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THE HANDLE ORIENTATION EFFECT: CRITICAL ATTENTIONAL FACTORS THAT HAVE RECEIVED LITTLE TO NO ATTENTION

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The thesis was submitted in English, containing:

- Main text (96 pages)
- 136 references (13 pages)
- 19 Tables
- 24 Figures
- 4 Appendices, showing all experimental stimuli and their visual specifications (28 pages)

Tables and Figures included in this extended abstract are numbered as they are found in the thesis.

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Abstract

In 1998, Tucker and Ellis found that keypress responses are faster when the task-irrelevant orientation of a graspable object's handle corresponds to the location of the response hand. Over the past fifteen years, researchers have disagreed over the extent to which grasping affordance or spatial compatibility contribute to the effect. However, this ongoing debate has been taking place in the absence of a thorough discussion on the low-level perceptual characteristics of experimental stimuli, which may be the cause behind conflicting findings and interpretations. The present investigation argued that these factors, relating to visual salience and the exogenous deployment of attention, may be critical to the occurrence of the stimulus-response compatibility effect. Six experiments were performed, which demonstrated that the compatibility effect can be reliably modulated to occur in the direction of the object handles, or their bodies, by manipulating the object's shape asymmetries between the two hemifields. Similar patterns of results across different levels of object detail (photographs and silhouettes) and across different tasks (form-processing and color-processing) indicated that the observed effects were of a perceptual nature, unrelated to grasping affordance. The notion of shape-based Simon effects was introduced to accommodate the findings of the investigation. They were argued to occur in relation to the perceptual asymmetries within the global shape of the stimuli, as a function of their horizontal positioning around the center. These shape-based Simon effects, which have not been addressed in the relevant literature, appeared to be different from the typical location-based Simon effect, in terms of temporal dynamics. Taken together, the findings of the six experiments suggested that the Tucker and Ellis paradigm for studying variable affordances is extremely vulnerable to perceptual effects, which are based on visual salience. This problem is only exacerbated when visually-complex stimuli are primarily discussed in terms of their graspable nature and relation to task, rather than their low-level, attention-capturing features.

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1. Structure and Overview of the Thesis

Chapter 1 provided a very brief overview of the origins of stimulus-response compatibility effects (SRC), tracing them back to the work of Fitts and Seeger (1953), and Fitts and Deininger (1954).

Chapter 2 introduced the Simon effect, including its main characteristics with regard to behavioural data, as well as the two most widely accepted dual-process models, which explain its occurrence.

Chapter 3 discussed Tucker and Ellis' original experiment (1998) and their motor interpretation of the Handle orientation effect.

Chapter 4 drew a parallel between the Simon and the Handle orientation effects, on the basis of visual attention. An overview of the most important theoretical developments in visual attention was provided, after which a number of prominent studies were discussed, suggesting that both the Simon and the Handle orientation effects may share similar underlying mechanisms rooted in attention.

Chapter 5 discussed some of the most notable methodological attempts in dissociating between the two effects.

Chapter 6 presented the rationale, focus and general considerations of the present investigation, in light of the previous findings.

Chapters 7 to 13 reported and discussed a series of six experiments, aimed at exploring the role of visual salience in the occurrence of the Handle orientation effect.

Chapter 14 offered a distributional analysis of the compatibility effects observed in Experiments 3-6, so as to compare and contrast them with respect to their temporal dynamics.

Chapter 15 discussed the findings of the investigation and their implications for past and future research involving the Tucker and Ellis paradigm (1998).

Following the list of references, Appendices A to D included all stimuli from the six experiments, along with their relevant visual specifications.

2. The Simon Effect

The Simon effect is an effect of irrelevant stimulus location, whereby responses are faster and more accurate when stimulus location, albeit irrelevant to the task, corresponds to response location. For example, participants would be faster in executing a left response to the color of a stimulus, if it appeared on the left side of the screen (see Simon, 1990). According to a comprehensive review by Proctor and Vu (2006), the Simon effect ranges between 15-30ms for visual and 40-60ms for auditory stimuli. An important characteristic of the Simon effect is that it is preserved across a variety of response mappings, including crossed (contralateral) hand placements (Wallace, 1971), as well as unimanual, two-finger choice reactions (Heister, Ehrenstein, & Schroeder-Heister, 1987).

Dual process models attribute the Simon effect to an interaction between two parallel processing routes. The "conditional" route is said to be slow, intentional and task-oriented, whereas the "unconditional" route is fast and automatic. It is argued that the Simon effect arises when the two routes converge at the stage of response-selection. If the task-dependent response that has been activated in the conditional route does not correspond to the automatic location-dependent code activated in the unconditional route, then a response conflict would have to be resolved, thereby increasing RTs and error rates (De Jong, Liang, & Lauber, 1994).

3. The Handle Orientation Effect

Tucker and Ellis (1998) found a SRC effect based on the task-irrelevant orientation of the handle of a common graspable object. In Experiment 1 of their original study (1998), they presented subjects with images of graspable everyday objects, such as frying pans, screwdrivers and teapots. The objects appeared at the center of the display, along two vertical orientations (upright vs. upside-down) and two horizontal orientations (object handle pointing leftward vs. rightward). The participants were required to perform a type of object recognition task, by responding bimanually whether the object was presented upright or it was inverted. Bimanual responses were faster when response-hand corresponded to the orientation of the graspable handle.

Unlike the Simon effect, which is preserved with unimanual responses, Tucker and Ellis (1998) did not observe any handle orientation effect for within-hand responses. As a result, they dismissed the abstract coding account of the Simon effect and advocated a view based on motor representations and grasping affordance. Their central idea was that the orientation of a graspable handle created action-compatibility for the corresponding hand, thereby facilitating RTs.

4. Visual Attention, the Simon and the Handle Orientation Effects

The field of research in visual attention is extremely broad and diverse. For the purposes of the thesis, an overview of the most important theoretical developments was provided, including the three main types of visual attention: spatial attention, object-based attention (OBA) and feature-based attention (FBA), as well as exogenous and endogenous deployments of spatial attention. Exogenous attention is a stimulus-driven component (bottom-up), which involuntarily allocates attention to a salient event in the visual field. This system allows a stimulus to automatically capture the attention of the observer so as to improve action and perception within the context of his/her surrounding environment. Conversely, endogenous attention is goal-driven (top-down) and is voluntarily deployed and sustained by the observer in light of his/her task requirements (see Posner, 1980).

An emphasis was placed on visual search paradigms, which have allowed us to identify basic visual features that attract attention exogenously. In visual searches, a subject has to locate a target amongst a variable number of distractors. According to Treisman and Gelade's "feature-integration theory" (1980), if the time to find the target is not affected by the number of distractors, the target is said to be a "singleton", which is unique in some basic visual dimension, compared to the distractors. On the basis of its uniqueness, this singleton is found at a relatively constant rate, irrespective of the number of surrounding distractors, because it automatically "pops out" and induces attentional capture, i.e., an exogenous shift in attention. Based on studies using the visual search paradigm, a number of basic visual features have been identified, which are conducive to automatic attentional capture. These are: relative size, color, luminance, orientation, depth and motion (for review, see Wolfe, 1998). The attentional capturing properties of basic visual features have given rise to the notion of "visual salience" as a guiding factor in the deployment of exogenous attention. It has been argued that a visual scene is initially scanned on the basis of exogenous deployments of attention, which begin at the most salient regions and sequentially move on to spatial locations in descending order of salience (Koch & Ullman, 1985).

It is also worth noting that Folk, Remington, and Johnston (1992) introduced the notion of contingent capture, to try to account for the interaction between endogenous and exogenous attention. They argued that automatic attentional capture depends on the observer's goal-directed attentional set. For example, if color is the observer's task-relevant dimension, then visual salience defined by color is much more likely to produce attentional capture, compared to other visual features, such as luminance (Folk et al., 1992).

With regard to visual attention and the Simon effect, this section discussed the attention-shift account (Nicoletti & Umiltà, 1989, 1994), which has received substantial empirical support. The fundamental idea of the attention-shift hypothesis is that the direction of the last shift of attention generates the stimulus spatial code prior to the response-selection phase (Rubichi et al., 1997). For example, if a stimulus appears on the right side of fixation, attention would have to be oriented rightward and this directional shift would generate a "right" spatial code for the stimulus. This "right" spatial code could then interfere with a "left" response code and produce slower RTs, essentially creating the Simon effect.

Two studies were discussed, which suggested that visual attention may also be critical to the occurrence of the Handle orientation effect, bringing it closer to the Simon effect. Anderson et al. (2002) argued that corresponding handles produce faster RTs, not because of grasping affordance, but because they represented visually-salient and asymmetric object cues, which attracted attention. Phillips and Ward (2002) also challenged the affordance account by showing a correspondence effect between handle orientation and response location for contralateral hand placements, as well as foot responses. These findings led the authors to suggest that the Handle orientation effect should be attributed to abstract spatial coding, rather than grasping affordances.

5. Dissociating the Simon and the Handle Orientation Effects

Based on the two studies by Anderson et al. (2002) and Phillips and Ward (2002), it became evident that attention may modulate the spatial coding within the affordance task in a manner similar to the Simon task, thereby rendering both effects more closely related than previously thought. These findings triggered a subsequent effort aimed at dissociating the Simon and the Handle orientation effects. One line of research manipulated both object orientation and object location. However, results were mixed, with Symes et al. (2005) suggesting that the two effects are independent of one another, while others argued that they are related (Iani et al., 2011; Riggio et al., 2008). Cho and Proctor (2010) took an altogether different view and insisted that the two effects are one and the same. According to them, the orientation effect was completely unrelated to the graspable nature of a handle, and instead represented a within-object Simon effect.

