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Practice and transfer with mappings of spoon tip and handle to keypress responses

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Yaqi Xu[1,2], Aiping Xiong[3] and Robert W Proctor[1]

Abstract

When orientation of a horizontal spoon image varies to the left or right, instructions can map left and right keypresses to the tip or handle location. We conducted Experiment 1 to determine whether practice with an incompatible mapping of the salient tip transfers to a test session in which the relevant part and/or mapping are changed. Participants performed 80 practice trials with tip-incompatible mapping, followed by 80 test trials with tip-compatible, tip-incompatible, handle-compatible, or handle-incompatible mapping. Performance improved across 20-trial blocks in the practice session. In the test session, responses were 65 ms faster with tip-compatible than tip-incompatible mapping but 31 ms faster with handle-incompatible than handle-compatible mapping. This latter result, and verbal reports, indicate that some participants adopted a strategy of responding compatibly to the salient tip even though instructed to respond to the handle. Experiment 2 focused on whether participants with handle-incompatible mapping instructions would adopt the tip-compatible strategy spontaneously or after receiving a hint: 77% of participants reported adopting the tip-compatible strategy in Session 1, showing that prior experience responding to the tip is not necessary and 9% of participants did not report using that strategy in Session 1 but reported changing to it in Session 2 after receiving the hint. Their responses in Session 2 were slower than those who used the strategy throughout, but this difference was minimal in the last two trial blocks. Compatible mapping of the salient spoon tip to keypresses dominated performance over prior practice with incompatible tip mapping and instructions with incompatible handle mapping.

Keywords

Object-based compatibility; salient feature coding; stimulus-response compatibility; transfer effect

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Compatible and incompatible spatial stimulus-response mappings refer to how participants are instructed to respond to stimulus locations. People respond faster when the responses are mapped to spatially corresponding stimulus locations. In two-choice reaction tasks, the typical result is shorter reaction time (RT) when the stimuli are mapped to responses on the same side (compatible mapping) than to responses on the opposite side (incompatible mapping). This result is referred to as the spatial stimulus-response compatibility (SRC) effect (Proctor & Vu, 2006). Similar results are obtained when stimulus location is task-irrelevant and another dimension is relevant (known as the Simon effect; Simon, 1990).

Spatial SRC effects have been widely used as a way of affecting response-selection processes, because they reflect neither the stimulus properties (perception) nor the response properties (response planning and execution) but the relation between the two (e.g., Proctor et al., 1995). Of concern in the present study are mappings of stimuli that have two opposing spatial parts, allowing stimulus-response mappings to be instructed in two different ways. Specifically, the concerns were whether practice with an incompatible mapping of the salient relevant part transfers to the other part and mapping, and the conditions under which participants would speed responding by adopting a

[1]Department of Psychological Sciences, Purdue University, West Lafayette, IN, USA
[2]University of Illinois at Urbana–Champaign, Champaign, IL, USA
[3]College of Information Sciences and Technology, The Pennsylvania State University, University Park, PA, USA

Corresponding author:
Robert W Proctor, Department of Psychological Sciences, Purdue University, 703 Third Street, West Lafayette, IN 47907, USA.
Email: rproctor@purdue.edu

strategy of responding compatibly to the salient part when instructed to respond incompatibly to the less salient part.

Object-based compatibility effects

As background, Tucker and Ellis (1998) reported a compatibility effect they attributed to automatic activation of a grasping response afforded by the stimuli. Their stimuli were photographs of objects with graspable handles for which the handle could be towards the right or left side of the base (e.g., the body of a frying pan). On each trial, participants were to make a left or right keypress response with the corresponding index finger to the upright or inverted orientation of the object, with handle location varying randomly. Although irrelevant to the task, the left or right handle location yielded a compatibility effect, with RT being shorter when the handle and response locations corresponded than when they did not. Tucker and Ellis interpreted this result and others as indicating that the handle activated a motoric response to execute a grasping action with the corresponding hand, even though the task required only keypresses.

