies have shown that participants respond more accurately and rapidly when the spatial location of a response is congruent with the spatial location of a stimulus, even though the location of the stimulus is *irrelevant* to the task at hand (i.e. the Simon effect (Simon, 1969; Simon & Rudell, 1967)). Three main accounts underlying the manifestation of task-unrelated motor affordance effects have been put forth: (1) specific motor coding, (2) abstract motor coding and (3) attention-directing coding (Symes, Ellis, & Tucker, 2005). Firstly, the notion of specific motor coding holds that there will be facilitation toward the hand of response that is most suited to perform an action. As demonstrated in Tucker and Ellis' (1998) experiment, handle orientation of a graspable object will trigger a quicker response when there is congruency between hand of response and the direction of an object's handle. However, in the past decade or so, the seemingly one-dimensional view of specific motor coding strictly linked to a right- or left-hand facilitation has been challenged. Research has shown that a spatial corresponding scheme may even be evoked from abstract motor codes (Phillips & Ward, 2002; Symes et al., 2005). More specifically, Phillips and Ward (2002) observed that it is not just the response 'hand' that is preferentially activated in SRC designs, but that when participants are asked to make speeded responses with their foot or crossed arms, the effector closest to the visually presented object will gain an advantage. Lastly, in regard to attention-directing coding, it has been proposed that the affordance effect may emerge as a result of the asymmetry of an object. The asymmetrical attribute may lead a viewer's attention toward the part of an object that carries salient features, thus generating an automatic attentional bias response code (Anderson, Yamagishi, & Karavia, 2002; Cho & Proctor, 2010). Phillips and Ward (2002) bring to light that salient features of objects may play an active role in both specific motor coding and abstract motor coding.

In the present study, a simple keypad response experimental design was used in order to investigate whether motor affordances would be evoked in two separate experimental conditions. The purpose of this study served to address: (1) if the observation of graspable objects elicits motor representations that favor a left hemisphere/right hand system (e.g. faster reaction times for the right hand when viewing graspable objects); and (2) whether affordances for graspable objects are automatic (i.e. if they exist independent of the viewer's intention). The novelty of the experimental design resided in that, in general, spatial compatibility influences were avoided. Importantly, for the graspable objects, the majority of stimuli were chosen based on their limited explicit grasping cues in order to steer clear of attentional bias or a SRC effect. More specifically, limited explicit grasping cues refer to objects that do not direct attention to a particular asymmetrical feature within the graspable stimuli. The vast majority of objects used in this study were symmetrical in shape (particularly the nature-made stimuli) and were presented in a wide range of orientations, providing little indication of an effector dependent grasping code. Thus, graspable objects that carried salient grasping features were limited. For the very few objects with handles for example, orientation was counterbalanced between stimuli (e.g. frying pan with handle oriented to the right vs. a coffee pot with handle oriented to the left). Furthermore, all visual stimuli were presented in the centre of a computer monitor in order to remove any influence of response location compatibility.

For the two experiments, pictures of common graspable (e.g. flower) and non-graspable (e.g. boat) objects were presented on a computer screen. In Experiment 1, participants were asked to use their right or left hand to make keypad responses according to whether the object was graspable or non-graspable. We hypothesized that if the left hemisphere specialization for grasping stems from an advantage in processing the visual properties of objects that afford manual interaction, we would expect faster reaction times for the right hand when identifying graspable objects. In a following experiment (Experiment 2) a new set of participants were presented with the exact same stimuli as in Experiment 1 but were asked to categorize objects according to their nature, explicitly, whether an object was nature-made (e.g. flower) or man-made (e.g. boat). The purpose of Experiment 2 served to examine whether task-unrelated motor affordances for graspable objects would be evoked. If the hypothesis put forth in Experiment 1 is confirmed, then Experiment 2 will allow for a further investigation into whether a right-hand advantage exists for graspable objects independent of the viewer's intention. If motor affordances do not require conscious action representations, then faster reaction times would be expected for graspable objects with the right hand regardless of categorization (i.e. nature-made/man-made).