A more recent approach in attempting to dissociate between the Simon and the Handle orientation effects was presented by Pappas (2014). In reviewing the literature, he argued that studies advocating the motor account of the Handle orientation effect typically used detailed photographs as stimuli (e.g., Symes et al., 2005; Tucker & Ellis, 1998), whereas research favoring the spatial coding or the attentional accounts, relied on simplistic drawings and silhouettes (e.g., Anderson et al., 2002; Cho & Proctor, 2010; Phillips & Ward, 2002). In his experiments, Pappas (2014) manipulated object detail by using both photographs and silhouettes of a frying pan. Additionally, responses were made between-hand or within-hand. Pappas argued that the absence of object detail and environmental depth (i.e., silhouettes) produced a Simon effect, characterized by a significant SRC effect for both bimanual and unimanual response types. In contrast, photographs yielded only a significant between-hand effect, which he interpreted as a SRC effect based on grasping affordance (Pappas, 2014).

6. Rationale for Current Work

Over the past fifteen years, the Tucker and Ellis paradigm (1998) has served as a breeding ground for hypotheses, findings and discussion. The initial debate, which was characterized by mutual exclusivity between the motor-account and the attention/spatial compatibility accounts, has in recent times, given way to a more balanced view that both grasping affordance and spatial compatibility contribute to the observed RT differences (Iani et al., 2011; Pappas, 2014; Riggio et al., 2008; Saccone, Churches, & Nicholls, 2016; Symes et al., 2005). Nevertheless, as discussed in the preceding sections, there is still a distinct lack of clarity regarding the underlying mechanisms involved.

The central idea behind the current investigation was to place an emphasis on visual salience, while exploring SRC effects using the Tucker and Ellis paradigm (1998). It can be said that, despite the presentation of pictures of graspable objects, the Tucker and Ellis procedure caters to attentional effects more so than to graspable affordance. One reason is that keypress responses are completely detached from actual reaching and grasping actions that may be afforded by a stimulus (Bub & Masson, 2010). Moreover, the abrupt onsets of the stimuli inevitably result in directional deployments of attention. As previously discussed, these very shifts in attention have been implicated in producing spatial compatibility effects (Nicoletti & Umiltà, 1989, 1994; Rubichi et al., 1997).

Some studies, which attempted to dissociate between the Simon and affordance effects, manipulated both handle orientation and object location (left or right hemifield; Riggio et al., 2008; Symes et al., 2005). However, this approach is unconvincing, considering that the Simon effect has been shown to occur within multiple frames of reference (i.e., within a hemifield; Lamberts et al., 1992; also see Anderson et al., 2002). Other studies have distinguished between the two effects on the basis of task (color-processing or form-processing; Tipper et al., 2006) or object detail (photographs or silhouettes; Pappas, 2014). These manipulations have demonstrated distinct compatibility components to the observed RT differences, but have come short of isolating an effect based purely on grasping affordance. On the other hand, researchers opposed to the affordance effect have used off-center stimuli, where most of the object area occupied either the left or right hemifield, essentially suffocating any affordance and resulting in explicit spatial compatibility (Cho & Proctor, 2010, 2013; Lien et al., 2013, 2014).

Against this backdrop of previous findings and methodological approaches, the main research question of the present investigation was whether or not an effect based solely on grasping affordance exists within the Tucker and Ellis paradigm (1998), and whether or not it can be isolated from spatial compatibility effects. The literature on the Handle orientation effect lacks an extensive discussion on the low-level perceptual characteristics of stimuli and their horizontal positioning. However, both of these factors relating to attentional capture, are critical in producing directional shifts based on visual salience (see Wolfe, 1998). A greater understanding of the exogenous deployment of visual attention, within the Tucker and Ellis paradigm (1998), would be beneficial in accounting for spatial compatibility effects of centered stimuli, in reconciling previous findings, and possibly, in controlling these confounding factors.

From a visual salience perspective, it could be argued that previous studies on the Handle orientation effect have adopted a haphazard approach of using very diverse stimulus sets, with large differences in color, shape and size between the graspable objects (e.g., Saccone et al., 2016; Yu et al., 2014). To allow for a more precise and ordered account of the effects, the stimulus set used in the present series of experiments was relatively homogeneous in terms of shape and consisted of grayscale photographs of 7 frying pans, 7 sauce pans and 7 bowls/plates. Under the attention-account of the Handle orientation effect (Anderson et al., 2002), frying/sauce pans were considered as suitable stimuli due to their high degree of visual asymmetry. They also met the prerequisites for the motor-account (Tucker & Ellis, 1998), with their everyday use relying, almost exclusively, on grasping interaction with their handles. Pictures of bowls/plates were selected as a control condition because of their vertical line symmetry and lack of handles. Taking note of the study by Pappas (2014), all photographs contained a high level of object detail, so as not to eliminate any effects of grasping affordance.

7. Experiment 1

The apparatus, design and procedure were almost identical across the six experiments. In the interest of brevity, aspects common to all experiments are presented together, at the beginning of this section, whereas the differences, such as stimuli and task, are emphasized in the respective experiment's description.

Participants

A total of 347 students (aged 18-51) from the New Bulgarian University participated in the study (Exp.1: 62; Exp.2: 61; Exp.3: 60; Exp.4: 48; Exp.5: 56; Exp.6: 60). All had normal or corrected-to-normal vision and were naïve as to the purpose of the experiments. On the basis of a modified handedness scale, those who failed to fulfil the criteria for strong right hand dominance were removed from the analysis (Exp.1: 5; Exp.2: 3; Exp.3: 9; Exp.4: 6; Exp.5: 4; Exp.6: 8). Those with error rates exceeding 10% were also excluded (Exp.1: 1; Exp.2: 5; Exp.3: 2; Exp.4: 2; Exp.5: 1; Exp.6: 2).

Apparatus and Stimuli

The experiments were conducted in a sound-proof booth using E-prime 2.0 for the presentation of stimuli, and recording of accuracy and RTs. Stimuli were presented at a distance of 65cm, on a 19" LCD display (1280x1024@60Hz). Each object was fit into a 768 x 323 pixel matrix, which corresponded to a visual angle of 19.8° x 8.4° (only in Experiment 6 was the stimulus size changed to 6° x 2.5°). Objects appeared centered, on a white background.

Procedure

Each trial began with a black fixation cross at the center of a white background. After 300ms, the stimulus object appeared in place of the fixation cross and remained on screen until the participant made a response, or up to a maximum of 1500ms. Inter-trial interval was set to 1000ms. Participants were required to respond bimanually, depending on the task. Responses were executed on a standard QWERTY keyboard by pressing "Z" or "Num 3" (37cm apart) with the left or right index finger, respectively. Response-mapping was counterbalanced across participants. Trials were pseudo-randomized so that no more than two consecutive responses were executed on the same side of space.

As discussed in the preceding sections, researchers have attempted to disentangle the Simon and the Handle orientation effects, by manipulating both object location (left or right hemispace) and handle orientation (Iani et al., 2011; Riggio et al., 2008; Symes et al., 2005). However, the overall utility of such procedures, in dissociating between the two effects, is questionable. Firstly, their results can be ambiguous, considering that the Simon effect does not only occur between hemispaces, but also within a hemifield (Lamberts et al., 1992) and within-object (Anderson et al., 2002). Secondly, their findings can be difficult to relate to the more standard variant of the Tucker and Ellis (1998) paradigm, where objects are presented centrally.

The idea behind Experiment 1 was to take a different approach and use centered objects, which would feature colored markers in their leftmost/rightmost regions (see Figure 5). When placed on grayscale photographs, these colored markers (red/green) were expected to “pop out” and reliably produce exogenous shifts of attention to the left or right side of space (see Wolfe, 1998). In Experiment 1, this set-up was applied to a Simon-like task, where participants had to respond based on the color of the marker. A Simon effect was expected based on the correspondence between color location (left/right) and response-hand (left/right). However, it was unclear whether a Handle orientation effect would also be observed. It has been argued that the Handle orientation effect is absent in color-processing tasks because it requires object recognition, as well as form-processing (Symes et al., 2005; Tipper et al., 2006), however, this claim has been disputed (see Cho & Proctor, 2010).

Figure 5. Examples of stimuli used in Experiment 1.

Table 1. Experiment 1: Means (in ms), (SDs) and (95% CIs) of RTs, as a function of stimulus-response type, collapsed into compatible and incompatible trials. Note: size of the compatibility effect was computed by subtracting compatible from incompatible RTs.

	Compatibility	Compatible Mean (SD)(95% CI)	Incompatible Mean (SD)(95% CI)	Compatibility Effect (ms)
Experiment 1	Hand-Handle	492 (75)(478-506)	492 (76)(478-507)	0
	Hand-Color	470 (73)(459-481)	515 (72)(504-526)	45^{***}

**p<.05, **p<.01, ***p<.001*

A significant Simon effect was present, with responses being 45ms faster when the location of the colored marker corresponded to response-hand. A Handle orientation effect was not detected. Typical Simon tasks usually involve two or more separate objects, which appear in distinct spatial locations (for review, see Proctor & Vu, 2006). The attentional capture, brought about by the onset of a new object (Yantis & Jonides, 1996), can be used to explain the effect of irrelevant stimulus location, using the attention-shift hypothesis (Nicoletti & Umiltà, 1989, 1994). In the case of Experiment 1, it was interesting to observe that the Simon effect can also emerge on the basis of the colored markers that were placed within the boundaries of a single, centered object. However, the locations of the markers themselves were distinctly to the left or right of the subject's midsagittal line. It should also be noted that the findings of Experiment 1 did not provide any evidence of an automatic attentional capture by the markers, because the task itself required the participants to attend to the colors. The distinct lack of a Handle orientation effect, during this color-processing task, could be interpreted in favor of the view that object recognition and form-processing are necessary for the occurrence of such an effect (Symes et al., 2005; Tipper et al., 2006).