Subsequent evidence has indicated that compatibility effects of the type reported by Tucker and Ellis (1998), for which participants make keypress responses to stimuli with handles, are mainly due to spatial coding of the stimulus properties and responses, like other spatial SRC effects (Bub & Masson, 2010; Cho & Proctor, 2010, 2011, 2013; Masson, 2018). However, certain researchers have continued to contend that grasping affordances are sufficiently automatic that activation occurs even when the responses are keypresses. Some have maintained that grasping affordance effects are observed when a task requires discriminating a property of the object that relates to its function (e.g., shape) but not a non-functional property like colour (Pellicano et al., 2010; Saccone et al., 2016; Tipper et al., 2006). However, this distinction has not fared well in other research (Cho & Proctor, 2013; Lien et al., 2014; Song et al., 2014) and is complicated by the fact that colour judgements typically yield faster responses than ones based on functional properties (Bub et al., 2018; Proctor et al., 2017). Others have proposed that the stimuli need to be detailed photographs of objects rather than less detailed renderings (Pappas, 2014). But, again, the evidence of more tightly controlled studies has favoured spatial coding accounts of the results based on salient visual properties over grasping affordance explanations (Azaad et al., 2019; Bub et al., 2018; Kostov & Janyan, 2021; Masson, 2018; Proctor et al., 2017).

Masson (2018) noted that with a pixel-centred display of commonly used frying pan stimuli, the pan body's position is relatively stable whereas the handle changes position from left to right across stimulus presentations. With the pixel-centred mode of presentation, a benefit of correspondence of the handle with response is obtained due to this salient change in position (see also Proctor et al., 2017). In contrast, with an object-centred display, the handle position remains relatively stable and the pan body switches left and right positions. Bub et al. (2021) have emphasised the necessity of using the object-centred mode to test claims about grasping affordances and noted that the evidence is against such claims:

> This mode of presentation generally yields either no effect of the depicted object on keypress responses . . . ., or in some cases, a reverse alignment effect in which keypress responses are faster and more accurate when the side of responding matches the side of the base rather than the handle . . . [These results] show that spatial features of a whole-object-centered image are entirely responsible for the reverse alignment effect on left/right keypress responses. For an object more broad than tall, like a frying pan, the left/right protrusion of the base is considerable for a whole-object-centered image, triggering a clear reverse alignment effect. (p. 55)

We emphasise this property of the base providing the salient spatial feature for frying pan stimuli because the spoon stimuli used in the present study have the same more broad than tall structure of an elongated handle extending from the spoon tip.

Notice that this assessment that spatial features are responsible for the reverse alignment effect is restricted to studies in which participants make left–right keypress responses. We are making no such claim with respect to results from keypress experiments that combine images of grasp postures with handled objects or other additional stimuli, such as those of Iani et al. (2019) and Scerrati, Iani, et al. (2020). However, Bub et al. (2021) concluded from a detailed evaluation of Iani et al.'s results that they also offer no unique evidence of a role for motor representation (see also Pellicano et al., 2017). Bub et al. (2021) did provide evidence that grasping actions are affected by the graspable properties of objects and their images, but this does not bear on the point that spatial coding is the primary determinant of object-based compatibility effects with keypress responses.

Horizontally oriented spoon stimuli

Gomez et al. (2017) conducted another study interpreted as supporting a grasping affordance account. Their argument was that real objects (three-dimensional [3D] objects) should afford grasping actions although 2D pictures do not. They designed a series of experiments that used horizontally oriented spoon stimuli (centred on the screen), with the handle positioned to the left or right, with flanking spoon stimuli above and below the target spoon whose orientations were congruent or incongruent with that of the target spoon. Participants were to respond with a keypress corresponding to the side of the target spoon handle, while ignoring the orientation of the flanking spoon stimuli. They wore liquid crystal occlusion glasses that were opaque until a signal from the computer, at which point they became transparent to reveal the stimuli. Results showed a large flanker correspondence effect (e.g., Eriksen & Eriksen, 1974) for both two-dimensional (2D) pictures and 3D objects, but the effect was larger in the 3D condition (37 ms) than in the 2D condition (29 ms), which Gomez et al. attributed to a grasping affordance for the 3D objects.

Xiong et al. (2019) performed a similar study, using only 2D spoon images. Instead of the flanker task, they varied compatible and incompatible mappings of single spoon stimuli and varied whether the handle or tip of the spoon was designated as relevant. Counter to the view that the handle affords grasping, results showed a 45-ms compatibility effect for the tip-relevant relevant condition and a compatibility effect of −15 ms for the handle-relevant condition (i.e., an advantage for the incompatible mapping). Xiong et al. (2021) had participants perform with both 2D images and 3D objects in experiments otherwise comparable to those of Gomez et al. (2017) and Xiong et al. (2019). They found no significant difference in the sizes of either the mapping effects for single spoon stimuli or the flanker effect with adjacent spoon stimuli as a function of 2D image versus 3D object. Their results provided little evidence that 3D objects activate grasping affordances that 2D images do not. Instead, visual salience of the tip was the primary factor determining these correspondence effects. Note that this conclusion is in agreement with that of Bub et al. (2021), in that there is no overlap of the left and right tip positions compared with overlap for approximately half of the handle. Consequently, the ratio between the areas of the parts that switch between left and right is more than three times as large for the tip than the handle (Xiong et al., 2021).