2. Experiment 1: Graspable/Non-graspable categorization

2.1. Methods

2.1.1. Participants

Twenty-one self-reported right-handed individuals and one self-reported left-handed individual took part in the study, ranging between the ages of 16-35. The majority of the participants (eighteen) were from the University of Lethbridge and received course credit for their participation. Four additional participants were recruited from a local high school and came in to the University for testing. Subjects were naïve to the purpose of the study. The study was approved by the local ethics committee and all participants provided written informed consent before commencing.

2.1.2. Material and methods

2.1.2.1. Handedness questionnaire. A modified version of the Edinburgh (Oldfield, 1971) and Waterloo (Brown, Roy, Rohr, & Bryden, 2006) handedness questionnaire was given to all participants (see Stone et al., 2013 for a full version of the questionnaire) at the end of the task. This version of the questionnaire included questions on hand use for 22 different tasks. Participants had to rate which hand they would use for various tasks on a scale of +2 (right always), +1 (right usually), 0 (equal), −1 (left usually), or −2 (left always). Each response was scored as (2, 1, −1, or −2) and a total score was obtained by adding all values. Possible scores range from +44 for exclusive right hand use to −44 for exclusive left hand use.

2.1.2.2. Stimuli. A total of 128 pictures of graspable and non-graspable objects (64 each) were selected from the Bank of Standardized Stimuli (Brodeur, Dionne-Dostie, Montreuil, & Lepage, 2010) and the Hemera Photo-Object Collection (Hemera Technologies Inc., Canada). Graspable objects were defined as objects that could be grasped and picked up with one hand in real-life, whereas non-graspable objects were defined as the opposite—objects that could not be picked up and held with one hand in real-life. This distinction was made clear to the participants at the beginning of the study. Care was taken in selecting stimuli without explicit cues that would prompt a specific hand use. For the few stimuli with explicit grasping cues (e.g. stove pot) included in the study, handle alignment was counterbalanced across the objects. Within each graspable/non-graspable category, 32 were nature-made (e.g. apple, pine tree) and 32 were man-made (e.g. baseball, car). Participants were unaware of this categorization. Stimuli (listed in Appendix A) were presented in a frame of 5.4 cm (width) × 3.4 cm (height) and centrally presented on a 19" computer monitor running at a resolution of 1280 × 1024. Each visual stimulus was presented independently for 185 milliseconds (ms). SuperLab software version 4.0 (Abboud, Schultz, & Zeitlin, 2006) was used for stimulus presentation and response time recording via a key pad (RB Series Cedrus response pad).

2.1.3. Procedure

Participants were seated in a chair in a quiet room with their chin resting on a chin strap to ensure that they maintained central head fixation. A computer monitor was centrally positioned at a distance of approximately 57 cm away from the participants' eyes subtended at a visual angle of 5.4 (horizontal) 3.4 (vertical) degrees. Prior to the experiment, participants were verbally instructed to respond as quickly and accurately as possible to visual stimuli presented on the computer monitor by pressing a key on the response pad. A given participant would respond with his/her index finger if the stimulus was a picture of a graspable object and with his/her middle finger if it was of a non-graspable object. Responding fingers were counterbalanced among participants. Starting hand (left/right) was also counterbalanced among participants and all participants alternated their responding hand halfway through the experiment. Prior to each trial, a black fixation cross (29 pt Arial font, bolded) was centrally presented for 1500 ms. Following the fixation cross, a visual stimulus then appeared for 185 ms. A question mark (29 pt Arial font, bolded) prompted participants to respond and was presented until a response was made or 3000 ms had elapsed. Immediately after the response was made, the fixation cross for the next trial appeared (see Fig. 1 for a schematic representation of the task). Data were analyzed using Statistical Package for the Social Sciences (SPSS) v. 19 with an alpha of 0.05 as significant.

2.2. Results

2.2.1. Handedness questionnaire

Twenty-one participants self-reported as right-handers and one participant self-reported as a left-hander and this was confirmed by the handedness questionnaire. Overall, the average score on the questionnaire was +30.3 (±1.0 SE; range −29 to +41) out of the maximum possible score of +44/−44. Although the left-hander self-reported to write and engage in numerous other activities with their left hand, the results of the behavioral data were consistent with the right-handers. Previous studies have also reported that right- and left-handers show similar hand use patterns (Gonzalez & Goodale, 2009; Gonzalez et al., 2007; Stone et al., 2013).