8. Experiment 2

Experiment 2 aimed to determine whether a form-processing task would yield a Handle orientation effect, which lacked in Experiment 1. In this case, subjects had to respond bimanually, depending on the vertical orientation of the object (upright/upside-down), as in Tucker and Ellis (1998). Based on previous findings, such an effect is expected to be observed (Symes et al., 2005; Tipper et al., 2006). Also of interest was whether or not a Simon effect based on the location of the colored markers would occur, despite the colors being completely irrelevant to the task. Finally, if both a Handle orientation effect, as well as a Simon effect emerge, it would be useful to ascertain whether they interact with each other or have separate and additive effects on performance. Such an analysis may indicate whether the two effects are independent, or they share common mechanisms (Sternberg, 1969).

Table 4. Experiment 2: Means (in ms), (SDs) and (95% CIs) of RTs, as a function of stimulus-response type, collapsed into compatible and incompatible trials. Note: size of the compatibility effect was computed by subtracting compatible from incompatible RTs.

	Compatibility	Compatible Mean (SD)(95% CI)	Incompatible Mean (SD)(95% CI)	Compatibility Effect (ms)
Experiment 2	Hand-Handle	551 (88)(537-565)	529 (87)(515-543)	-22**
	Hand-Color	530 (78)(517-543)	548 (89)(533-563)	18*

**p<.05, **p<.01, ***p<.001*

The critical finding of Experiment 2 was that the obtained Handle orientation effect was reversed, i.e., responses were faster toward the bodies and not the handles of graspable objects. This finding ran contrary to both the motor and the attentional accounts. The motor account predicts a compatibility effect toward the handle, as a result of grasping affordance for the corresponding hand (Tucker & Ellis, 1998), whereas the attentional account attributes the compatibility effect to an attentional shift towards the salient handle (Anderson et al., 2002). The typical finding, across the majority of studies, is that the orientation effect occurs relative to the handles and not the bodies of graspable objects, regardless of whether object location (Riggio et al., 2008; Symes et al., 2005), or object detail (Pappas, 2014) have been manipulated. There are instances of negative Handle orientation effects in the literature, but they are very scarce and not extensively discussed (e.g., Yu, Abrams, & Zacks, 2014). A possibility existed, that the use of colored markers had distorted the visual integrity of the objects and influenced the form-processing task in such a manner as to contribute to the occurrence of the observed negative Handle orientation effect. Experiment 3 was conducted to address this issue.

Another interesting finding in Experiment 2 was the observed Simon effect based on the colored markers. On average, responses were 18ms faster when response-hand corresponded to color location, compared to non-corresponding trials. In Experiment 1, the Simon effect was more pronounced because participants had to attend to the color. However, the occurrence of a similar effect in Experiment 2 suggested that the colored markers were effective in attracting exogenous shifts of attention. According to the contingent capture hypothesis by Folk et al.

(1992), an irrelevant stimulus is more likely to capture attention if an observer's task-oriented attentional set shares attributes with said irrelevant stimulus, e.g., a colored distractor stimulus appearing in the context of a color-processing task. In the case of Experiment 2, the task was to recognize the object and discern whether it is in an upright or an upside-down vertical orientation. This form-processing attentional set should render the colored markers irrelevant and outside the focus of participants' endogenous attention. However, the results indicated that the colored markers were not completely under top-down control and did indeed produce a form of obligatory attentional capture, as evidenced by the Simon-like spatial compatibility effect. It could be argued that exogenous attention was automatically shifted toward the location of the markers, on the basis of their unique basic features relative to the rest of the object, i.e., differences in color, luminance and contrast (Wolfe, 1998).

9. Experiment 3

The intention behind the third experiment was to serve as a replication of Experiment 2, without the use of colored markers. The original grayscale photographs were used as stimuli. If a regular Handle orientation effect was observed, it could be reasonably assumed that the visual salience elicited by the colored markers was a key factor in reversing the effect in Experiment 2. In such a scenario, the course of the present investigation would continue in attempting to explain the modulating effect of the colored markers, in the context of the graspable objects. However, if the negative Handle orientation effect continued to persist even in the absence of the colored markers, the focus of the present study would shift away from the use of such markers, in favor of following different lines of inquiry, so as to trace the source of the rare negative SRC effect.

Table 7. Experiment 3: Means (in ms), (SDs) and (95% CIs) of RTs, as a function of stimulus-response type, collapsed into compatible and incompatible trials. Note: size of the compatibility effect was computed by subtracting compatible from incompatible RTs.

	Compatibility	Compatible Mean (SD)(95% CI)	Incompatible Mean (SD)(95% CI)	Compatibility Effect (ms)
Experiment 3	Hand-Handle	544 (97)(516-574)	523 (97)(495-552)	-21**

**p<.05, **p<.01, ***p<.001*

A pattern of negative stimulus-response compatibility, similar to that in Experiment 2, was observed using the original grayscale photographs. Overall, RTs for corresponding trials were 21ms slower compared to non-corresponding trials (see Table 7). This result strongly suggested that the occurrence of the reversed Handle orientation effect could not be attributed to the use of colored markers.

Taken together, the findings of Experiments 1-3 indicated that a regular Simon effect occurred relative to the location of the colored markers, regardless of the task: color-processing (Exp. 1) or form processing (Exp. 2). Additionally, a negative stimulus-response compatibility effect was observed, with slower responses on the side of space containing the handle and faster responses on the side of space corresponding with the object's body. This reversed Handle orientation effect occurred in form-processing tasks, regardless of whether colored markers automatically captured attention (Exp. 2), or were altogether absent (Exp. 3).

As previously discussed, neither the motor (Tucker & Ellis, 1998), nor the attentional account (Anderson et al., 2002) can explain the reversed Handle orientation effect. Across a large number of studies, despite differences in tasks, stimuli and experimental manipulations, the typical finding is that the orientation effect occurs relative to the handles and not the bodies of graspable objects (e.g., Ambrosecchia et al., 2015; Cho & Proctor, 2010; Iani et al., 2011; Pappas, 2014; Phillips & Ward, 2002; Riggio et al., 2008; Saccone et al., 2016; Symes et al., 2005; Tucker & Ellis, 1998).

The attention-shift account of the Simon effect (Rubichi et al., 1997) could be used to explain an effect occurring relative to the body of an object, if that body attracted exogenous attention on some basis. There is a lack of literature on the Simon effect in the context of single, centered and asymmetrical objects. However, the study by Anderson et al. (2002) demonstrated that an object's asymmetrical nature itself is capable of causing shifts in attention and suggested that the handle of a graspable object captures attention due to its salience. This raises the question of whether the body of a graspable object can also attract attention under certain conditions.

It is widely known that the Simon effect is a SRC effect based on irrelevant stimulus location (for review, see Proctor & Vu, 2006). Centering a highly asymmetrical object, such as the ones used in the current study, gives rise to vastly different features of the object being presented on either side of space. For example, the left side of space may contain a large body, whereas the right side of space contains a slender handle. This visual asymmetry between the two hemifields can be modulated on the basis of horizontal positioning. In fact, it has been argued that "manipulating horizontal location influences the affordance compatibility effect, and research on affordance effects should therefore control for horizontal location" (Pappas, 2014, p. 717). However, the literature on the Handle orientation effect does not include an extensive discussion as to how asymmetrical objects should be centered on-screen.

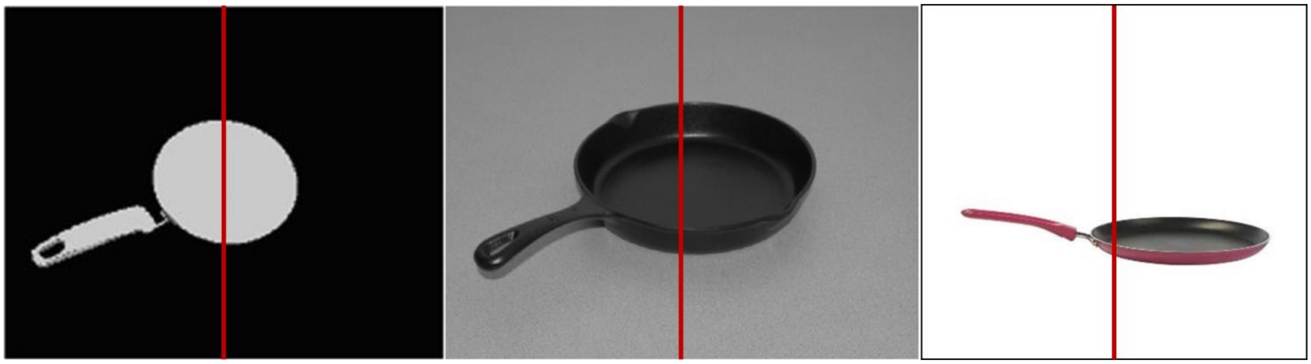

Figure 13. Three approaches to centering an object. Base-centered (left; taken from Cho & Proctor, 2010); Area-centered (middle; taken from Pappas, 2014); Width-centered (right; taken from Saccone et al., 2016). Red mid-sagittal line added for the purpose of illustration.

Some studies do not provide detailed specifications as to how their stimuli were centered, whereas those that do, appear to take very different approaches (see Figure 13). Cho and Proctor (2010) disregarded the object's handle and centered the body (base) of the object. As a result, the object not only contained more area (pixels) on the handle's side of space, but was also heavily lateralized toward that same side. Other researchers (e.g., Pappas, 2014) have positioned objects based on area, so that there are an equal number of object pixels on either side of space. However, this adjustment still rendered the handle as the most lateralized part of the object during presentation. Yet another approach, such as the one used in the present study, has been to center the object based on its horizontal dimension (width), so that it is the same on either side of the mid-sagittal line (e.g. Saccone et al., 2016). However, this positioning resulted in an uneven distribution of pixels, with the object occupying a larger area on the side of space containing the body. There existed an alarming possibility that, in the case of asymmetrical objects with large bodies and small handles, the first two approaches produce spatial compatibility effects with regard to the handle, while the last favors the body. To this end, Experiment 4 was conducted in order to explore the effects of horizontal positioning, in the context of the same stimulus set.