Xiong et al. (2019, 2021) varied the tip-relevant and handle-relevant conditions between-subjects, and only the compatible and incompatible mappings within-subjects. This method was used so that responding to the left or right salient tip location would not alert participants to the possibility of responding to it when instructions were in terms of the less conspicuous left or right handle location. Specifically, for an instructed incompatible mapping of handle location to responses, performance would benefit from a strategy of responding compatibly to the salient tip location. Also, an association acquired in a session of trials with the tip relevant might carry over to a subsequent session with the handle relevant. We investigated these issues of transfer and strategy use in the present study with only the more easily controlled 2D spoon images using a paradigm in which participants performed two short sessions in succession.

Transfer of practice mappings to test task

Although there has not been any study that looks at the change in spatial correspondence effect after practicing with a graspable spoon with incompatible mapping, similar studies have been conducted using a Simon task in the test session, for which stimulus location is irrelevant (Lu & Proctor, 1995; Simon, 1990). Proctor and Lu (1999) established that practice with an incompatible mapping of left and right visual stimulus locations transferred to the Simon task, with several hundred practice trials producing a reversal of the Simon effect to favour the incompatible spatial relation. Tagliabue et al. (2000) showed that the Simon effect was absent after as little as 72 trials (plus 10 practice trials) with a spatially incompatible mapping. They attributed this to the establishment of what they called short-term memory links, or associations, of the stimuli to the incompatible response locations, which offset the long-term links between corresponding locations that produce the typical Simon effect. Other studies confirmed that the standard Simon effect is typically absent after less than 100 practice trials with an incompatible spatial mapping (Vu, 2007; Zhong et al., 2018).

A study that examined transfer in the context of object-based compatibility is that of Ambrosecchia et al. (2015). Their participants performed an upright-inverted categorisation task for objects with intact (Experiment 2) or broken handles (Experiment 3), 5 min or 30 min after performing 160 incompatible trials of a spatial SRC task. We focus on the 5-min delay, which is similar to the short delay of the present study, at which the object-based correspondence effect was reduced significantly relative to a baseline task without the prior practice. This result was obtained for both intact handles (30 vs. 16 ms) and broken handles (29 vs. 6 ms). However, whether the intact objects showed a transfer effect is somewhat unclear because ancillary analyses suggested that the 14-ms difference in mean RT could be due to a general practice benefit. Ottoboni et al. (2013) found elimination of the correspondence effect for intact handles in the upright-inverted categorisation task after participants practised for 600 trials with an incompatible mapping of left and right stimulus locations to responses. The combined results of the two studies suggest that the associations between incompatible stimulus-response locations acquired from the initial practice session transferred to the irrelevant handle locations when objects subsequently had to be classified as upright or inverted.

In the prior studies, transfer of the incompatible mapping of stimulus location was to a Simon task in which stimulus location or graspable handle location is irrelevant. The spoon has unique characteristics in that, as noted, one end can be defined as relevant and the other as irrelevant. Thus, the instructed mapping, relevant part, or both can be changed between practice and test sessions. These conditions allow evaluation of whether the acquired incompatible associations of the salient tip to responses are general and facilitate performance when applied to the non-salient handle. Such a relation would be expected if participants have learned a general "respond opposite rule." The conditions also allow assessment of whether the incompatible tip-response associations established during practice or the preexisting long-term compatible associations dominate when the mapping of the tip is changed to compatible. In addition, the extent to which participants will continue to respond on the basis of the more salient spoon tip when the less salient handle has been defined as relevant can be determined.

