Attention, Perception, & Psychophysics (2019) 81:1454–1463
https://doi.org/10.3758/s13414-019-01679-7

Visual salience, not the graspable part of a pictured eating utensil, grabs attention

Aiping Xiong [1] · Robert W. Proctor [2] · Howard N. Zelaznik [3]

Published online: 13 February 2019

Abstract

Three experiments used compatible and incompatible mappings of images of eating utensils to test the hypothesis that these images activate affordances for grasping with the corresponding hand when the required response is a key-press. In Experiment 1, stimuli were photographs of a plastic spoon oriented on the horizontal axis, with the handle location varying randomly between left and right. Participants were instructed to respond to the handle or the tip, with a compatible mapping in one trial block and an incompatible mapping in another. A benefit for the compatible mapping was evident when the spoon tip was defined as relevant and a smaller cost when the handle was defined as relevant, suggesting a larger influence of the tip than the handle. In Experiment 2, the stimuli were photographs of bamboo chopsticks, for which the functional end is pointed and the graspable end is squared. East Asian participants familiar with chopsticks showed compatibility effects that did not differ significantly between the two ends. In Experiment 3, the chopstick handles were colored red to make them relatively more distinct than the tips. Both East Asian participants (Experiment 3B) and a more diverse sample (Experiment 3A) showed a benefit of the compatible mapping when the handle was defined as task relevant but not when the functional end was. Altogether, the results provide evidence that left-right location of a visually salient feature is the main factor driving these compatibility effects, rather than the automatic activation of a grasping affordance.

Keywords Grasping affordance · Spatial compatibility · Object-based correspondence effect

Introduction

Because graspable objects such as coffee pots and frying pans have handles, it is tempting to consider that their handles "afford" grasping. Beginning with a study by Tucker and Ellis (1998), many researchers have concluded that the grasping affordance for graspable objects is sufficiently strong that pictures of those objects automatically activate the affordance and, thus, will influence even key-press responses. In that study, participants executed a key-press with the left or right index finger to signify whether an object with a graspable handle was upright or inverted. Reaction time (RT) was shorter when the location of the handle corresponded with that of the response than when it did not. Tucker and Ellis interpreted their findings as support for a grasping affordance account, in which the handle primes the response on the corresponding hand. However, evidence has accrued that at least in many cases the effect is attributable to spatial compatibility unrelated to grasping (Bub, Masson, & Kumar, 2018; Proctor & Miles, 2014). Consequently, although some authors call this handle-press correspondence effect *affordance compatibility* (e.g., Pappas, 2014), we prefer the more theoretically neutral term *object-based compatibility* (e.g., Proctor, Lien, & Thompson, 2017).

Among the evidence against a grasping affordance account is that similar correspondence effects can be obtained with two fingers on the same hand (Cho & Proctor, 2010), left and right foot-press responses (Phillips & Ward, 2002), and relative to the salient non-graspable spout of a teapot (Cho & Proctor, 2011). Of particular relevance is a study by Song, Chen, and Proctor (2014) that deconstructed a correspondence effect obtained for pictures of flashlights (torches) with a graspable handle at one end, which Pellicano, Iani, Borghi, Rubichi, and Nicoletti (2010) attributed to a grasping affordance.

✉ Aiping Xiong
axx29@ist.psu.edu

[1] College of Information Sciences and Technology, The Pennsylvania State University, E373 Westgate Building, University Park, PA 16802, USA

[2] Department of Psychological Sciences, Purdue University, West Lafayette, IN, USA

[3] Health and Kinesiology Department, Purdue University, West Lafayette, IN, USA

Specifically, Pellicano et al. found that when participants made left/right key-presses to the upright/inverted orientation of a laterally oriented flashlight, responses were faster when the handle end corresponded with the response than when it did not. Song et al. noted that the flashlights had salient strip markings on the barrel that were asymmetric and, thus, would be located more toward the side of the handle. They showed that making the barrel markings more asymmetric by removing the handle of the flashlight increased the correspondence effect, whereas including only the half of the markings nearest the light end of the flashlight reversed the correspondence effect to favor the light end. That is, the pattern of correspondence effects was determined primarily by the asymmetry of a salient visual feature, rather than the location of the graspable end.

Despite the substantial evidence to the contrary, advocacy for a grasping affordance account has persisted. Pappas (2014) reported experiments purporting to show that although spatial effects predominate with schematic depictions of objects, true affordance effects do occur with higher fidelity pictures of objects. Furthermore, Kourtis and Vingerhoets (2015) concluded that affordances offered by photographs of objects play a role with key-press responses. In opposition to this view, Yu, Abrams, and Zacks (2014), Proctor et al. (2017), and Bub et al. (2018) provided evidence that even with photographs of objects, key-press responses do not show a grasping affordance effect. Instead, the results are most easily explained by spatial coding accounts that apply to spatial compatibility effects more generally (Proctor & Vu, 2006).

In a recent study, Gomez, Skiba, and Snow (2018) concluded that they found evidence of a grasping affordance effect with key-press responses using a version of the flanker task in which distracting stimuli occurred above or below a target stimulus. The stimuli were white plastic spoons, and the task was to make the response corresponding with the side of the handle of a centered spoon, while ignoring the spoons located above and below the target spoon, on which the handles pointed in a congruent or incongruent direction. Gomez et al. obtained a flanker correspondence effect, for which responses were faster when the flanker handles corresponded with the target handle than when they did not. This effect was present for conditions in which the stimuli were two-dimensional (2D) photographs and three-dimensional (3D) objects, albeit slightly larger for the 3D objects (37 ms vs. 29 ms). Gomez et al. (2018, p. 216) interpreted their results as providing "strong support for the affordance-competition hypothesis (Cisek, 2007)," according to which the larger effect for 3D than 2D objects is due to the former activating a stronger automatic grasping tendency than the latter. Because their study included responses to the handle part only, without a comparison to conditions with responses to the functional end (the tip), their results are not sufficient to support the view of automatic activation due to a grasping affordance.