10. Experiment 4

The intention behind the fourth experiment was to determine whether the horizontal positioning of the centered, asymmetrical stimuli modulated the hand-handle compatibility effect. In Experiments 2 and 3, the objects were centered based on their horizontal dimension (width), so that it was the same on both sides of the mid-sagittal line. However, in the context of highly asymmetrical objects (e.g., large body/small handle), this positioning produced an uneven distribution of pixels, with the object occupying a larger area on the side of space containing the body. It could be argued that attention was captured and shifted toward the side of space containing the majority of object pixels, thereby resulting in a correspondence effect relative to the bodies of the objects and not their handles (Exps. 2 & 3). In light of such a scenario, Experiment 4 had an identical design to Experiment 3, except the objects were centered based on their area, so that an even number of pixels occupied the two hemifields (see Figure 14). If this adjustment yielded a different pattern of hand-handle compatibility, it would be an indication that horizontal positioning plays a critical role in the occurrence of compatibility effects for asymmetrical stimuli, even when they are "centered".

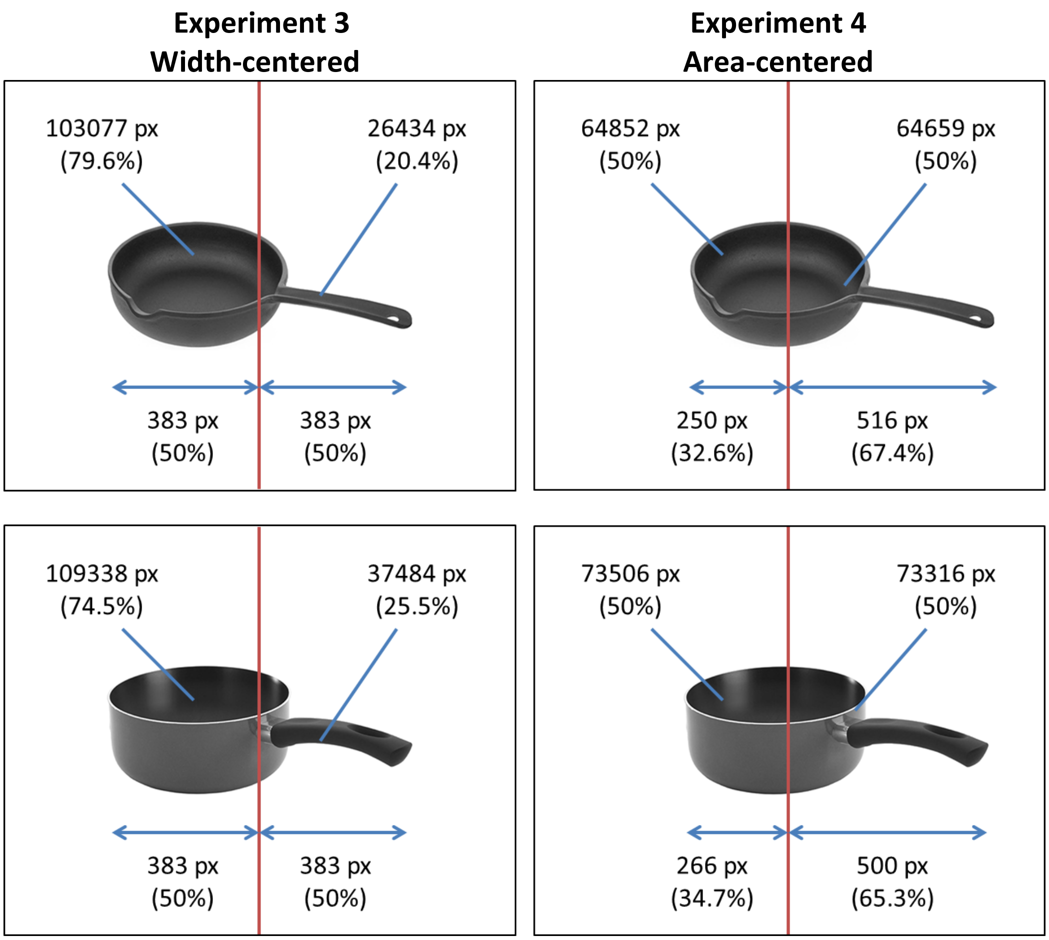

Figure 14. Example stimuli and their visual specifications in Experiment 3 (left column, width-centered) and Experiment 4 (right column, area-centered). Width measurements are presented as the distance in pixels (px) from the midsagittal line to the object's leftmost/rightmost extremity. Area measurements provide the number of object pixels in each hemifield. Stimuli are shown to scale, as they would appear on the 1280x1024 display. The crimson midsagittal line is shown for illustrative purposes only.

Table 10. Experiment 4: Means (in ms), (SDs) and (95% CIs) of RTs, as a function of stimulus-response type, collapsed into compatible and incompatible trials. Note: size of the compatibility effect was computed by subtracting compatible from incompatible RTs.

	Compatibility	Compatible Mean (SD)(95% CI)	Incompatible Mean (SD)(95% CI)	Compatibility Effect (ms)
Experiment 4	Hand-Handle	506 (98)(474-539)	528 (105)(493-565)	22**

**p<.05, **p<.01, ***p<.001*

Experiments 3 and 4 employed an identical procedure and used the same stimulus set. The only difference between the two was the method used to center the objects. Width-centered stimuli in Experiment 3 were shown to produce a compatibility effect of around 21ms toward the bodies of the objects, whereas area-centered stimuli produced a compatibility effect of similar magnitude (22ms) toward the handles of the objects. These results suggested that horizontal positioning may be the primary factor in modulating and even reversing the compatibility effect, with regard to highly asymmetrical objects.

11. Handle Orientation or Horizontal Position?

Over the past four years, a handful of studies have become increasingly sensitive to the role of horizontal positioning in producing compatibility effects. Cho and Proctor (2013), as well as Lien et al. (2014) performed a replication of a study by Tipper et al. (2006), which used pictures of door handles. Cho and Proctor (2013) introduced an object-centered, as well as a base-centered condition. In their object-centered condition, the door handles were horizontally positioned with respect to their width, ensuring that it is the same in both hemifields. On the other hand, in their base-centered condition, the base of the door handle was in the center of the screen, while the handle extended to the left or right side of space. Cho and Proctor (2013) found no effects for shape judgments (rounded or rectangular handles) in the object-centered condition, whereas a compatibility effect toward the handle was observed in the base-centered condition. Lien et al. (2014) performed the same procedure using a shape judgment task, as well as a color task (blue or green handle). They found that, regardless of task (form-processing or color-processing) an effect was only observed for base-centered stimuli and not object-centered. This led the authors to conclude that “given that the only difference between the base-centered display condition and the object-centered display condition was the relative location of the door handle with respect to the center of the display, those findings ubiquitously support the spatial-coding view and suggest that the correspondence effect is driven primarily by the activation of object location, not the activation of object affordance" (Lien et al., 2014, p. 691).

It is very important to note, however, that advocates of the spatial compatibility account have yet to produce a detailed analysis on the interplay between horizontal positioning and the perceptual characteristics of graspable objects, such as shape asymmetry, in producing compatibility effects. In the absence of such a discussion, findings related to the horizontal positioning of stimuli are prone to misinterpretation. For example, Saccone et al. (2016) argued that "Lien et al. (2013) found a handle effect, not with centered objects, but when stimuli appeared off-center in the direction of the handle. That is, the effect only emerged when left-facing handles appeared obviously leftward and vice versa for right-facing handles, when there was an obvious spatial association between handle and response. These results, however, contrast many other studies that have found handle effects with centered images" (p. 2). In other words, the recent study by Saccone et al. (2016) presupposed that object-centered stimuli (width-centered) were not subject to spatial compatibility effects, and found a Handle orientation effect in support for grasping affordance. However, upon closely examining their stimulus set, it could be seen that a number of their highly asymmetrical objects contained a large portion of area on the side of the graspable handle. Based on the findings of Experiments 2-4 within the current investigation, it could be argued that the Handle orientation effect observed by Saccone et al. (2016) was not a product of grasping affordance, but rather resulted from a compatibility effect toward the side of space containing the majority of object pixels.

Another critical issue raised by the current investigation was the distinction between "early" and "late" salience. Based on the literature on visual attention, it is apparent that visual salience is determined by basic features, such as size, orientation, color, contrast (for review, see Zhao & Koch, 2013). In other words, when a graspable object appears on the screen, the handle may be visually salient based on its low-level perceptual features (early salience), or based on its status as a "handle" within the context of the experimental task, as well as compatible actions associated with the graspable object (late salience; see Matheson et al., 2014). Was attention allocated to "bodies" or "handles", as components of a graspable object, within the context of detailed object representation and a task involving form-processing? Or, was attention simply captured on the basis of the low-level perceptual asymmetries in the global shape of the stimulus, irrespective of task demands or level of object detail? There was a possibility that early salience may have played a greater role in producing the compatibility effects, compared to late salience. For instance, following abrupt stimulus onset, attention may have been captured based on relative pixel area in the width-centered condition, or relative eccentricity in the area-centered trials. Experiment 5 was designed to explore these issues.

12. Experiment 5

Experiment 5 aimed to investigate whether detailed object representations, along with a form-processing task, are necessary for the modulation of the compatibility effect on the basis of horizontal positioning. In Experiment 5, all object detail was removed from the photographs by reducing them to solid-colored silhouettes (green or blue). Horizontal position was manipulated on a trial by trial basis, in order to determine whether the same pattern of results would be obtained based on early visual salience, elicited by asymmetrical global shape. Essentially, Experiment 5 represented a Simon task, in which participants had to respond based on the color of asymmetrical stimuli, which were centered according to two different approaches (width-centered vs. area-centered; see Figure 18). To the best of the author's knowledge, no such experiment has been reported in the literature on the Simon, or the Handle orientation effects.