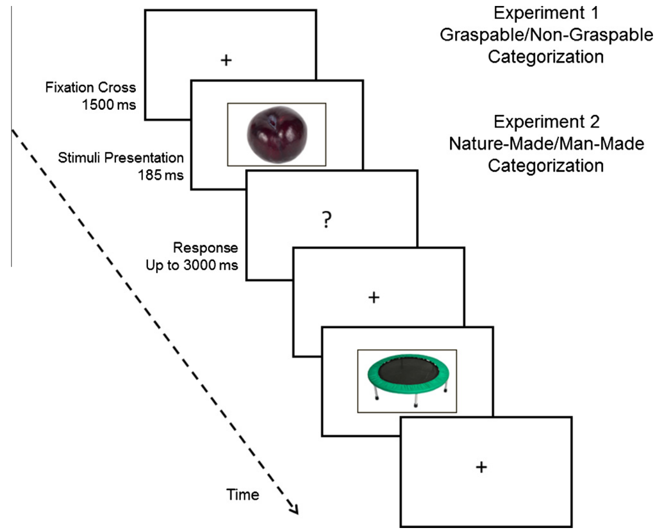

Fig. 1. Experimental Design – Prior to each trial, a black fixation cross was centrally presented for 1500 ms followed by the presentation of a visual stimulus for the duration of 185 ms. A question mark prompted participants to respond and was presented until a response was made or 3000 ms had elapsed. Immediately after the response was made, the fixation cross for the next trial appeared.

2.2.2. Response time

All error (incorrect) responses were excluded from the analysis (3.9%). That is, if a participant responded to a graspable object as non-graspable or vice-versa. Also excluded were reaction times (RT) of 2000 ms or more or 100 ms or less (0.2%). In addition, any responses 2 standard deviations from the mean RT for each participant were also excluded (4.7%). A total of 8.8% of responses were removed from analysis.

The RTs of the remaining responses were submitted into a repeated-measures ANOVA with object type (graspable, non-graspable) and response hand (right, left) as within-subjects factors. A significant main effect was obtained for response hand ($F(1,21) = 5.7$; $p = 0.03$). Participants responded quicker with their right hand ($M = 412.3 \pm 22.4$ ms) than with their left hand ($M = 449.0 \pm 19.9$ ms). Results also revealed a significant interaction between object type and response hand ($F(1,21) = 4.8$; $p = 0.04$; see Fig. 2). Follow-up analysis (pairwise *t-test*) indicated that participants responded quicker with their right hand than with their left hand if an object was graspable ($M = 400.8 \pm 22.2$ ms for the right hand and $M = 451.4 \pm 21.7$ ms for the left hand; $t(21) = -3.16$; $p = 0.01$). Also worthy of remark, is that when responding with the right hand, graspable objects were identified more quickly than non-graspable objects and this finding approached significance ($p = 0.06$). No significant difference was found between hands for non-graspable objects ($M = 423.9 \pm 24.1$ ms for the right hand and $M = 446.6 \pm 19.4$ ms for the left hand; $p > 0.1$).

Lastly, in order to examine whether the finding of a speeded response time favoring the right hand in identifying graspable objects was being driven by a specific object nature (nature-made vs. man-made), a further analysis was performed. Examining RTs for only the graspable objects, a repeated-measures ANOVA with object nature (nature-made, man-made) and response hand (right,