In a study published prior to that of Gomez et al. (2018), Skiba and Snow (2016) obtained results that they interpreted as evidence that attention toward tool images is driven by the head (functional end) but not the handle of the tool. Using cuing tasks, participants detected a target dot that was positioned near either the handle or head of a centrally presented photo of a tool (i.e., the cue, such as spoon or knife). Non-tool images – graspable vegetables or fruits (e.g., eggplant, pepper) matched approximately to the tool images in size, length, and left/right shape asymmetry – were included as a control condition. Experiment 1 used a long cue-target stimulus-onset asynchrony (SOA) of 800 ms, whereas Experiment 2 used a short SOA of 200 ms. Participants detected targets near the head of tools faster than those near the handle at the 800-ms SOA but not at the 200-ms SOA, whereas the non-tool images showed no mean difference in RT between the two ends at either SOA. The authors concluded that their results indicated "affordance effects on attentional capture are driven by the head end of a tool" (p. 2500). Although the cuing task differed from the flanker task used by Gomez et al., Skiba and Snow's conclusion of an affordance for the functional end of a graspable tool is opposite to that of Gomez et al.'s conclusion of an affordance for the graspable end. Examination of the individual non-tool images used in Skiba and Snow's study suggests that they did not control adequately for salience asymmetry (e.g., the spoon was matched with a banana), a point to which we return in the General discussion.

In the present study we only addressed the issue of whether the handle part of a spoon or another eating utensil, chopsticks, in 2D photographs automatically produces a grasping affordance that affects the latency of a key-press response. Instead of using the flanker task, we used a simpler task in which only a single utensil was presented on a trial, with participants instructed to respond via a key-press with a compatible or incompatible mapping to the handle or tip. This is a more direct method than that used in most other studies of object-based compatibility effects that have examined correspondence effects of the object property of interest when it is irrelevant to the assigned task. By studying what is sometimes called stimulus-response compatibility proper (Stoffer, 1991), we were able to compare RT with the compatible mapping for handle-relevant and tip-relevant conditions. When compatibility is manipulated in distinct trial blocks, participants can adopt a strategy of responding on the basis of bottom-up processes in the block with compatible mapping because they know that the immediate response tendency is correct (Shaffer, 1965; Xiong & Proctor, 2018). Therefore, a benefit for the compatible mapping of the tip versus the handle should provide evidence as to which end of the utensil draws attention at onset, or, in other words, is most salient. We also could compare compatibility effects (difference in RT between incompatible and compatible mappings) for the tip- and handle-relevant conditions, which likewise would be expected to be larger when the relevant part is the one to which attention is drawn initially, which we infer is also automatic.

In Experiment 1, the stimuli were photos of plastic spoons, as in Gomez et al.'s (2018) study, whereas in Experiments 2 and 3 they were photos of chopsticks, with a single bamboo appearance in the former experiment and a salient red grasping end in the latter one. In all cases, if the stimuli activate a grasping affordance, then the compatibility effects should be larger when the graspable end is relevant compared to when the functional end (tip) is relevant. If the stimuli activate a functional-end affordance, the opposite result pattern should be found. However, if the most critical factor is relative salience of the graspable or functional end, that is, the part that is most obviously varying in left and right positions across trials, then the compatibility effect should be larger for the salient tip end of the spoon in Experiment 1, differ less for the two ends in Experiment 2, and be larger for the salient handle end in Experiment 3.

Experiment 1

Experiment 1 was designed to evaluate whether the typical graspable part of a spoon image (used by Gomez et al., 2018) exerts more influence on attention and reduces RT than does the functional part. Participants completed a choice-reaction task in which they responded to the location of one part (tip or handle) of a spoon with a spatially corresponding response or a spatially non-corresponding response. A larger benefit of the spatially compatible mapping than for the spatially incompatible mapping was expected regardless of the handle or the tip. For centered objects, the salient location feature that determines spatial correspondence effects is the part that differs in left-right location the most for the alternative orientations (Cho & Proctor, 2011; Masson, 2018). In the case of the spoon stimuli, that feature is the tip (compare the images in the left column of Fig. 1). If the grasping affordance hypothesis (Tucker & Ellis, 1998) holds for the object image, we expected that the spatial compatibility effect of the handle should be larger than that of the tip. Otherwise, if participants respond mainly according to the location of the object's salient feature (Kourtis & Vingerhoets, 2015) – the spoon tip – a larger spatial compatibility effect is predicted for the tip than for the handle.

Using G*Power (Version 3.1.9.2; Faul, Erdfelder, Lang, & Buchner, 2007), we estimated that with a sample of 28 participants for each responding relevant part, we would have 95% power to detect a medium-sized (0.57) spatial compatibility effect given an F test and an α level of .05 (based on Kourtis and Vingerhoets' (2015) experiment, which showed a compatibility effect relative to the functional end of graspable objects).

Method

Participants Fifty-six students (24 male; $M_{\text{age}} = 19.1$; seven left-handed) participated in the study. All participants in this and the remaining experiments (1) were enrolled in an introductory psychology course at Purdue University and received research participation credit, (2) reported to have normal or corrected-to-normal vision and auditon, (3) were naïve to the purpose of the study, (4) provided informed consent, and (5) satisfied a predetermined criterion of error rate of < 10%.

Apparatus and stimuli Stimulus presentation and response recording were achieved by means of E-Prime 2.0 software installed on a PC workstation. Participants were seated in front of a 76-cm high table on which an E-Prime response box with a row of five response buttons was placed. Instructions, visual stimuli, and response feedback were presented on a 19-in. LCD monitor in front of participants, with an unconstrained viewing distance of approximately 60 cm in a dimly lit room. The response box was center-aligned with the display. Visual stimuli were the 2-D spoon images used by Gomez et al. (2018), with the spoon tip located to the left or to the right (see Fig. 1 left column). The spoon within each image was centered at the vertical and horizontal midpoint on a black background, and subtended 13.7° × 2.9°. The fixation point was a small plus sign (1.3 mm). The spoon appeared with the tip randomly oriented to the left or right of the screen. Response were made by pressing the symmetric center-left and center-right buttons on the response box with the corresponding index finger.