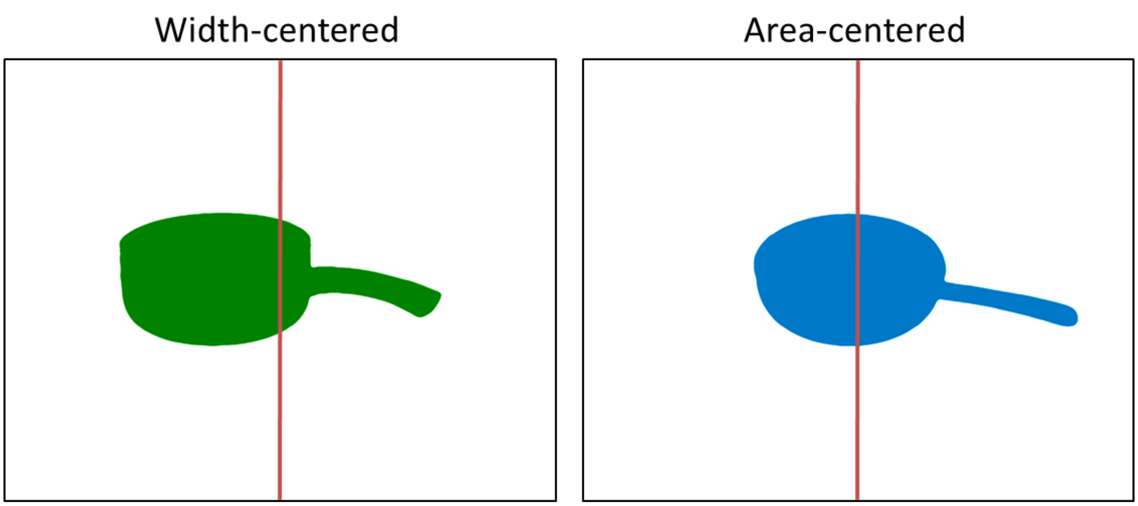

Figure 18. Green and blue silhouettes used in Experiment 5 were derived from the original photographs of frying pans and sauce pans. Stimuli were centered according to width (left), or according to area (right). Silhouettes are shown to scale, as they would appear on the 1280x1024 display. Crimson midsagittal line included for illustration only.

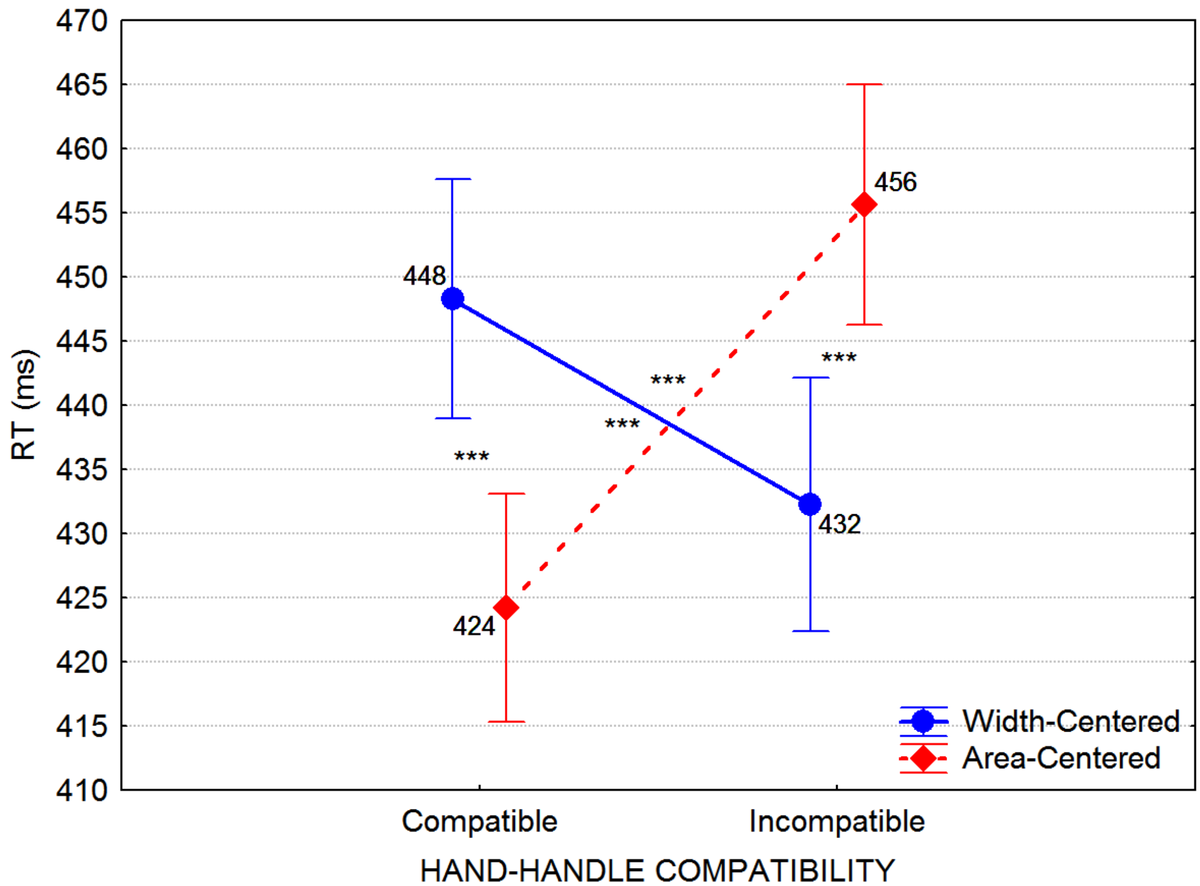

Figure 19. Experiment 5: Interaction between hand-handle compatibility and horizontal position, showing that the direction of the compatibility effect is modulated by horizontal position. Vertical bars denote standard errors. **p<.05, **p<.01, ***p<.001*

The critical finding of Experiment 5 was that the horizontal positioning of the silhouettes modulated the direction of the observed compatibility effects, even in the context of a color-processing task. Collapsing data into compatible and incompatible trials revealed that, similar to Experiments 2 and 3, a negative hand-handle compatibility effect of -16ms was observed when the asymmetrical stimuli were centered according to their width. Conversely, as in Experiment 4, the compatibility effect was positive (32ms), when stimuli were centered based on pixel area (see Figure 19).

The findings of Experiment 5 could be interpreted as a novel demonstration of a Simon effect for centered objects, where the compatibility effect arises as a function of irrelevant global shape, which is asymmetric across the two hemifields.

Due to the lack of literature on Simon effects in the context of centered and asymmetrical stimuli, the underlying mechanisms of the compatibility effects observed in Experiment 5 were unclear. Under the attention-shift account (Nicoletti & Umiltà, 1989, 1994) of the Simon effect, it can be argued that in the width-centered condition, attention shifted toward the bodies of the objects, whereas it favored the handles in area-centered trials. It appeared that these directional shifts in attention were of an exogenous nature, possibly in response to low-level visual salience. Such an account accommodated the findings of Experiments 2-5, which showed a similar pattern of compatibility, irrespective of task demands or level of object detail.

It is important to note that all of the asymmetrical stimuli used in the present investigation were relatively shape-homogeneous in having a large area body and a small area handle. In the width-centered condition, the objects occupied a much larger area in the hemifield containing the body (average of 78.3% of total object area). The abrupt onset of such an object would produce a much greater change in luminance on the side of the body, thereby making it more visually salient (see Donk et al., 2009; Franconeri et al., 2005; Gellatly et al., 1999). As a result of this luminance-based attentional capture, attention shifted from fixation, toward the bodies of the objects, and produced a compatibility effect in that same direction. An account based on the relative size of luminance changes would predict compatibility effects with respect to the handle, in situations in which stimuli contain a majority of pixels on the side of the handle. Such may have been the case in Saccone et al. (2016), who attributed the effect to grasping affordance. The findings of the present investigation should be taken as evidence that even when graspable objects are width-centered, compatibility effects may still arise (cf. Saccone et al., 2016), based on low-level visual properties, irrespective of the orientation of a graspable handle.

In the area-centered condition, the relative change in luminance at object onset was balanced to a similar number of pixels in both hemifields. However, as already pointed out, such an adjustment in horizontal positioning shifted the asymmetrical object toward the side of space containing its smaller part. Given the stimulus set that was used within the present investigation, the object handles were always smaller than the bodies and therefore became much more lateralized during presentation in the area-centered condition (average of 66.7% of total object width was on the side of space containing the handle). This manipulation yielded a regular Handle orientation effect in the context of detailed objects and a form processing-task (Experiment 4), as well as with silhouettes and a color-processing task (Experiment 5). Therefore, the observed Handle orientation effect was more likely a product of spatial compatibility, rather than grasping affordance. Some studies on exogenous attention have argued that exogenous orienting to peripheral stimuli may be stronger compared stimuli at smaller eccentricities (Van der Lubbe & Postma, 2005). Hence, a lateralized handle presented in area-centered trials, may have captured attention simply based on its eccentricity. Such an explanation would account for the similar Handle orientation effects, which were observed in Experiment 4, involving detailed objects, as well as the silhouettes in Experiment 5.

Taken together, the results of Experiments 2 – 5 have suggested that the observed compatibility effects were Simon-like and perceptual in nature, rather than the result of grasping affordance. Based on the findings, it can be argued that there is no adequate way to center a highly asymmetrical graspable object, so as to avoid low-level spatial compatibilities and isolate an effect elicited solely on the basis of motor representations. There is a distinct possibility that previous studies have misattributed handle orientation effects to grasping affordance, when in fact they were the result of attentional shifts to low-level visual characteristics. It may be advisable for future studies on the affordance effect to rely on graspable objects, whose global shape is relatively symmetrical, so that horizontal positioning does not become a confounding factor. However, that is easier said than done because a large proportion of everyday graspable objects usually feature some degree of asymmetry, with functional ends being relatively larger than handles or vice versa. Having established that task-irrelevant global shape modulated the compatibility effect for centered, asymmetrical stimuli, Experiment 6 sought to explore whether this "shape-based" Simon effect can be attenuated, or even eliminated altogether, by using smaller stimuli.