Present study

Experiment 1 was designed to examine transfer of practice with an incompatible mapping of the salient spoon tip to task performance with either the tip or handle defined as relevant and the mapping relation defined as spatially compatible or incompatible. We focused on the practice condition with incompatible mapping of the spoon tip because the tip, and not the handle, yields a large compatibility effect (Xiong et al., 2019). Four groups of participants practised with the tip-incompatible mapping for 80 trials—a number of trials that has been shown to be sufficient to eliminate the standard Simon effect (Tagliabue et al., 2000; Vu, 2007). Afterwards, each group performed with a distinct relevant part and mapping pairing in the test session. One group continued performing with the tip-incompatible mapping, which allows measurement of learning/retention across the two sessions. A second group continued with the tip relevant but using a tip-compatible mapping. The third and fourth groups performed with handle-compatible and handle-incompatible mappings, respectively.

Comparison of the first two groups offers evidence as to whether the short-term incompatible tip-response associations established in practice or the long-term associations of spatial compatibility for the second session dominate performance. An advantage for the tip-incompatible condition would support the former, whereas an advantage for the tip-compatible condition would support the dominance of spatial SRC. When the handle is relevant in the test session, the prior tip-incompatible associations could exert their effect in either of two ways. First, if the tip-incompatible association attained through practice benefits performance, that should lead to superior performance in the handle-compatible condition (for which Xiong et al., 2019, found responses to be slower than in the handle-incompatible condition). This benefit would occur because the prior association would activate the correct response. Second, if the rule to respond incompatibly is general, then it would benefit the handle-incompatible condition for which the relevant mapping is incompatible.

Experiment 1 provided evidence that some participants in the handle-incompatible test session adopted a strategy of responding compatibly to the tip, consistent with our prior findings (Xiong et al., 2019, 2021). Because such a strategy would defeat the purpose of examining transfer of incompatible associations after practice with the instructed handle-incompatible mapping, we chose instead to focus in Experiment 2 on the extent to which participants instructed with the handle-incompatible mapping would report using the tip-compatible strategy in a first (practice) session. Those who did not indicate doing so were prompted prior to the second (test) session to try to adopt a strategy that enabled fast responding. Comparison of performance and reported strategies in Session 1 of Experiment 2 to those of participants who performed with the handle-incompatible instructions in the test session of Experiment 1, after practicing with the tip-incompatible mapping first, allowed determination of the influence of that practice. Comparison of Session 2 for the two experiments allowed determination of whether there was any benefit of having practised specifically with the same mapping (i.e., in Experiment 2, a retention benefit for the handle-incompatible mapping) compared to practice in general (i.e., in Experiment 1, with the tip-incompatible mapping).

Experiment 1

In this experiment, participants performed a practice session with a spatially incompatible mapping of the salient spoon-tip location to keypress response. After a brief break, they were instructed to respond to the stimuli with the same tip-incompatible mapping, a compatible mapping of the tip or the handle, or an incompatible-handle mapping. Our primary concern was with performance in the second, test session. Both this experiment and Experiment 2 were conducted in accord with a protocol approved by the Purdue University Institutional Review Board, and all participants consented to participation.

Method

Participants. In all, 112 participants (41 males and 71 females) were recruited from an introductory psychology course. Participants completed the study for partial credits to satisfy a course requirement. Participants in this experiment and Experiment 2 were to be excluded if they exceeded an error rate of 10%, but none did.

Apparatus and stimuli. Stimulus presentation and registration of responses were controlled by E-Prime 3.0 (Psychology Software Tools) installed on a PC. Participants were seated in front of a 19-in. LCD monitor on a 76 cm high table on which a Chronos response box with a row of five response buttons was placed. The stimuli were the same as the 2D images used by Xiong et al. (2021): A standard, white plastic spoon was presented horizontally, centred on the computer monitor on each trial. There were two spoon orientations—tip on the left side (and handle on the right) and tip on the right side (handle on the left; see Figure 1). A highlight at the top of the left image was at the bottom of the right one, which was rotated 180°. Similar results have been shown to occur when this factor is not

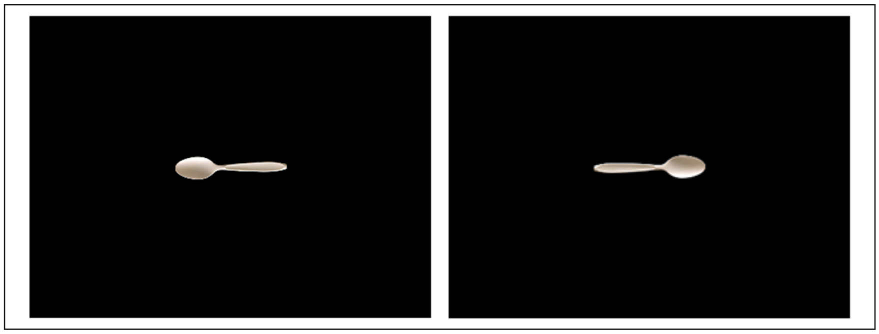

Figure 1. Stimuli used in Experiment 1. A single, plastic, white spoon with the tip to the left and handle to the right (left panel) and the handle to the left and tip to the right (right panel).

present (Xiong et al., 2019, 2021). The spoon was displayed at the centre of the black background of a computer monitor and subtended 13.7° × 2.9° of visual angle when viewed from a distance of approximately 60 cm.