Procedure The part of the spoon to which the participant was told to respond was varied between participants. Half of the participants were instructed to respond to the tip, and the other half to respond to the handle. Each participant was directed to respond to the assigned part with spatially compatible responses in one block and spatially incompatible responses in the other. For the compatible block the correct response was the one to the same side as the instructed part, whereas for the incompatible block the correct response was to the opposite side of the part. The two blocks were separated by a self-paced break. Presentation order of blocks was counterbalanced between participants. Each block included 80 trials and was preceded by eight practice trials. A spoon image with a left tip or a right tip appeared randomly and equally often, centered on the screen.

Each trial began with presentation of the fixation point for between 200 and 500 ms in duration in interval steps of 100 ms, after which a spoon image was presented at the screen center until a button-press response was made. An intertrial interval of 500 ms began immediately after a correct response or following a 1,000-ms visual error message ("Incorrect!") after an incorrect response. A trial would terminate if no

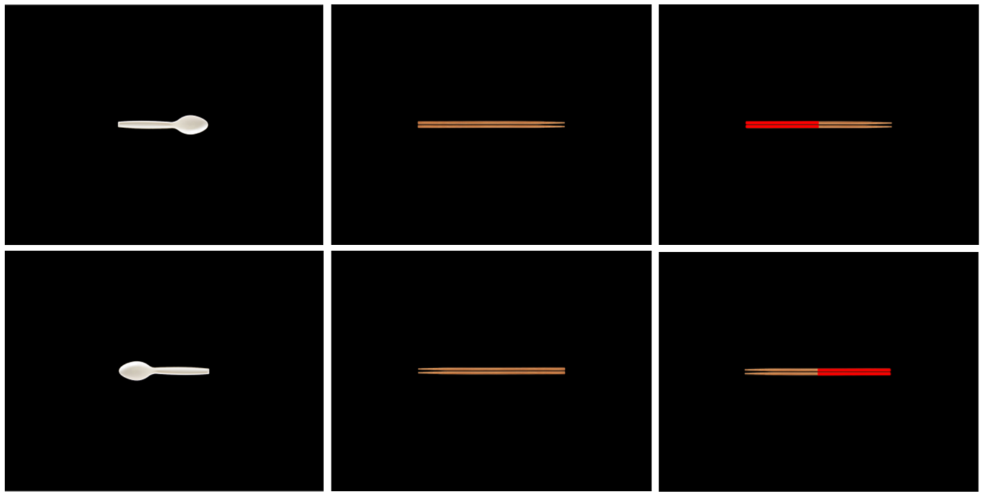

Fig. 1 Examples of stimuli presented on a dark screen with the tip located to the right (top row) and to the left (bottom row) in Experiments 1–3. The left column illustrates the 2D images of the spoons from Gomez et al. (2018), used in Experiment 1. The middle column illustrates the bamboo chopsticks used in Experiment 2. The right column shows the bamboo chopsticks with red handle used in Experiments 3A and 3B

response was detected within 2,000 ms of stimulus onset and a message ("No response detected! Please respond faster!") was presented for 1,000 ms on the screen.

The experiment was conducted in a quiet, dimly lit room. Participants were seated comfortably in a chair and were instructed to put their index fingers on the response buttons during the whole experiment. For each mapping condition, the experimenter went through the instructions and practice with the participant and stayed in the room for the test trials.

Results

In all experiments, only correct trials were included for RT analysis. Trials with premature responses (RT < 150 ms) or for which RTs > 2.5 standard deviations (*SD*s) above each participant overall mean were excluded (1.3% for the tip condition and 1.4% for the handle condition). For analysis of the spatial compatibility effect, mean RT and percentage error of compatible and incompatible mappings were calculated for each participant. Repeated-measures analyses of variance (ANOVAs) were carried out with one within-subjects factor (Compatibility: compatible, incompatible) and one between-subjects factor (Spoon Relevant Part: tip, handle). Follow-up simple effects ANOVAs, comparing the tip- and handle-relevant conditions for the compatible mapping and the incompatible mapping separately, were conducted on the interaction.

Mean RT Table 1 lists mean RT and percentage error for each condition. Mean RT was 15 ms shorter for the compatible mapping than for the incompatible mapping, $F(1,54) = 5.58$, $p = .022$, $\eta_p^2 = .094$. The main effect of responding part was also significant, $F(1,54) = 4.22$, $p = .045$, $\eta_p^2 = .072$, with mean RT being shorter when the tip was relevant (359 ms) than when the handle was relevant (381 ms). Moreover, the compatibility × relevant part interaction was also significant, $F(1,54) = 23.17$, $p < .001$, $\eta_p^2 = .300$. The tip-relevant condition showed a 45-ms compatibility effect, whereas the handle-relevant condition showed a −15-ms compatibility effect (see Fig. 2). The larger compatibility effect for the tip-relevant condition was due entirely to the compatible mapping: For that mapping, RT was 53 ms shorter in the tip-relevant condition than in the handle-relevant condition, $F(1,54) = 20.24$, $p < .001$, $\eta_p^2 = .273$, whereas for the incompatible mapping, RT was a nonsignificant 7 ms shorter for the hand-relevant condition than for the tip-relevant condition, $F < 1.0$.

Mean percent error Percent error for the compatible mapping (1.0%) did not differ from that of the incompatible mapping (1.2%), $F < 1.0$. The error rate for the tip condition (0.9%) was only numerically lower than that for the handle condition (1.3%), $F(1,54) = 1.01$, $p = .319$, $\eta_p^2 = .018$. In addition, the interaction between compatibility and spoon-relevant part was not significant, $F < 1.0$.