13. Experiment 6

Experiment 6 aimed to establish whether or not the observed shape-based Simon effect in Experiment 5 would continue to persist in the context of much smaller stimuli. There may be a link between eye movements and the occurrence of the Simon effect (Buetti & Kerzel, 2010). There may also be an "optimal" size of 4° - 6°, at which an object is processed without incurring additional saccades (Biederman & Cooper, 1992). The literature on the Handle orientation effect has not offered much discussion or guidance in terms of stimulus size. Researchers have typically selected the size of stimuli at their own discretion, thereby producing quite a vast range of horizontal dimensions: e.g., 5° (Iani et al., 2011; Riggio et al., 2008); 10° – 14° (Anderson et al., 2002); 11° – 18° (Tucker & Ellis, 1998); 14° – 15° (Lien et al., 2014); 18.6° (Pappas, 2014); 21.7° (Philips & ward, 2002). The idea behind Experiment 6 of the current investigation was to use an identical procedure to Experiment 5, but reduce silhouette sizes from 768 x 323 px (19.8° x 8.4°) to 232 x 98 px (6° x 2.5°) (see Figure 21). Obtaining a similar pattern of results as in Experiment 5, where the width-centered condition produced a compatibility effect toward the body and the area-centered condition produced a compatibility effect toward the handle, would reinforce the view that there is no adequate way to center a highly asymmetrical graspable object, so as to avoid low-level spatial compatibilities. However, the reduction in stimulus size may serve to dampen, or even eliminate this "shape-based" Simon effect. Such an outcome would benefit future studies, in controlling for Simon-like compatibilities and isolating an effect elicited solely by the grasping affordance of an object's handle, if such an affordance effect does indeed exist within this experimental paradigm.

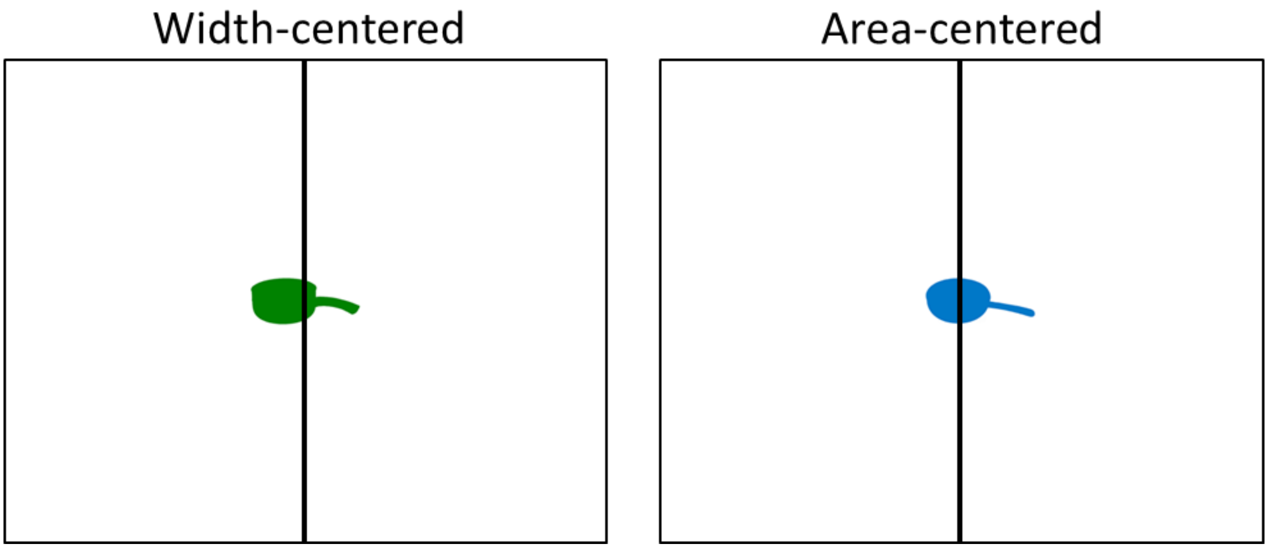

Figure 21. Green and blue silhouettes used in Experiment 6. Stimuli were centered according to width (left), or according to area (right). Silhouettes are shown to scale, as they would appear on the 1280x1024 display. Black midsagittal line included for illustration only.

Experiment 6 yielded a strikingly similar pattern of results as Experiment 5. Again, the horizontal positioning of the silhouettes was shown to play a critical role in modulating the direction of the compatibility effect. In the width-centered condition, responses were 14ms faster toward object bodies, whereas the area-centered condition produced faster responses (26ms) toward object handles (see Figure 22).

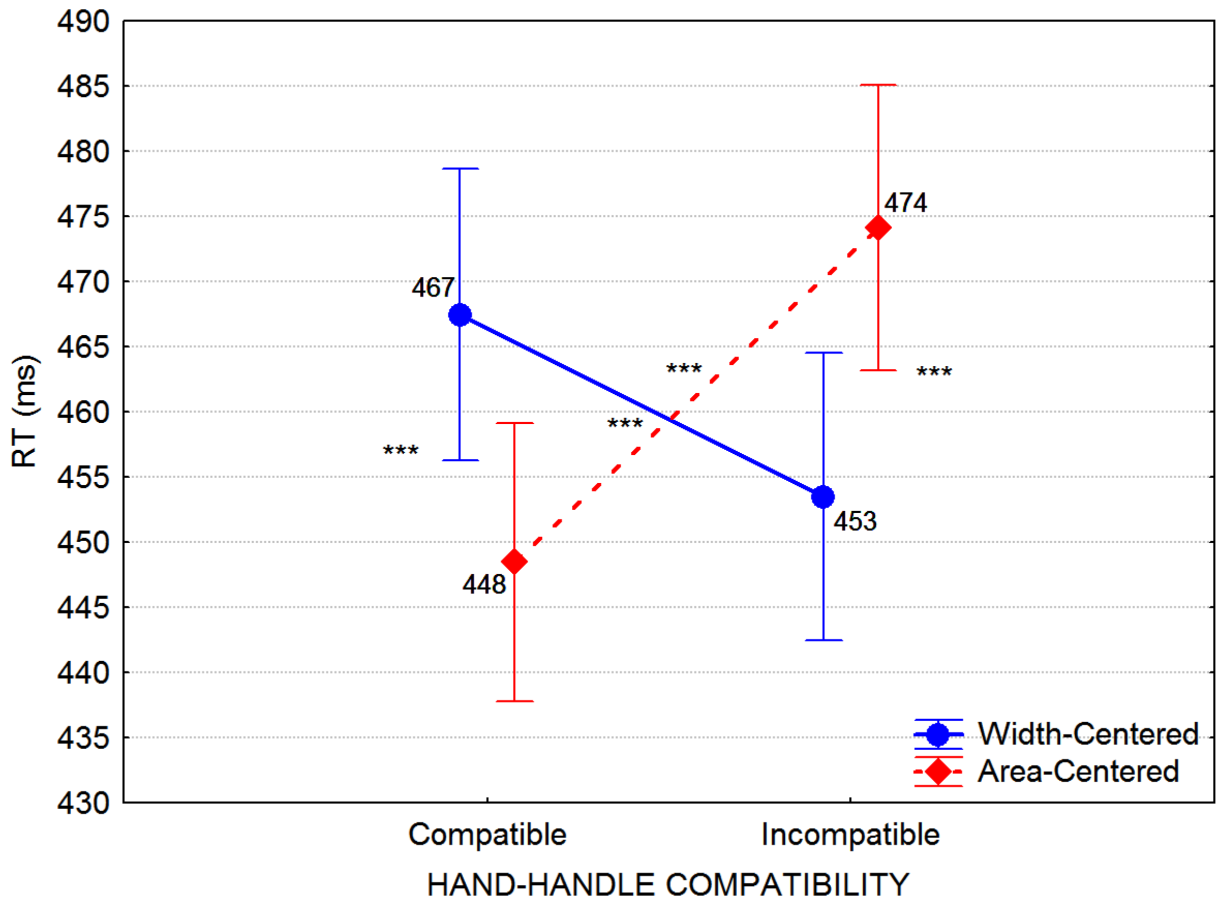

Figure 22. Experiment 6: Interaction between hand-handle compatibility and horizontal position, showing that the direction of the compatibility effect is modulated by horizontal position. Vertical bars denote standard errors. **p<.05, **p<.01, ***p<.001*

Taken together, Experiments 2-6 have found that global shape asymmetry, coupled with horizontal positioning, have been the most critical factors in modulating the direction and magnitude of the compatibility effect, irrespective of object detail (photographs vs. silhouettes), irrespective of task (form-processing vs. color-processing) and irrespective of stimulus size. These observations could not be accommodated by an effect rooted in motor representations and grasping affordance. Instead, the observed compatibility effects appeared to be perceptual in nature and based on interplay between attention and low-level visual characteristics.

A particularly interesting result was obtained in Experiment 2 featuring width-centered photographs of objects, which also contained colored markers. Subjects responded based on the vertical orientation of the objects, resulting in a compatibility effect toward the location of the irrelevant colored marker (18ms), as well as a compatibility effect toward the body of the graspable object (22ms). The effect toward the colored marker could clearly be characterized as a Simon effect, based on an exogenous shift of attention toward the distinct spatial location of the marker. On the other hand, all of the follow-up experiments suggested that the effect toward the body was also of a perceptual, Simon-like nature. Interestingly, however, no second-order interaction was found between the two effects in Experiment 2, which according to Additive Factor Logic (Sternberg, 1969), suggested that different mechanisms may underlie the two perceptual effects. In other words, two distinct types of Simon effects could have occurred in the course of the current investigation. In order to further explore this issue, the next section presents distributional analyses of Experiments 3-6, in an attempt to gain an insight into the nature and time-course of the compatibility effects, which occurred toward the bodies and the handles.