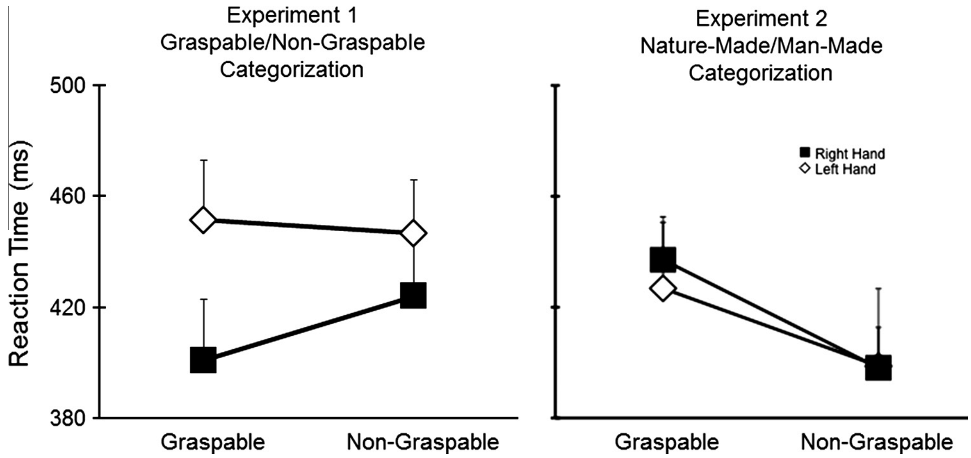

Fig. 2. Mean reaction times measured in milliseconds for graspable and non-graspable visual stimuli in the categorization of graspable vs. non-graspable objects (Experiment 1) and the categorization of nature-made vs. man-made objects (Experiment 2). The black squares represent the mean right hand keypad responses and the white diamonds represent the mean left hand keypad responses.

left) as within-subjects factors, showed a main effect of hand ($F(1,21) = 9.95$; $p = 0.01$). Right hand responses ($M = 400.8 \pm 22.2$ ms) were faster than left hand responses ($M = 451.4 \pm 21.7$ ms). A main effect of object nature was also revealed ($F(1,21) = 32.56$; $p < 0.001$). Reaction times to nature-made objects ($M = 405.9 \pm 20.8$ ms) were significantly quicker than to man-made objects ($M = 446.3 \pm 20.6$ ms). However, no interaction effect was observed ($p > 0.1$), demonstrating that the right hand advantage in identifying graspable objects was not being swayed by the nature of the object.

3. Experiment 2: Nature-made/man-made categorization

The purpose of Experiment 2 was to explore if the right-hand advantage for identifying graspable objects is independent of the viewer's intent.

3.1. Methods

3.1.1. Participants

Twenty-one self-reported right-handed individuals took part in the study, ranging between the ages of 16–35. Thirteen participants were from the University of Lethbridge and received course credit for their participation. Eight additional participants were recruited from a local high school and came in to the University for testing. Subjects were naïve to the purpose of the study. The study was approved by the local ethics committee and all participants provided written informed consent before commencing.

3.1.2. Materials and methods

All apparatus and stimuli were the same as in Experiment 1.

3.1.3. Procedure

All procedures were the same as in Experiment 1 except that participants were instructed to respond to whether the object on the screen was nature-made (e.g. apple) or man-made (e.g. car). No other instruction was given to the participants and they were not informed of the graspable/non-graspable categories of the stimuli.

3.2. Results

3.2.1. Handedness questionnaire

All participants self-reported as right-handers and this was confirmed by the handedness questionnaire. Overall, the average score on the questionnaire was +31.5 (±1.0 SE; range +20 to +39) out of the maximum possible score of +44/−44.

3.2.2. Response time

All error (incorrect) responses were excluded from the analysis (3.1%). Also excluded were reaction times (RT) of 2000 ms or more or 100 ms or less (0.3%). In addition, any responses 2 standard deviations from the mean RT for each participant were also excluded (4.5%). A total of 7.9% of responses were removed from analysis.

The RTs of the remaining responses were submitted into a repeated-measures ANOVA with object type (graspable, non-graspable) and response hand (right, left) as within-subjects factors. Results revealed a main effect of object type ($F(1,20) = 18.96$; $p < 0.001$). Participants responded quicker to non-graspable objects ($M = 398.4 \pm 16.3$ ms) than to graspable objects ($M = 431.0 \pm 18.6$ ms). No main effect of hand and no significant interactions were found ($p > 0.4$).