Discussion

In Experiment 1 RT was shorter when participants responded to the tip (functional end of the spoon) rather than to the handle (graspable end of the spoon), but this benefit held only for the compatible mapping. This advantage for the tip-relevant condition with the compatible mapping indicates that the left or right location of the spoon tip is more salient than that of the handle. This difference in salience is an expected consequence of the spoon stimuli being centered on the display such that the trial-to-trial change in left or right location is larger for the tip than for the handle (Masson, 2018; Proctor et al., 2017). Accordingly, the tip location yielded a large spatial compatibility effect when it was relevant, whereas handle location yielded

Table 1 Mean correct reaction time (RT, in ms) and percentage error (PE), with standard error in parentheses, as a function of relevant part and compatibility in all experiments

Experiment	Relevant part	Mean RT		PE	
		Compatible	Incompatible	Compatible	Incompatible
1	Tip	336 (4.9)	381 (7.1)	0.7% (0.3%)	1.0% (0.2%)
(Spoon)	Handle	389 (10.8)	374 (11.6)	1.3% (0.3%)	1.4% (0.5%)
2	Tip	399 (9.0)	424 (9.0)	0.8% (0.2%)	1.2% (0.3%)
(Chopsticks)	Handle	428 (10.4)	436 (14.1)	0.7% (0.2%)	1.3% (0.6%)
3A	Tip	367 (12.2)	365 (9.5)	0.8% (0.3%)	0.8% (0.2%)
(Chopsticks Red)	Handle	345 (7.1)	374 (12.6)	0.6% (0.2%)	0.7% (0.2%)
3B	Tip	366 (5.9)	363 (9.2)	0.9% (0.2%)	1.0% (0.3%)
(Chopsticks Red)	Handle	356 (8.8)	380 (10.8)	0.9% (0.3%)	1.5% (0.7%)

a slightly negative compatibility effect when it was relevant. In other words, the spoon-tip information tended to attract attention and allowed a response on the bottom-up, immediate tendencies when participants knew that they were to make the response corresponding to tip location. When the tip location was mapped incompatibly to the responses, participants apparently relied on slower, top-down decision processes of the type used when the handle was relevant. This result is similar to that obtained when spatially compatible and incompatible mappings for two-choice tasks are mixed within a trial block. Such mixing results in elimination of the advantage for the compatible mapping over the incompatible mapping (Shaffer, 1965; Vu & Proctor, 2004; Xiong & Proctor, 2018), implying that participants can take advantage of the initial response tendency when they know it will be correct. The greater influence of tip location rather than handle location on performance provides evidence against an account according to which a tendency to grasp the handle is a primary factor. It is in agreement, though, with both a functional-end affordance account in terms of the "head" of the implement and a spatial coding account in terms of location of the object's salient part.

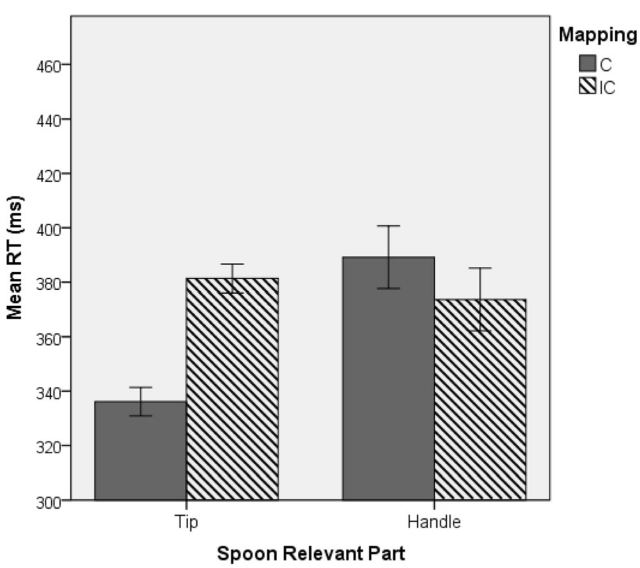

Fig. 2 Mean reaction time (RT) as a function of Spoon Relevant Part (Tip, Handle) and Compatibility for Experiment 1. Error bars represent ±2 standard errors of the mean calculated based on Cousineau's (2005) method for within-subject variables. *C* compatible mapping, *IC* incompatible mapping

Experiment 2

Our purpose in Experiment 2 was to obtain evidence adjudicating between the functional-end affordance and visual salience accounts by using chopsticks, which seem to have a less salient tip part compared to the spoon but serve a similar function to a spoon in everyday life. To make sure that participants knew which end was the functional one, only East Asian native students (e.g., Chinese, Korean, and Japanese) were recruited as participants. If the results of Experiment 1 were mainly due to participants attending to the functional end regardless of salience, the chopstick images should produce similar results to the spoons. However, if relative salience of the tip-changing location was the main factor, the advantage of the functional end should be reduced or eliminated because the functional and graspable ends of the chopsticks are more similar than they are for the spoons. Consequently, the left-right location distinction for the tip end should not be greater than that for the handle end.

Method

Participants Fifty-six East Asian students (41 male; M_{age} = 20.1; one left-handed) participated in the study, 28 in the tip condition and 28 in the handle condition.

Apparatus, stimuli, and procedure These were same as in Experiment 1, except the spoon photographs were replaced by photographs of bamboo chopsticks (see Fig. 1, middle column). The chopsticks in each image were centered at the vertical and horizontal midpoint on a black background, and subtended 25.6° × 1.3°.

Results

Using the same criteria as in Experiment 1, 1.4% of trials for the tip condition and 1.3% for the handle condition were excluded from analysis. Mean correct RT and percentage error as a function of compatibility were calculated for each participant. ANOVAs of mean RT and mean percentage were conducted in the same way as Experiment 1.

Mean RT Table 1 lists mean RT and percent error for each condition. Only the main effect of mapping was statistically significant, $F(1,54) = 7.45$, $p = .009$, $\eta_p^2 = .121$. Responses were 16 ms faster for the compatible stimulus-response mapping than for the incompatible mapping. The main effect of responding part was not significant, $F(1,54) = 2.05$, $p = .158$, $\eta_p^2 = .037$, but RT was numerically smaller when the tip was relevant (412 ms) than when the handle was relevant (432 ms). The two-way interaction of compatibility and relevant part also was not significant, $F(1,54) = 1.85$, $p = .179$, $\eta_p^2 = .033$. However, comparisons similar to those performed for Experiment 1 showed a 25-ms compatibility effect for the tip-relevant condition compared to 8 ms for the handle-relevant condition (see Fig. 3). Also, for the compatible mapping, RT was a significant 29 ms shorter in the tip-relevant condition than in the handle-relevant condition, $F(1,54) = 4.25$, $p = .044$, $\eta_p^2 = .072$, whereas for the incompatible mapping this difference was a nonsignificant 12 ms, $F < 1.0$.