14. Distributional Analyses

Previous studies have investigated the temporal dynamics of the Simon and Handle orientation effects by conducting bin distributional analyses (Ratcliff, 1979). Findings have typically shown that the Simon effect is transient in nature and tends to rapidly decay as RTs increase (De Jong et al., 1994). On the contrary, it has been shown that affordances may develop over time, producing increased effect sizes as RTs increase (Tucker & Ellis, 2001).

Ratcliff's Vincentization procedure (1979) was performed with respect to the data from Experiments 3-6. Results are presented in Figure 24. Effect size (in ms) was calculated by subtracting compatible RTs from incompatible RTs for each bin, 1 through 5.

The findings of the bin analyses for Experiments 3-6 revealed an apparent distinction between compatibility effects induced by width-centered and area-centered stimuli. Negative compatibility effects, which occurred towards the bodies of width-centered objects, had a relatively constant magnitude across all bins. In contrast, area-centered stimuli produced compatibility effects toward object handles, which increased with RTs (see Figure 24). Of particular relevance was the observation that the effects in Experiments 3 and 4 shared a similar time-course to those in Experiments 5 and 6, which used silhouettes and a color task. In other words, horizontal positioning appeared to be the key factor in modulating these effects, not object detail (photographs/silhouettes; as in Pappas, 2014) or task (form-processing/color-processing; as in Tipper et al., 2006). This finding strongly suggested that the observed compatibility effects were of a low-level and perceptual nature, thereby reinforcing the view that grasping affordance played a negligible role (if any) within the current investigation.

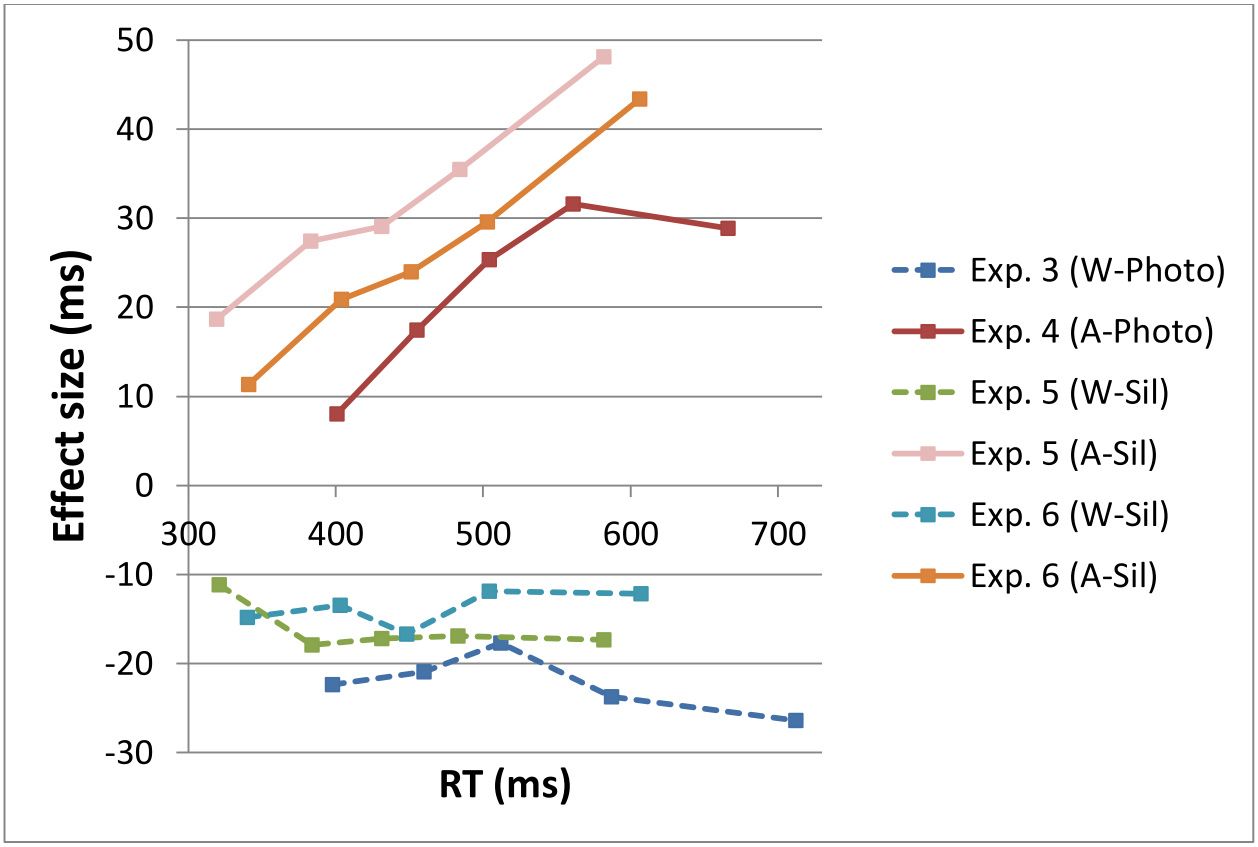

Figure 24. The size of the compatibility effects in Experiments 3-6, plotted for bins 1 through 5. Width-centered trials are represented by dashed lines, whereas area-centered trials are solid lines.

The different magnitudes and time-courses of the two Simon-like effects suggested that, although they both resulted from the horizontal positioning and global, asymmetrical shape of the stimuli, they may have different underlying mechanisms. It has been argued that different types of Simon effects may exist, where some are characterized as transient and visuomotor (Buhlmann, Umiltà, & Wascher, 2007), while others are sustained and based on cognitive interference processes (Wascher, Schatz, Kuder, & Verleger, 2001). According to Wiegand and Wascher (2007), a visuomotor Simon effect is based on egocentric spatial codes and is elicited in the more traditional Simon tasks, which involve a direct anatomical mapping between lateralized stimuli and lateralized responses. The shape-based Simon effects observed in the present experiments did not rapidly decay over time and therefore appeared to be of a more cognitive, rather than visuomotor nature. Increasing Simon effects, similar to those obtained in the area-centered conditions have been found for centrally presented arrows and spatial words (Pellicano et al., 2009), as well as for centered biological stimuli, such as gaze direction (Ansorge, 2003). However, more work is needed to be able to understand and relate the current shape-based Simon effects to those findings.

15. General Discussion

Over the past fifteen years, the Tucker and Ellis paradigm (1998) has been extensively used in the study of variable affordances. A wealth of data has been amassed on the SRC effects which occur in relation to pictures of graspable objects and keypress responses. Whether or not grasping affordance is a component of these SRC effects has been a contentious issue amongst researchers in the field. Some have argued that both spatial compatibility and grasping affordance influence RTs (Iani et al., 2011; Pappas, 2014; Riggio et al., 2008; Saccone et al., 2016; Symes et al., 2005), whereas others have questioned the utility of the paradigm in eliciting any affordance effects (Cho & Proctor, 2010, 2013; Lien et al., 2013, 2014). Whatever the case may be, the most surprising aspect of this debate is that neither side has attempted to provide an extensive account of the factors, relating to visual salience, that contribute to the observed compatibility effects, based on the exogenous deployment of attention.

Low-level visual features, such as size, shape, luminance, color and contrast have been shown to play a critical role in producing exogenous shifts in attention (Wolfe, 1998). As such, they may be responsible for the occurrence of spatial compatibility effects under the attention shift account (Nicoletti & Umiltà 1989, 1994; Rubichi et al., 1997). However, these perceptual characteristics of the stimuli have not been discussed, let alone controlled within the field of research on variable affordances. Perhaps this oversight was due, in large part, to the lack of literature on Simon effects involving centered objects that contain perceptual asymmetries across the two hemifields. Anderson et al. (2002) did demonstrate that centered object and non-object stimuli can produce compatibility effects based on visually salient features, which are not related to action. However, despite having been cited many times, these findings appear not to have been fully digested and acted upon, as there is still no line of research into visual salience and its influence in SRC tasks involving visually-complex, centered stimuli.

As previously stated, an improved awareness of the exogenous deployment of visual attention, within the Tucker and Ellis paradigm (1998), would be beneficial in accounting for spatial compatibility effects of centered stimuli, in reconciling previous findings, and possibly, in controlling these confounding factors. Therefore, the present investigation placed an emphasis on visual salience, while exploring SRC effects using highly asymmetrical objects. The six conducted experiments, along with their findings are summarized in Table 19.

Table 19. Summary of Experiments 1-6, including task, type of stimuli and horizontal positioning. Direction of compatibility effect refers to the stimulus feature, which produced faster RTs when its location corresponded to response-hand.