3.2.3. Comparison between Experiment 1 and Experiment 2

To further compare the results from both experiments, a repeated-measures ANOVA was conducted, with Experiment (1, 2) as the between-groups factor and object type (graspable, non-graspable) and response hand (right, left) as within-subjects factors. The analysis revealed a significant main effect of object type ($F(1,41) = 4.06$ $p = 0.05$) where non-graspable objects ($M = 416.8 \pm 13.0$ ms) were identified more quickly than graspable objects ($M = 429.0 \pm 13.8$ ms). Results also showed a significant interaction between response hand and Experiment ($F(1,41) = 4.59$ $p = 0.04$). Participants in Experiment 1 responded faster with their right hand ($M = 412.3 \pm 22.4$ ms) when compared to their left hand ($M = 449.0 \pm 19.8$ ms). This was not the case for Experiment 2 in which comparable RTs were found for both hands ($M = 417.6 \pm 20.9$ ms for the right hand and $M = 412.8 \pm 14.6$ ms for the left hand). Moreover, there was a significant interaction between object type and Experiment ($F(1,41) = 12.43$, $p < 0.01$). Participants from Experiment 2 responded to non-graspable objects

($M = 398.4 \pm 16.3$ ms) significantly quicker than participants from Experiment 1 ($M = 435.3 \pm 20.1$ ms). Importantly, a significant interaction between response hand, object type, and Experiment was observed ($F(1,41) = 4.05$, $p = 0.05$). A follow-up independent samples *t-test* indicated that graspable objects were identified faster with the right versus the left hand ($p < 0.01$) but only in Experiment 1 ($M = 400.8 \pm 22.2$ ms for the right hand and $M = 451.4 \pm 21.7$ ms for the left hand in Experiment 1; $M = 437.1 \pm 23.8$ ms for the right hand and $M = 426.1 \pm 19.7$ ms for the left hand in Experiment 2). All other comparisons between hands were not significant ($p > 0.19$).

4. Discussion

The purpose of the current research was to investigate whether the visual presentation of graspable objects would elicit motor affordances that favor the left hemisphere/right hand. While numerous studies have shown support for the idea that perceiving graspable objects (e.g. mainly objects with handles) potentiates components of the actions they afford (e.g. grasping), few have investigated manual asymmetries in response to task-unrelated graspable objects that carry limited explicit grasping cues (e.g. fruit). The results showed a right hand advantage in identifying graspable objects but only when participants were asked to specifically attend to an object's graspability. In other words, when participant's attended to properties that were unrelated to motor affordances, no hand differences were found.

Numerous studies have shown laterality for manual movements (e.g. Corballis, 2003; Hinojosa, Sheu, & Michel, 2003; Knecht et al., 2000) with a right-hand preference for grasping (Fagard & Lockman, 2005; Gonzalez et al., 2006; Mamolo et al., 2004, 2005, 2006; Sacrey et al., 2012). This has even been demonstrated when equal opportunity to use both hands is given to participants (e.g. Carlier et al., 2006; Stone et al., 2013). Moreover, this right hand preference is more pronounced when the action is guided by vision (Stone & Gonzalez, 2013) and has even been observed in some left-handers (Gonzalez & Goodale, 2009; Stone et al., 2013). Kinematic studies have also evidenced right-hand advantages for reaching (Bryden & Roy, 2006; Gabbard & Rabb, 2000; Mamolo et al., 2004) and grasping (Flindall, Doan, & Gonzalez, 2013; Flindall & Gonzalez, 2013; Gonzalez et al., 2006). For example, reaching movements have been shown to be faster and more accurate when executed with the right hand (Elliott & Chua, 1996; Fisk & Goodale, 1985). This result has led investigators to infer that the asymmetries stem from a left-hemisphere advantage in processing and/or integrating visual information relevant for action (Flowers, 1975; Roy, Kalbfleisch, & Elliott, 1994).