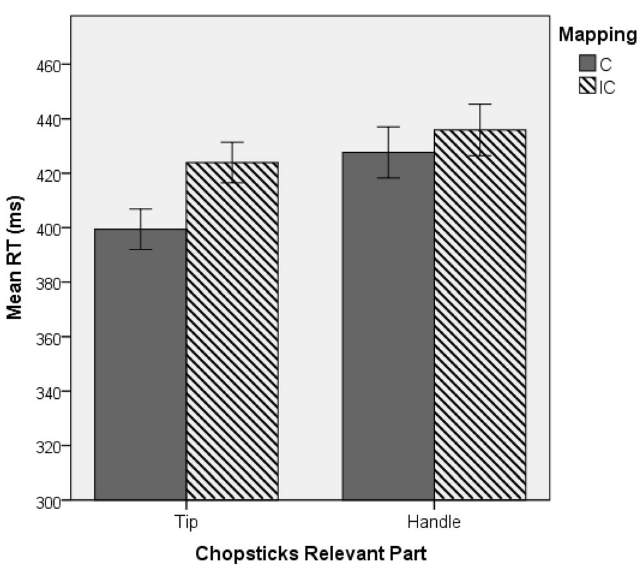

Fig. 3 Mean reaction time (RT) as a function of Chopsticks Relevant Part (Tip, Handle) and Compatibility for Experiment 2. Error bars represent ±2 standard error of the mean calculated based on Cousineau's (2005) method for within-subject variables. *C* compatible mapping, *IC* incompatible mapping

Mean percent error Error for the compatible mapping (0.7%) was slightly smaller than the incompatible mapping (1.2%), $F(1,54) = 2.81$, $p = .099$, $\eta_p^2 = .049$. Error for the tip condition was similar to that of the handle condition, $F < 1.0$. The interaction between compatibility and relevant chopsticks part was not significant, $F < 1.0$.

Discussion

In Experiment 2, RT values were not significantly different overall when responding to the tip (functional end of chopsticks) or the handle (graspable end of chopsticks), and there was no significant interaction with compatibility. For the compatible mapping, though, responses were still faster for the tip-relevant condition than for the handle-relevant condition, but at about half the size of the difference in Experiment 1. Therefore, using chopsticks, the asymmetry of compatibility effects between tip and handle obtained in Experiment 1 was reduced, though not eliminated entirely. This result pattern provides evidence that a decrease in salience of the tip relative to the handle makes the compatibility effects for the two ends more comparable. However, the tip and handle do not seem to be of equal salience because there was still evidence with the compatible mapping that participants were able to respond in a more bottom-up manner to the tip location than to the handle location.

We also assume that if there were any object-relevant effect, East Asian participants would likely exhibit a larger compatibility effect when the handle was relevant. Yet, the nonsignificant interaction of compatibility and relevant part was in the opposite direction of that expected if the handle were favored, which provides no support for automatic activation of a grasping affordance in key-press response situations.

Experiments 3A and 3B

As noted, although the mean compatibility effect was positive for the chopstick handle in Experiment 2, the compatibility effect of the handle end was still numerically smaller than that for the tip end. This result, along with the benefit for the tip-relevant condition with the compatible mapping, leaves open the possibility that an affordance for the functional end may be contributing to the compatibility effects. Experiments 3A and 3B were conducted to increase the visual salience of the chopstick handle, to determine whether this would increase the size of the compatibility effect for the handle compared to the tip, as predicted by a relative salience account. Moreover, the results predicted by the visual salience hypothesis should be obtained regardless of whether all participants are very familiar with chopsticks or not. Therefore, we conducted Experiment 3A without restriction of participants' national heritage, as in Experiment 1, but restricted participants to East Asians for Experiment 3B, as in Experiment 2.

Method

Participants We conducted Experiment 3A first, in which we released the restriction on participants because only a limited number of East Asians remained in the semester's subject pool. Fifty-six students (41 male; M_{age} = 19.3; four left-handed; nine East Asian) participated in Experiment 3A. Experiment 3B was conducted the following semester with another 56 students (31 male; M_{age} = 19.1; three left-handed and one ambidextrous), all of whom were of East Asian origin. In both experiments, 28 participants were randomly assigned to the tip condition and the other 28 to the handle condition,

Apparatus, stimuli, and procedure These were the same as in Experiment 2, except that the chopstick handle part (from the middle to handle end) was painted red (R:255, G:0, B:0) using Photoshop (see Fig. 1, right column).

Results

Using the same criteria as in Experiment 1, 1.5% of trials for the tip condition and 1.4% for the handle condition in Experiment 3A and 1.8% for the tip condition and 1.7% for the handle condition in Experiment 3B were excluded from analysis. Mean correct RT and percentage error as a function of compatibility were calculated for each participant. ANOVAs of mean RT and mean percentage error were conducted in the same way as in prior experiments.

Mean RT Table 1 lists mean RT and percentage error for each condition. For Experiment 3A, there was a main effect of mapping, $F(1,54) = 7.36$, $p = .009$, $\eta_p^2 = .120$. RT was 14 ms shorter for the compatible mapping than for the incompatible mapping. The main effect of relevant part was not significant, $F < 1.0$, with mean RT of 366 ms for the tip-relevant condition and 359 ms for the handle-relevant condition. Unlike Experiment 2, the two-way interaction of compatibility × relevant part was significant, $F(1,54) = 9.42$, $p = .003$, $\eta_p^2 = .148$, reflecting a 29-ms compatibility effect for the handle-relevant condition compared to a −2-ms compatibility effect for the tip-relevant condition (see Fig. 4). In this case, neither the compatible nor the incompatible mapping showed a significant difference in RT between the two relevance conditions, although RT was 22 ms shorter in the handle-relevant condition than in the tip-relevant condition for the compatible mapping, $F(1,54) = 2.53$, $p = .117$, $\eta_p^2 = .045$, compared to 9 ms longer for the incompatible mapping, $F < 1.0$.