A small plus sign measuring 1.3 mm in width and height served as a fixation point. Responses were made by pressing the leftmost or rightmost of five buttons on the Chronos response box with the left and right index fingers, respectively.

Procedure. The experiment was conducted in a well-lit room. Participants were randomly assigned to one of four groups, which differed in the relevant part and mapping defined for the second session. Each session included 80 trials. Between sessions, participants could take a short break if desired, but most started the second session immediately or after a delay no longer than a minute. In the first session, all participants were instructed to respond to the tip location with an incompatible mapping (if tip is to the left, press the right key). In the second session, half of the total participants were told to respond to the tip, some with compatible mapping and some with incompatible mapping, whereas half were told to respond to the handle, some with compatible mapping and some with incompatible mapping. Thus, there were 28 participants in each of the four groups composed from two relevant parts (tip and handle) and two mappings (compatible and incompatible). For the second session, the number of trials with each stimulus type was equated within each of four 20-trial blocks.

Each trial began with presentation of the fixation point for 500 ms. The spoon image was presented immediately after and remained on the screen until a response was registered or 2 s expired. The spoon appeared with the tip located on the left or right of the screen, randomly determined by the computer program but with an equal number of trials per orientation. If the response was correct, there was then a 500-ms intertrial interval, after which the next trial started. If the response was incorrect or no response was registered within 2 s, an error tone sounded and the message "incorrect!" or "please respond faster!" was presented for 1,000 ms, prior to the 500-ms intertrial interval.

At the end of the experiment, participants were asked the question, "Did you notice anything about the experiment?" For participants who responded "yes," the experimenter asked them to clarify and describe exactly what they noticed and were doing during the experiment. Their answers were recorded in writing by the experimenter.

Results

The primary measures of performance were RT and percentage error (PE). For RT, only trials on which participants responded correctly were included in the data analysis. Trials with RT < 150 ms or > 2.5 *SD*s above each participant's overall mean were excluded (3.9% for the practice session and 3.5% for the test session). Table 1 shows the means and standard errors for this experiment and Experiment 2 as a function of group and mapping, and the online Supplementary Material includes the data also specified by blocks. Probability values for within-subject terms in the analyses of variance (ANOVAs) include the Huynh–Feldt correction.

Practice session. For the practice session, all participants received the tip-incompatible mapping, and the results were analysed in a 4 (group) × 4 (trial block) ANOVA, with trial block as a within-subject factor. RT decreased across blocks (*M*s = 453, 415, 414, and 401 ms for Blocks 1–4), $F(3, 324) = 58.46$, $p < .001$, $\eta_p^2 = .351$, whereas PE varied less systematically (*M*s = 1.29%, 0.94%, 1.34%, and 1.12%, respectively), $F(3, 324) = 18.82$, $p < .001$, $\eta_p^2 = .148$. These results indicate that performance improved as participants practised the task, particularly between Blocks 1 and 2. Neither the group main effect for RT or PE, $F(3, 108) = 1.67$, $p = .178$, $\eta_p^2 = .044$, and $F < 1.0$, respectively, nor the group × block interaction, $Fs < 1.0$, was significant.

Test session. For the test session, the data were analysed with the within-subject factor of trial block (1–4) and the between-subject factors of mapping (compatible or incompatible) and relevant part (tip or handle). For RT, there was a main effect of block, $F(3, 324) = 5.16$, $p = .003$, $\eta_p^2 = .046$. RT was longer in the 1st block of the test

Table 1. Mean reaction time (in milliseconds) and percent error of Experiments 1 and 2, with standard error (*SE*), as a function of group and session.