Here we hypothesized that the right-hand advantage reported for visually-guided grasping could stem from a left-hemisphere advantage in identifying visual stimuli that afford a grasping representation. Furthermore, we hypothesized that if motor affordances do not require conscious action representations, then faster reaction times would be expected for graspable objects with the right hand regardless of categorization (i.e. nature-made/man-made). In Experiment 1 we explicitly asked participants to categorize objects as graspable/non-graspable depending on whether, in real-life they would be able to grasp it and pick it up using one hand. The results from Experiment 1 supported the preliminary hypothesis; participants responded faster with their right hand than with their left hand when categorizing graspable objects. This finding was reinforced through a between Experiment comparison. A 3-way significant interaction showed that responses to graspable objects were quicker when made with the right hand but only in Experiment 1. It is reasonable to speculate that upon judging an object's potential for grasping, participants formed a manual representation that featured the right hand, specifically because it is the hand most often used for grasping (e.g. Fagard & Lockman, 2005; Stone et al., 2013). This conscious representation would explain the quicker right hand reaction times observed when categorizing objects as graspable. This finding supports the idea of a left-hemisphere advantage in identifying visual stimuli relevant to grasping. This advantage however, appears only to be for conscious representations as there was no right-hand advantage for graspable objects when participants categorized them as nature-made/man-made (Experiment 2).

Bub and Masson (2010) apply the term *standard mapping* to refer to the phenomenon of automatically evoked action representations that are independent of the observer's intentions. Standard mapping effects have been reported on numerous accounts (McBride, Sumner, & Husain, 2012; Tipper, Paul, & Hayes, 2006; Tucker & Ellis, 1998; Vainio, Symes, Ellis, Tucker, & Ottoboni, 2008). Such studies have shown for example, that if the handle of a coffee pot is oriented toward the right, responses are faster if made with the right hand (as opposed to the left) even though information about the orientation of the coffee pot is irrelevant to the participant's response. Likewise, if the object's handle is oriented toward the left, a left-hand advantage will be yielded (Tucker & Ellis, 1998). In contrast to standard mapping, the term *contextual mapping* is used to refer to action representations that depend upon the observer's intentions (Bub & Masson, 2010). While standard mapping would facilitate a right hand grasp if an object's handle is oriented to the right, contextual mapping could apply to a right or left hand grasp depending on the individual's intentions. For example, when a coffee pot is located on the left side of a table (regardless of handle orientation) and an individual decides to use their left hand to grasp the pot in ipsilateral space, a contextual mapping scheme would be actuated. Moreover, contextual mapping would be congruent with standard mapping if an individual decides (or is required) to use his/her right hand when an object's handle is oriented toward the right or incongruent if an individual uses his/her left hand.

The current study supports the contextual mapping view of affordances, as action representations facilitated right hand responses only when participants were asked to judge an object's graspability (Experiment 1). The fact that motor affordances were not revealed in Experiment 2, even in light of some stimuli carrying a grasping configuration, suggests that task-unrelated motor affordances (i.e. standard mapping) reported in previous research may be due to attentional or spatial bias. Further support for the contextual mapping notion has been shown in a study conducted by Tipper et al. (2006). Their results demonstrated that when participants were instructed to attend to the color of an object (e.g. a door handle), automatic motor representations did not occur. However, when responding to the shape of the handle, automatic motor representations were observed. Color is irrelevant to motor affordances, whereas shape is central to motor affordances (i.e. how an object might be grasped). Thus, Tipper et al. (2006) posited that the property of an object being attended to is imperative to whether action affordances will be potentiated or not. Similarly, the results from our study demonstrated that when responding to whether an object was nature-made/man-made (a property unrelated to an object's graspability), motor affordances did not translate even though the exact same stimuli were presented in both Experiment 1 and Experiment 2. Upon comparing the 'color' condition of Tipper et al. (2006) study to the 'nature-made/man-made' condition (Experiment 2) of the present study, it can be noted that both required participants to respond to object properties that were not intrinsic to any general motor scheme.