Similar results were obtained for Experiment 3B, in which the participants were all East Asians. There was a main effect of mapping, $F(1,54) = 4.38$, $p = .041$, $\eta_p^2 = .075$, and no significant difference overall when the tip was relevant (365 ms) than when the handle was relevant (368 ms), $F < 1.0$. There was again a significant two-way interaction of compatibility × relevant part, $F(1,54) = 7.67$, $p = .007$, $\eta_p^2 = .124$. The 24-ms compatibility effect for the handle-relevant condition was larger than the −3-ms compatibility effect for the tip-relevant condition (see Fig. 5). As in Experiment 3A, neither the compatible nor the incompatible RT showed a significant difference, but mean RT was 10 ms shorter in the handle-relevant condition than in the tip-relevant condition for the compatible mapping, $F < 1.0$, compared to 17 ms longer for the incompatible mapping, $F(1,54) = 1.49$, $p = .227$, $\eta_p^2 = .027$.

A comparison between Experiments 3A and 3B that included experiment as another factor showed, as in the individual experiments, a significant two-way interaction of compatibility and relevant part, $F(1,108) = 17.07$, $p < .001$, $\eta_p^2 = .136$. Most importantly, there was no three-way interaction of those variables with experiment, $F < 1.0$, consistent with the effects being of similar magnitude regardless of participants' familiarity with the function of chopsticks.

Mean percent error For both Experiments 3A and 3B, the error rate for the compatible mapping was similar to that of

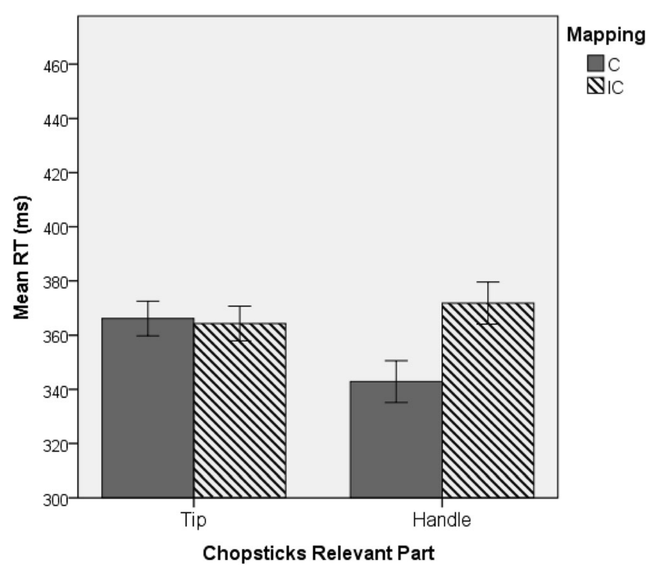

Fig. 4 Experiment 3A: Mean reaction time (RT) as a function of Chopsticks Relevant Part (Tip, Handle) and Compatibility. Error bars represent ±2 standard error of the mean calculated based on Cousineau's (2005) method for within-subject variables. *C* compatible mapping, *IC* incompatible mapping

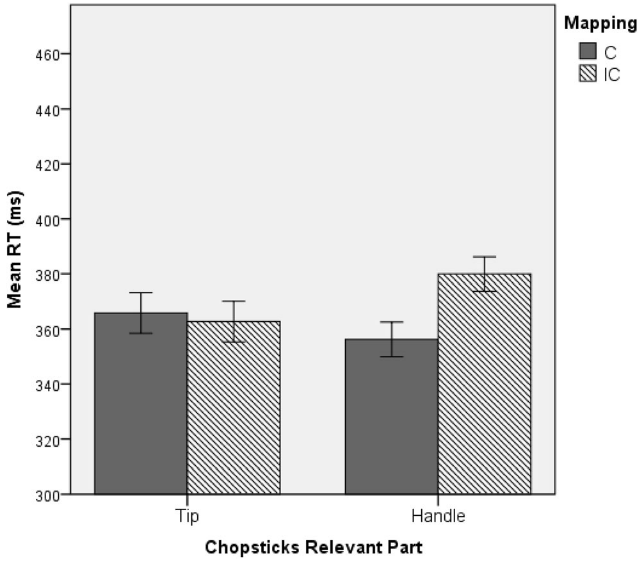

Fig. 5 Experiment 3B: Mean reaction time (RT) as a function of Chopsticks Relevant Part (Tip, Handle) and Compatibility. Error bars represent ±2 standard error of the mean calculated based on Cousineau's (2005) method for within-subject variables. *C* compatible mapping, *IC* incompatible mapping

the incompatible mapping, *F*s < 1.0. Error for the tip condition was similar to that for the handle condition, *F*s < 1.0. The interaction between compatibility and relevant chopstick part was not significant either, *F*s < 1.0.

Experiment 1 versus Experiment 3A Because the participants in Experiments 1 and 3A were from the same unrestricted subject pool, we conducted a between-experiment comparison of RT with experiment as another factor. The results showed a compatibility main effect, $F(1,108) = 12.51$, $p = .001$, $\eta_p^2 = .104$: Mean RT for the compatible mapping was 15 ms shorter than the incompatible mapping. The two-way interaction of compatibility and relevant part approached significance, $F(1,108) = 3.48$, $p = .065$, $\eta_p^2 = .031$, signifying that the compatibility effect tended to be larger for the tip (21 ms) than for the handle (7 ms) across the two experiments. Most important, the three-way interaction of experiment × compatibility × relevant part was significant, $F(1,108) = 32.24$, $p < .001$, $\eta_p^2 = .230$, indicating the opposite pattern between compatibility and relevant part with the spoon stimuli and the chopstick stimuli with red handles.