Exp.	Group	Reaction time (ms)				Percent error			
		Practice session		Test session		Practice session		Test session	
		M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
1	Tip-compatible	414	11	350	9	1.29	0.22	0.22	0.49
	Tip-incompatible	433	16	415	15	0.94	0.26	0.49	0.71
	Handle-compatible	437	14	409	16	1.34	0.36	1.12	1.64
	Handle-incompatible	399	14	378	18	1.12	0.23	1.15	1.87
2	Handle-incompatible	426	16	351	16	1.47	0.30	1.00	0.30

For Experiment 1, the mapping in the practice session for all conditions was tip-incompatible. For Experiment 2, the mapping for the practice and test sessions was handle-incompatible.

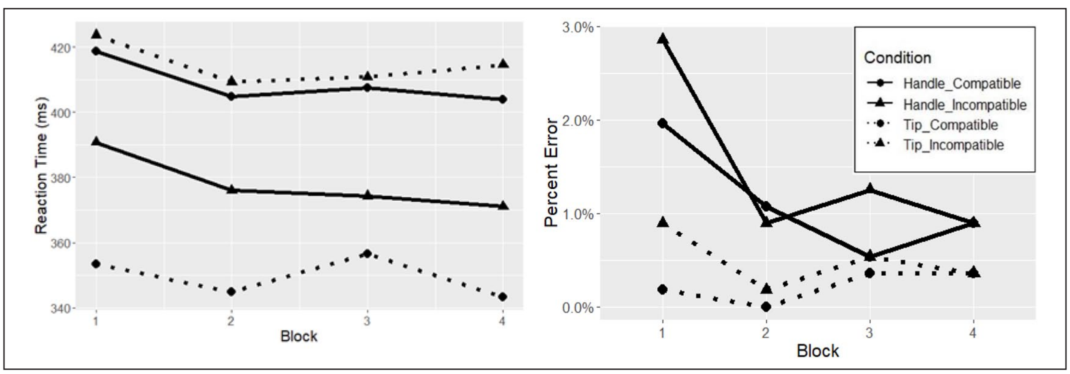

Figure 2. Test session of Experiment 1: Mean reaction time (left panel) and percent error (right panel) across trial blocks for the relevant part (tip or handle) and mapping conditions.

session than in the 2nd, 3rd, and 4th blocks (see Figure 2, left panel). There was also an interaction of relevant part × mapping, $F(1, 108) = 10.07$, $p = .002$, $\eta_p^2 = .085$. The tip-relevant condition showed a 65-ms compatibility effect, whereas the handle-relevant condition showed a reversed −31 ms compatibility effect (faster responses for incompatible than compatible mapping). Neither the main effect of relevant part, that of mapping, nor any other two-way or three-way interaction was significant, $Fs < 1.46$. Separate ANOVAs for each of the four trial blocks showed a significant relevant part × mapping interaction, $Fs(1, 108) \geqslant 7.59$, $ps \leqslant .007$.

A similar ANOVA for PE showed significant main effects of block, $F(3, 324) = 4.83$, $p = .004$, $\eta_p^2 = .044$, and relevant part, $F(1, 108) = 14.23$, $p < .001$, $\eta_p^2 = .116$, but not mapping, $F(1, 108) = 1.58$, $p = .047$, $\eta_p^2 = .036$. Error rates decreased across blocks and were less for the tip-relevant condition than for the handle-relevant condition (see Figure 2, right panel). The only other effect was the block × relevant part interaction, $F(3, 324) = 2.73$, $p = .044$ (Huynh–Feldt adjusted, 0.051), $\eta_p^2 = .044$. Separate ANOVAs for each block showed an effect of relevant part for the first two trial blocks, $Fs(1, 108) = 9.53$ and 8.18, $p = .003$ and .005, respectively, with the effect not significant in blocks 3 and 4. Note that in the first block, the PE was numerically highest for the handle-incompatible condition for which participants could respond compatibly to the tip as an alternative. This difficulty early in the transfer session was not evident in the second trial block, suggesting that at least some participants had recognised the tip-compatible strategy at that point.

Post-experiment answers to question. Several participants from the tip-incompatible group reported that they noticed that the two sessions were the same ($N = 13$), which is to be expected because they were instructed to use the same mapping. Also, 15 participants in the handle-compatible group reported that they noticed the two sessions were essentially the same and that they could keep responding the same as in the first session. The participants who continued using the tip-incompatible strategy had mean RT of 388 ms compared with 432 ms for those who did not indicate noticing that relation, $F(1, 26) = 1.97$, $p = .172$, $\eta_p^2 = .070$. The participants in the handle-compatible group who noticed and used the tip-incompatible mapping also tended to respond faster on average than the participants instructed with the tip-incompatible mapping in the second session ($M = 415$ ms).