An important point to consider concerns the stimuli utilized in the current investigation. Participants were presented with pictures of common graspable objects that carried limited explicit grasping cues that could be associated with the use of a particular hand. Explicit grasping cues such as handle alignment or an object's location in space have been shown to lead to SRC effects where one effector may be favored over the other. It is hard to imagine man-made graspable objects that would not convey any type of grasping scheme—an object that fits in the hand, by definition, would afford grasping. Although some of the graspable objects in the present study did indeed carry a grasping representation (e.g. Nintendo controller), attentional bias to the left or right side of space was generally avoided by presenting participants with primarily symmetrical objects. By the same token, spatial facilitation cues were omitted given that objects were centred in the middle of the screen. This experimental design and choice of stimuli generally afforded the possibility for either hand to be equally activated in the formation of a grasping representation. Furthermore, half of the stimuli included in the graspable object repertoire consisted of natural objects (fruits and vegetables). This is important because tool use (praxis) has been widely studied and known to be lateralized to the left cerebral hemisphere, particularly the left parietal and premotor cortices (Chao & Martin, 2000; Creem-Regehr & Lee, 2005; Culham & Valyear, 2006; Grafton, Fadiga, Arbib, & Rizzolatti, 1997; Johnson-Frey, 2004; Johnson-Frey, Newman-Norlund, & Grafton, 2005), but much less is known in regard to the motor activation involved while interacting with common graspable objects such as fruits and vegetables. Worthy of remark, is that if man-made graspable objects (e.g. Nintendo controller) held greater motor affordances than nature-made graspable objects, we would have expected a main effect of object nature favoring the former (i.e. faster reaction times for man-made objects) or an interaction of hand $\times$ object nature in Experiment 1 (See Section 3.2). Opposite to this expectation, we found that reaction times to nature-made graspable objects were significantly quicker than to man-made graspable objects.

The results of our study suggest that the presentation of graspable objects in general, might not automatically activate left frontoparietal networks. If these networks were automatically induced upon viewing graspable objects, one would expect a left-hemisphere advantage for graspable objects regardless of categorization mode (graspable/non-graspable, nature-made/man-made). It has been shown that tool-selective parietal areas of the brain show significantly greater activation during the naming of tools than during the naming of graspable objects (e.g. an apple; Culham, Valyear, & Stiglick, 2004). This finding suggests that tool recognition is allocated to a distinctive neural network in the brain, as opposed to other graspable objects. Creem-Regehr and Lee (2005) explain how tools are unique objects because of the visual cues that tools possess in terms of action affordance and functional identity. Therefore, it is possible that viewing pictures of tools, but not everyday graspable objects (e.g. apple, baseball), may evoke robust lateralized neural network activation for automatic action representations. On the other hand, our results lend support to the notion that motor affordances for graspable objects might be lateralized to the left hemisphere but only during the conscious formation of a grasping representation. This is, perhaps, because grasping actions are preferentially performed with the right hand—a preference that can be found in some left-handed individuals (Gonzalez & Goodale, 2009; Gonzalez et al., 2007; Stone et al., 2013) and that can be traced to non-human primates (Hopkins, 1993; Hopkins, Cantalupo, Wesley, Hostetter, & Pilcher, 2002; Hopkins, Russell, Hook, Braccini, & Schapiro, 2005).

Lastly, it is worth noting that although our results demonstrate a right hand/left-hemisphere advantage when categorizing visual stimuli as graspable, a study has shown hand advantage differences depending on the size of an object (Vainio, Ellis, Tucker, & Symes, 2006). The researchers asked participants to respond to a target arrow (pointing left or right) displayed over a computer generated wood-texture object by squeezing a precision or power grip device or by making left or right hand keypad responses. The experimental objects varied in size, either affording a power or precision grasp. The results revealed that the right hand responded more quickly to objects that would afford a precision grasp and the left hand to objects that would afford a power grasp. Based on this result, the authors speculated a left hemisphere specialization for precision grasps and a right hemisphere specialization for power grasps. In the current investigation, objects that could afford both a precision or a power grasp were included. In fact, more objects (particularly man-made) afforded a power grasp than a precision grasp and yet, only a right hand advantage was observed. It is possible that differences in the experimental design may have led to the different results between the two studies. In the current study, 64 different real-world common objects were used as stimuli, whereas only 24 non-real-world 3D computer-generated objects were used in the study by Vainio et al. (2006). Importantly too, research has shown left hemisphere activation when individuals are presented with pictures that represent real-world small objects (e.g. strawberry) and right hemisphere activation for pictures that represent real-world big objects (e.g. piano; Konkle & Oliva, 2012). The real-world graspable objects investigated by Konkle and Oliva included objects that could afford both types of grasps (precision/power) and nevertheless, activation occurred primarily in the left hemisphere. It is possible that the results observed by Vainio et al. are due to their use of size-manipulated, unfamiliar, non-real world stimuli that would not carry a semantic representation.