Experiment 2 versus Experiment 3B Likewise, we conducted a between-experiment comparison of RT for Experiments 2 and 3B because the participants were all East Asians. There was a main effect of compatibility, $F(1,108) = 11.82$, $p < .001$, $\eta_p^2 = .099$. Mean RT for the compatible mapping was 15 ms shorter than the incompatible mapping. There was also a main effect of experiment, $F(1,108) = 37.45$, $p < .001$, $\eta_p^2 = .226$. Participants' responses were faster overall in Experiment 3B (366 ms) than in Experiment 2 (422 ms), indicating that having the handle and tip in different colors made it easier to identify the location of the relevant part of the chopsticks. The two-way interaction of compatibility and relevant part was not significant, $F < 1.0$, but RT was 16 ms shorter in the handle-relevant condition than in the tip-relevant condition for the compatible mapping, $F(1,108) = 4.79$, $p = .031$, $\eta_p^2 = .042$, compared to a nonsignificant 13 ms longer for the incompatible mapping, $F < 1.0$. More critically, the three-way interaction of experiment × compatibility × relevant part was significant, $F(1,108) = 7.84$, $p = .006$, $\eta_p^2 = .068$: Coloring the handle red in Experiment 3B eliminated the advantage for the tip with the compatible mapping that was evident in Experiment 2, providing evidence that the handle was indeed made more salient by being colored red.

Discussion

In Experiments 3A and 3B, when the handle end of the chopsticks was made more salient by adding a color cue, the asymmetry of compatibility effects, which was reduced in Experiment 2, reappeared and reversed. The larger compatibility effect was now obtained for the handle and not the tip, which is opposite of the relation found with the spoon stimuli in Experiment 1. Comparison of Experiments 3A and 3B showed no significant difference in the result pattern for a general sample of university students compared to one composed of East Asians. This outcome implies that past experience using chopsticks had little impact on the compatibility effects obtained with the red handles of chopstick images. The overall faster responses of Experiment 3B (in which the handles were colored) than Experiment 2 (in which they were not) indicates that the locations of the respective ends of the chopsticks could be discriminated more readily when they were of different colors. The lack of an overall compatibility effect for the tip and handle conditions combined, coupled with the shift of the compatibility × relevant part function compared to Experiment 2, illustrates the importance of visual salience.

General discussion

Across the three experiments, the results are consistent with previous work (Cho & Proctor, 2011; Song et al., 2014) showing that salient parts of objects that change position across trials are an important contributor to compatibility effects obtained with key-press responses. Furthermore, these effects are difficult to reconcile with an "affordance" explanation. Skiba and Snow (2016) attempted to control salience asymmetry for their study in which they concluded that they had demonstrated a functional-end affordance effect for tools. However, their non-tool fruit and vegetable pictures differed greatly in appearance from their tool pictures. In fact, the result patterns for the individual stimuli illustrated in their Fig. 4 seem to be comparable for the non-tools that are most similar to their counterpart tools and to reverse for two non-tool images (pepper and banana) that are less similar to their tool counterparts (peeler and spoon, respectively). In short, their results do not provide strong evidence against a salience account.

A point to note about the present study is that a compatible mapping of the tip is an incompatible mapping of the handle, and vice versa. If the tip and handle were equally salient, and participants adopted a strategy of remapping an incompatible relation for one end to a compatible one for the other, then responding would be equally fast in both cases and no compatibility effect would be evident. Although some participants may have engaged in this strategy, the compatibility effects that were apparent in all three experiments indicate that most did not. This outcome is in agreement with results obtained by Proctor, Wang, and Pick (2004) for wheel-rotation responses to left and right tone stimuli. With the wheel held at the bottom, the direction of hand movement is opposite to that of the wheel rotation, which means that responses can be coded with respect to either the hand or wheel reference frame. Yet, participants showed large compatibility effects with respect to the frame emphasized in instructions or by movement of a visual cursor, showing that they continued to code responses relative to that reference frame even when it resulted in an incompatible mapping to the stimulus locations.

If one end of the eating utensils is more salient than the other, and participants responded to it regardless of instructions, they would show a positive compatibility effect when the instructions were to respond to that dimension. However, when the instructions were to respond to the less salient dimension, then a complete reversal to a negative effect of the same size would be obtained when participants adopted a remapping strategy. Again, this result did not occur. The closest approximation to it was in Experiment 1, where the compatibility effect was 45 ms for the spoon tip and −15 ms for the handle. That result, and the opposite ones of Experiments 3A and 3B, for which the chopstick tip yielded a compatibility effect of −3 ms compared to the 27-ms compatibility effect for the handle, suggests that, regardless of their prior experience with chopsticks, participants were not able to ignore the salient part of the utensil entirely and attend solely to the less salient part.

There was no evidence in the present results of a contribution from a grasping affordance because the compatibility effect was larger for the functional end of the utensil than for the handle end in Experiment 1. This difference was reduced in Experiment 2 with the non-saliently colored chopsticks, for which there was a non-significant tendency for the compatibility effect to be larger for the functional tip end than for the handle end. The interaction pattern obtained in Experiment 1 reversed to show a larger compatibility effect for the handle end than the functional end when the salience of the chopstick handle was increased in Experiments 3A and 3B. Thus, the results are in agreement with findings of other studies that the compatibility effects obtained with pictorial depictions and photographs of objects with graspable handles are due primarily to correspondence of spatial codes derived from salient properties of the objects that vary in location across trials (Cho & Proctor, 2011; Pellicano, Koch, & Binkofski, 2017).

The majority of evidence obtained with key-press responses in a variety of specific tasks, including those of the present study, imply that affordances play at most a small role in the obtained compatibility effects (Bub et al., 2018; Masson, 2018; Proctor & Miles, 2014). In accord with this conclusion, in an extensive study, Yu et al. (2014, p. 1867) concluded: "The results from seven experiments indicate that action priming [affordance compatibility] for button-pressing actions is difficult to obtain, despite our attempts to do so with multiple response methods, experimental tasks, and stimulus sets." We have not attempted to address in the present experiments whether 3D objects produce "true" affordance compatibility effects with key-press responses, as Gomez et al. (2018) concluded. But, given the repeated failure of evidence for such effects to stand up to close scrutiny, we are skeptical that they will do so in the case of 3D objects. However, this is still an open question.