	Task	Stimuli	Horizontal position of stimuli	Direction of compatibility effect toward	Effect size (ms)
Experiment 1	Color	Photos w/ colored markers	width-centered	markers	45***
Experiment 2	Form	Photos w/ colored markers	width-centered	markers	18*
				bodies	22**
Experiment 3	Form	Photos	width-centered	bodies	21**
Experiment 4	Form	Photos	area-centered	handles	22**
Experiment 5	Color	Silhouettes	width-centered	bodies	16***
			area-centered	handles	32***
Experiment 6	Color	Small silhouettes	width-centered	bodies	14***
			area-centered	handles	26***

Experiment 1 found a Simon effect with respect to colored markers located in distinct left/right locations within the centered graspable objects. Such a result was anticipated in a color-processing task, where irrelevant stimulus location is known to produce faster RTs for corresponding, compared to non-corresponding trials (for review, see Proctor & Vu, 2006). On the other hand, form-processing tasks were expected to give rise to the Handle orientation effect (Symes et al., 2005; Tipper et al., 2006). However, when such a vertical orientation task was introduced in Experiments 2 and 3, a negative compatibility effect emerged, with faster responses toward the bodies of graspable objects, rather than the handles. It is important to note that the vast majority of studies using variants of the Tucker and Ellis paradigm (1998) have reported compatibility effects toward the handle, despite differences in tasks, stimuli and experimental manipulations (e.g., Ambrosecchia et al., 2015; Cho & Proctor, 2010; Iani et al., 2011; Pappas, 2014; Phillips & Ward, 2002; Riggio et al., 2008; Saccone et al., 2016; Symes et al., 2005; Tucker & Ellis, 1998). Therefore, the reversed effect in Experiments 2 and 3 presented a rare and valuable finding that could not be explained by the motor account, which predicts a compatibility effect toward the handle based on grasping affordance (Tucker & Ellis, 1998), or the attention account, which attributes the compatibility effect to an attentional shift toward a salient handle (Anderson et al., 2002).

Perhaps the most pivotal finding of the current study was that the horizontal positioning of the stimuli modulated the direction of the compatibility effect between Experiments 3 and 4. As noted earlier, the literature on the Handle orientation effect does not contain an analysis or specific guidelines as to how asymmetrical stimuli should be centered on-screen. As a result, researchers have positioned stimuli at their own discretion. Cho and Proctor (2010) can be said to have sparked a discussion on horizontal positioning by adopting a heavily unbalanced centering procedure, which explicitly catered to spatial compatibility effects. Their base-centered approach involved centering the body (base) of the object, while disregarding the handle. As a result, the object not only contained more area (pixels) on the handle's side of space, but was also heavily lateralized toward that same side (see Cho & Proctor 2010, 2013; Lien et al., 2013, 2014). Pappas (2014) and Saccone et al. (2016) criticized the above approach and in turn advocated area-centering and width-centering, respectively. Area-centered stimuli are positioned so that there are an equal number of object pixels in both hemifields (see Pappas, 2014). However, in the case of a highly asymmetrical object, such as a frying pan, this adjustment renders the handle as the most lateralized part of the object, so as to compensate for the large area of the body. The width-centered approach, on the other hand, ensures that an object's horizontal dimension is equally divided between both hemifields, but leads to an uneven distribution of pixels (i.e., a frying pan would occupy a much larger area in the hemifield containing its body; see Saccone et al., 2016). Experiments 3 and 4 demonstrated that both the width-centered and area-centered approaches are inadequate in avoiding spatial compatibility effects when using highly asymmetrical stimuli. Width-centered stimuli in Experiment 3 were shown to produce a compatibility effect toward the bodies of the objects, whereas area-centered stimuli in Experiment 4 produced a compatibility effect toward the handles.

Experiment 5 removed any basis for grasping affordance by reducing the detailed object representations to solid-colored silhouettes and employing a color-processing task, instead of form-processing. A similar pattern of results emerged, as in Experiments 2 - 4, whereby horizontal positioning modulated the direction of the compatibility effect. This finding strongly suggested that within the course of the investigation it was perceptual effects that were at the heart of the observed RT differences, whereas grasping affordance was altogether non-existent, or drowned out by spatial compatibilities. It could be argued that Simon effects, based on the global asymmetrical shape and horizontal positioning of the stimuli, were responsible for the observed compatibility effects, regardless of task or level of object detail. A strikingly similar pattern of results was obtained in Experiment 6, demonstrating that these perceptual effects continue to persist even in the case of much smaller stimuli, and reinforcing the view that previous studies may have misattributed handle orientation effects to grasping affordance or a "salient" handle, when in fact they were the result of attentional shifts to low-level visual characteristics.

In reconciling the findings of Experiments 1-6, it should be noted that all experimental conditions produced compatibility effects with regard to the orientation of the stimuli, except Experiment 1 (see Table 19). The contingent orienting hypothesis by Folk et al. (1992) dictates that an irrelevant stimulus, or feature of a stimulus, is more likely to capture attention if it shares attributes with the observer's task-dependent attentional set. In Experiment 1, subjects had to respond based on the color of a marker, which was placed in a distinctly left or right spatial location. It could be argued that under these circumstances, the global shape of the stimulus was not attended to and therefore, a compatibility effect based on horizontal orientation was not observed. Instead, this condition only produced a Simon effect based on the relative location of the colored markers, i.e., a location-based Simon effect, which is well-known and extensively documented in the literature (see Proctor & Vu, 2006). Conversely, it could be said that attention to shape was responsible for the observed orientation effects in Experiments 2-6. Experiments 2, 3 and 4 involved a form-processing task, so it is only reasonable to assume that stimulus shape was attended to. Experiments 5 and 6, on the other hand, illustrated a more interesting case because of their color-processing task. The colored silhouettes represented the task-relevant color in the shape of the stimulus, therefore, under the contingent orienting of Folk et al. (1992), it could be argued that in these cases, shape was also, indirectly, attended to.

The orientation effects observed in Experiments 2-6 were not so much based on the irrelevant spatial location of a target stimulus or feature, but instead occurred in relation to the perceptual asymmetries within the global shape of the stimuli, as a function of their horizontal positioning around the center. Across the width-centered conditions, the hemifield featuring object bodies contained an average of 78.3% of total object area. It could be argued that the Simon effect occurred toward the bodies of the objects due to the attention capturing properties of the larger change in luminance, associated with the side of space containing the bodies (see Donk et al., 2009; Franconeri et al., 2005; Gellatly et al., 1999). On the other hand, area-centered trials featured an average of 66.7% of total object width on the side of space containing the handle. In this case, the handles may have been awarded higher visual salience on the basis of their increased eccentricity (see Van der Lubbe & Postma, 2005). Additionally, bin analyses revealed that the width-centered and area-centered conditions may have produced two distinct types of Simon effects, with the former having a relatively constant magnitude across bins, while the latter increased in size as RTs increased. Moreover, both these shape-based Simon effects appeared to be different from the more traditional and location-based effect, which typically decays over time (De Jong et al., 1994). Shape-based Simon effects warrant much more additional research, considering they have not been addressed in the literature on the Simon or the Handle orientation effects.

In summary, research on variable affordances using the Tucker and Ellis paradigm (1998) has employed abrupt onsets of complex visual stimuli, in the absence of a thorough discussion on the low-level perceptual features of such objects, and a framework for positioning them on screen. The present work has demonstrated that the paradigm is extremely vulnerable to perceptual effects, which are unrelated to the graspable nature of the objects presented, and are based on early visual salience. In the case of highly asymmetrical shapes, it was shown that both the width and the area-centered approaches produce unavoidable Simon effects toward the larger, or smaller part of the object, respectively. Perhaps a recommendation can be made, that future studies, trying to find an effect based on grasping affordance, should make use of the width-centered approach, coupled with relatively symmetrical objects. However, shape and relative size are only two factors out of a multitude of basic visual features which produce attentional capture. Therefore, research on the Handle orientation effect, and SRC effects in general, should focus on deeper collaboration with the field on visual attention, so that meaningful progress can be made in both domains.

Summary of Contributions

- Demonstrated a rare negative compatibility effect, where responses were faster toward the bodies and not the handles of graspable objects (Experiments 2 and 3). Evidence against motor-account (Tucker & Ellis, 1998), also against “salient” handle interpretations of Anderson et al.’s attention-account (2002).

- Established that the horizontal positioning of asymmetrical objects around the center modulates the direction of the compatibility effect – toward the relatively larger body when width-centered; toward the smaller handle when area-centered (Experiments 3 and 4). Showed, for the first time, that width-centered objects, which are not lateralized to any side, are also subject to compatibility effects, unrelated to grasping affordance.

- Demonstrated the perceptual nature of the effects by replicating the results using small and large silhouettes and a color-processing task. Experiments 5 and 6 represented a novel demonstration of a shape-based Simon effect for centered stimuli, where compatibility arises as a function of irrelevant global shape and its perceptual asymmetries between the two hemifields. Evidence in favor of an attention-shift account of the Simon effect, based on visual salience.

- Distinguished the shape-based Simon effect, from the more typical location-based effect using time-course analysis. The distributional data also suggested that the two shape-based effects in the width and area-centered conditions may be inherently different.

- Illustrated major shortcomings of studies on the Handle orientation effect, related to their use of complex stimuli, without taking into account the visually-salient characteristics.

Author’s Publications

Kostov, K., & Janyan, A. (2012). The role of attention in the affordance effect: can we afford to ignore it? *Cognitive Processing*, 13(1), 215-218. DOI: 10.1007/s10339-012-0452-1.
(Impact Factor: 1.340)

Citations (as per Google Scholar):

Ambrosecchia, M., Marino, B. F., Gawryszewski, L. G., & Riggio, L. (2015). Spatial stimulus-response compatibility and affordance effects are not ruled by the same mechanisms. *Frontiers in Human Neuroscience*, *9*, 283.

Dagaev, N., Shtyrov, Y., & Myachykov, A. (2016). The role of executive control in the activation of manual affordances. *Psychological Research (2016)*, 1-15.

Myachykov, A., Ellis, R., Cangelosi, A., & Fischer, M. H. (2013). Visual and linguistic cues to graspable objects. *Experimental Brain Research*, *229*(4), 545-559.

Wilf, M., Holmes, N.P., Schwartz, I., & Makin, T.R. (2013). Dissociating between object affordances and spatial compatibility effects using early response components. *Frontiers in Psychology, 4,* 591.

Kostov, K., & Janyan, A. (2015). Reversing the affordance effect: negative stimulus–response compatibility observed with images of graspable objects. *Cognitive Processing*, 16(1), 287-291. DOI: 10.1007/s10339-015-0708-7. (Impact Factor: 1.340)

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