Unlike the manipulation of object size applied by Vainio et al., all stimuli used in our study were presented as the same size. One may argue that displaying both graspable and non-graspable objects in the same visual dimension may introduce a discrepancy in that non-graspable-objects are in fact much larger in real-life. However, differences in object size may potentially lead to speeded reaction times in favor of larger objects. For instance, studies that have compared graspable objects of varying sizes have reported that the larger objects are responded to faster than the smaller objects (e.g. Grèzes, Tucker, Armony, Ellis, and Passingham, 2003; Derbyshire, Ellis, & Tucker, 2006; Olivier & Velay, 2009; Tucker & Ellis, 2001). Of equal importance, previous studies have found a motor scheme activation for graspable objects even while keeping stimuli size consistent among graspable and non-graspable objects (Rice, Valyear, Goodale, Milner, & Culham, 2007; Wilf, Holmes, Schwartz, & Makin, 2013). For example, Wilf et al. (2013) reported task-irrelevant affordance effects for graspable objects while participants engaged in a keypad response task. By the same token, Rice et al. (2007) conducted an fMR adaptation study and presented participants with images of graspable and non-graspable objects of the same dimensions where it was observed that a region of the dorsal stream (the lateral occipito-parietal junction) was sensitive to the orientation of graspable objects but not to non-graspable objects. Lastly, it has been shown that certain regions of the brain are preferentially activated depending on whether an object is graspable or non-graspable, regardless of object size manipulation (Konkle & Oliva, 2012). These findings suggest that the absolute real-world size of the object holds constant, despite the illusory size of the object. Also worth noting is that, in regard to our findings, if the discordance between screen size and real-world object size of the non-graspable objects being viewed acted as a confound, we would likely not have observed a hand by object interaction in Experiment 1 in favor of responding to *graspable* objects with the right hand.

In conclusion, the results from the current investigation indicate that motor affordances for everyday graspable objects favor the right hand but may not always be automatic, requiring a conscious representation relevant for object interaction.

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Conflicting interests

The authors declare no conflicting interests.

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Appendix A

Nature-made graspable objects:	Nature-made non-graspable objects:
Almond	Bear
Ammonite	Buffalo
Artichoke	Bull
Asparagus	Camel
Avocado	Cougar
Banana	Cow
Birch leaf	Deer
Blood orange	Dog
Blueberries	Elephant
Broccoli	Elk
Cantaloupe	Fawn
Carrot	Fox
Celery	Giraffe
Cherry	Goat
Chili pepper	Goose
Cilantro	Hippopotamus
Corn on the cob	Horse
Daisies	Kangaroo
Leek	Leopard
Mango	Lion
Mushroom	Mountain goat
Oak leaf	Oak tree
Peach	Panda
Peanut	Penguin
Pomegranate	Pine tree
Purple plum	Polar bear
Raspberry	Pony
Red berries	Seal
Red flower	Tiger
Red plum	Wallaby
Tulip	Wolf
Yellow rose	Yak

Man-made graspable objects:	Man-made non-graspable objects:
Baseball	Ambulance
Bleach bottle	Army tank
Bowling pin	Bench
Bowtie	Boat
Calculator	Building
Champagne bottle	Bulldozer
Cigarette	Castle
Coffee pot	Chest
Cup	Crib
Eye shadow	Desk
Film roll	Door
Flashlight	Dresser
Flask	Drum set
Gameboy	Dune buggy car
Golf ball	Fountain
Hot chocolate package	Garbage bin
I pod	Gazebo
Lego man	Glass cart
Lipstick	Go cart
Mickey Mouse hat	Golf cart
Necklace	Helicopter
Nintendo controller	House boat
Oven mit	Reclining chair
Paintbrush	School bus
Potato chips	Shopping cart
Spray bottle	Staircase
Stove pot	Stove
Sunglasses	Swing set
Toy cow	Theatre chairs
Visa card	Tractor
Watch	Trampoline
Wok	Wagon

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