Where does this leave matters with regard to the notion of affordances more generally? From our perspective, there is little reason to think that a grasping affordance would be activated when the task set is to make key-press responses. However, it is possible that a task set to make grasping responses may enable a true affordance-based compatibility effect, as Bub et al. (2018) have tentatively concluded. Any such effect, however, can be explained in terms of dimensional overlap (Kornblum, Hasbroucq, & Osman, 1990) and the response-discrimination hypothesis (Ansorge & Wühr, 2004): Stimulus-response compatibility effects arise when a stimulus dimension overlaps with, or is similar to, a dimension along which the response alternatives are discriminated. Consequently, even in the case of grasping responses, we agree with Bub et al. that "very strong evidence is needed" (p. 66) before reaching a firm conclusion that even a subset of compatibility effects in choice-reaction tasks is a consequence of limb-specific motor representations rather than abstract response codes. Regardless of whether such effects are due predominantly to spatial coding (Proctor & Vu, 2006) or to affordances (Gibson, 1979), it is apparent that the decisions and actions a person tends to make directly, or automatically, are determined by various factors including task goals, object properties, and the environmental context in which the person is operating (e.g., Zelaznik & Forney, 2016).

Author Note We thank Jennifer Cathlyn Chan and Yaqi Xu for assistance in conducting the experiments.

References

Ansorge, U., & Wühr, P. (2004). A response-discrimination account of the Simon effect. *Journal of Experimental Psychology: Human Perception and Performance, 30*, 365–377.

Bub, D. N., Masson, M. E. J., & Kumar, R. (2018). Time course of motor affordances evoked by pictured objects and words. *Journal of Experimental Psychology: Human Perception and Performance, 44*, 53-68.

Cho, D. T., & Proctor, R. W. (2010). The object-based Simon effect: Grasping affordance or relative location of the graspable part? *Journal of Experimental Psychology: Human Perception and Performance, 36,* 853-861.

Cho, D. T., & Proctor, R. W. (2011). Correspondence effects for objects with opposing left and right protrusions. *Journal of Experimental Psychology: Human Perception and Performance, 37*, 737-749.

Cisek, P. (2007). Cortical mechanisms of action selection: The affordance competition hypothesis. *Philosophical Transactions of the Royal Society, B: Biological Sciences*, *362*, 1585–1599.

Cousineau, D. (2005). Confidence intervals in within-subject designs: A simpler solution to Loftus and Masson's method. *Tutorial in Quantitative Methods for Psychology*, *1*, 42-45.

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*, 175-191.

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

Gomez, M. A., Skiba, R. M., & Snow, J. C. (2018). Graspable objects grab attention more than images do. *Psychological Science*, *29*, 206-218.

Kornblum, S., Hasbroucq, T., & Osman, A. (1990). Dimensional overlap: Cognitive basis for stimulus–response compatibility—A model and taxonomy. *Psychological Review, 97,* 253–270.

Kourtis, D., & Vingerhoets, G. (2015). Perceiving objects by their function: An EEG study on feature saliency and prehensile affordances. *Biological Psychology*, *110*, 138-147.

Masson, M. E. J. (2018). *Canadian Journal of Experimental Psychology, 72*, 219-228.

Pappas, Z. (2014). Dissociating Simon and affordance compatibility effects: Silhouettes and photographs. *Cognition, 133*, 716–728.

Pellicano, A., Iani, C., Borghi, A. M., Rubichi, S., & Nicoletti, R. (2010). Simon-like and functional affordance effects with tools: The effects of object perceptual discrimination and object action state. *Quarterly Journal of Experimental Psychology, 63*, 2190–2201.

Pellicano, A., Koch, I., & Binkofski, F. (2017). Location-coding account versus affordance-activation account in handle-to-hand correspondence effects: Evidence of Simon-like effects based on the coding of action direction. *Journal of Experimental Psychology: Human Perception and Performance*, *43*, 1647-1666.

Phillips, J. C., & Ward, R. (2002). S-R correspondence effects of irrelevant visual affordance: Time course and specificity of response activation. *Visual Cognition, 9,* 540–548.

Proctor, R. W., Lien, M. C., & Thompson, L. (2017). Do silhouettes and photographs produce fundamentally different object-based correspondence effects? *Cognition*, *169*, 91-101.

Proctor, R. W., & Miles, J. D. (2014). Does the concept of affordance add anything to explanations of stimulus-response compatibility effects? In B. H. Ross (Ed.), *The psychology of learning and motivation* (Vol. 60; pp. 227-266). San Diego, CA: Academic Press.

Proctor, R. W., & Vu, K.-P. L. (2006). *Stimulus–response compatibility principles: Data, theory, and application*. Boca Raton, FL: CRC Press.

Proctor, R. W., Wang, D. Y. D., & Pick, D. F. (2004). Stimulus-response compatibility with wheel-rotation responses: Will an incompatible response coding be used when a compatible coding is possible? *Psychonomic Bulletin & Review*, *11*, 841-847.

Shaffer, L. H. (1965). Choice reaction with variable S-R mapping. *Journal of Experimental Psychology, 70*, 284–288.

Skiba, R. M., & Snow, J. C. (2016). Attentional capture for tool images is driven by the head end of the tool, not the handle. *Attention, Perception, & Psychophysics, 78*, 2500–2514.

Song, X., Chen, J., & Proctor, R. W. (2014). Correspondence effects with torches: Grasping affordance or visual feature asymmetry? *Quarterly Journal of Experimental Psychology, 67,* 665–675.

Stoffer, T. H. (1991). Attentional focussing and spatial stimulus-response compatibility. *Psychological Research*, *53*, 127–135.

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

Vu, K. L., & Proctor, R. W. (2004). Mixing compatible and incompatible mappings: Elimination, reduction, and enhancement of spatial compatibility effects. *Quarterly Journal of Experimental Psychology, 57A*, 539–556.

Xiong, A., & Proctor, R. W. (2018). The role of task space in action control: Evidence from research on instructions. In K. D. Federmeier (Ed.), *The psychology of learning and motivation* (Vol. 69; pp. 325-364). San Diego, CA: Academic Press.

Yu, A. B., Abrams, R. A., & Zacks, J. M. (2014). Limits on action priming by pictures of objects. *Journal of Experimental Psychology: Human Perception and Performance, 40,* 1861-1873.

Zelaznik, H. N., & Forney, L. A. (2016). Action-specific judgment, not perception: Fitts' law performance is related to estimates of target width only when participants are given a performance score. *Attention, Perception, & Psychophysics, 78*, 1744-1754.