Of more interest, eight participants in the handle-incompatible group indicated that they responded to the spoon tip instead (for which the mapping was compatible). Those participants showed a trend of shorter mean RT of 323 ms than that of 399 ms for the 20 participants who did not indicate they used the tip-compatible strategy, $F(1, 26) = 3.74$, $p = .064$, $\eta_p^2 = .126$. The overall mean of the handle-incompatible condition is similar to that of 374 ms reported by Xiong et al. (2019), suggesting that a similar proportion of participants adopted the tip-compatible strategy in their study when there was no prior practice responding to the tip as in the current experiment.

Discussion

The first session showed decreases in RT across the four 20-trial blocks of performing with the tip-incompatible mapping. In the second session, performance also improved from the first to second block of trials, with both RT and PE decreasing. Of most interest is the relevant part × mapping interaction in that session. RT was shorter for the tip-compatible mapping than for the tip-incompatible mapping, and the difference between the two mappings was larger than the difference between the RTs of the handle-compatible and handle-incompatible conditions. This result is consistent with the view that the change in position of the spoon tip is more visually salient than that of the handle, and responding compatibly to the tip location was natural for participants (e.g., Ferguson et al., 2021; Kostov & Janyan, 2021; Xiong et al., 2019, 2021).

Although the tip-relevant mappings yielded a typical benefit for the compatible mapping, the opposite was evident for the handle-relevant mappings. Participants who were instructed to respond to the handle were faster in the handle-incompatible condition than in the handle-compatible condition. This reversal was also evident in the prior studies of Xiong et al. (2019, 2021). Subjective reports indicated that many participants who were instructed to use the handle-compatible mapping in the second session continued to use the tip-incompatible relation, and they responded 44 ms faster than those who did not indicate doing so. This result is consistent with the view that the tip location across trials is salient with the displays used in this study. The difference in RT was even larger for participants who were instructed to use the handle-incompatible mapping but reported adopting a strategy of responding compatibly to the salient tip location. Those participants responded 76 ms faster on average than the participants in the handle-incompatible condition who did not report using the tip-compatible strategy. The error data suggest that the tip-compatible strategy was identified during the first 20 trials, as the handle-incompatible condition showed the highest error rate numerically in the first trial block of the test session but not in the second one. Because the results for the handle-incompatible mapping were the most interesting, we designed a second experiment to investigate this mapping condition in more detail.

Experiment 2

In Experiment 1, several participants in the handle-incompatible group reported noticing that it was easier to respond compatibly to the more salient tip. Their awareness of this fact is crucial because it is likely the main reason why participants in the handle-incompatible group responded faster than those in the handle-compatible group. Because several participants reported ignoring the instruction to respond incompatibly to the handle and instead responded compatibly to the tip location, Experiment 2 was designed to investigate how use of such a strategy may affect participants' performance.

Experiment 2 also had two sessions, but all participants responded with an instructed incompatible mapping of handle location in both sessions. The first session was the same as the handle-incompatible test session in Experiment 1, as was the second session. We used twice as many participants as in each of the four conditions of Experiment 1 so that we could analyse the results as a function of whether they indicated use of the tip-compatible strategy or not in the initial session. As noted, we did not examine transfer to the remaining three conditions (handle-compatible mapping; tip-compatible mapping; tip-incompatible mapping) because we knew from our prior experiments that there is no cost associated with the handle-incompatible mapping compared to the handle-compatible mapping (and, indeed, a benefit; Xiong et al., 2019, 2021). The lack of compatibility effect when instructed in terms of the handle implies that at least some participants adopt the strategy of responding compatibly to the tip when instructed with the handle-incompatible mapping.

Performance with the handle-mapping condition in Session 1 allowed determination of whether participants focused on the tip as much as in Experiment 1, even though the tip had not previously been relevant. Comparison of performance in Session 1 to that of participants with the handle-incompatible condition in the test session of Experiment 1 allowed determination of whether prior practice responding to the spoon tip influenced the tendency to respond to it when instructed to respond with an incompatible response to the handle. After Session 1, participants were asked whether they had used a strategy to speed performance. If they reported not using one, they were encouraged to try to adopt such a strategy. Session 2 was intended to allow determination of whether participants who reported not using the tip-compatible strategy in the first session could use it after being told more explicitly to try to adopt a strategy.

Method

In all, 56 participants were recruited from the same pool as Experiment 1. No person had previously participated in that experiment. The setup for Experiment 2 was the same as for

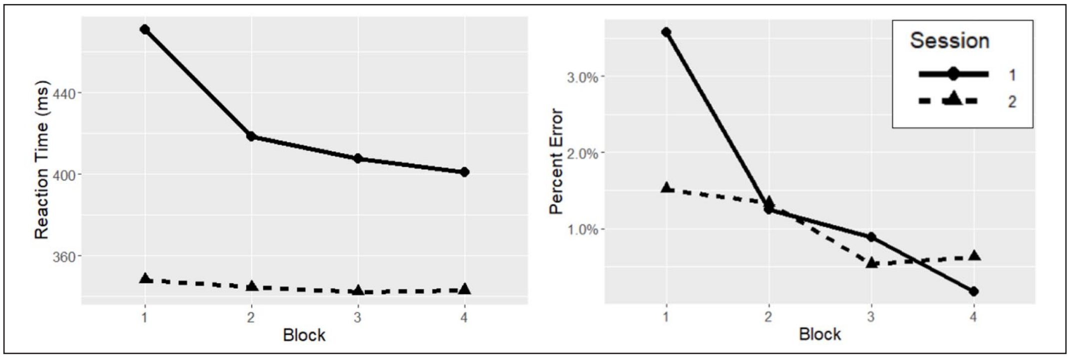

Figure 3. Experiment 2: Mean reaction time (left panel) and percent error (right panel) as a function of session and block.

Experiment 1. The procedure was similar, except as noted. In the first session, all participants were instructed to respond to the handle of the spoon with an incompatible mapping; this was the same instruction used for the handle-incompatible condition in the test session of Experiment 1. After Session 1, the experimenter asked the following question and clarification: "Did you apply any strategy in Session 1?" If yes, the experimenter asked the participants, "Please describe your strategy." The experimenter wrote the answers. Before the second session, participants were encouraged to continue using the strategy and, if they reported not using one in Session 1, to try to use one that would speed responses Session 2. After performing in Session 2, participants were asked the following questions: "Did you apply any strategy in Session 2? How did you feel about your strategy? Did it help you respond faster?"

Results

Performance analyses including all participants. Because the relevant part and mapping were the same for all participants in both sessions, within-subject ANOVAs were conducted on RT and PE that included session and block as factors. RT outliers were excluded using the same criteria as in Experiment 1 (4.6% for Session 1 and 2.5% for Session 2). The analyses showed main effects of both factors and their interaction. Mean RT (see Figure 3, left panel), decreased across sessions, $F(1, 55)=66.49$, $p<.001$, $\eta_p^2=.547$, and blocks within a session, $F(3, 165)=21.89$, $p<.001$, $\eta_p^2=.285$. The session effect was due to RT being more than 50 ms longer in Session 1 than in Session 2, and the block main effect was mainly a difference between Block 1 and the other blocks. As indicated by the interaction, $F(3, 165)=20.86$, $p<.001$, $\eta_p^2=.275$, the decrease in RT from Block 1 to Block 2 was limited mainly to the first session. We examined this interaction in more detail in the analyses reported later that included strategy as a factor.

In accord with the RT data, PE also decreased across sessions, $F(1, 55)=44.81$, $p<.001$, $\eta_p^2=.449$, and blocks, $F(3, 165)=78.39$, $p<.001$, $\eta_p^2=.588$, and showed an interaction, $F(3, 165)=40.35$, $p<.001$, $\eta_p^2=.423$. As with RT, the primary reduction in error rate occurred between Blocks 1 and 2 of the first session (see Figure 3, right panel).

Comparison of Experiment 2 with Experiment 1. Comparisons of participants who received the handle-incompatible mapping after practice with the tip-incompatible mapping (Experiment 1) with those who only performed with the handle-incompatible mapping (Experiment 2) allow determination of whether prior experience responding to the tip mattered. Because there were only 28 participants per condition in Experiment 1 compared with 56 participants in Experiment 2, we collected data for another 28 participants in the tip-incompatible followed by handle-incompatible condition of Experiment 1, with the same question about whether they noticed anything asked at the end. Comparison of these two groups showed no significant differences between them, and they were combined for comparison to Experiment 2.

The first ANOVA compared the practice session of the handle-incompatible condition in Experiment 2 to the test session of the group who transferred to the handle-incompatible condition of Experiment 1. For RT, this comparison showed a main effect of experiment, $F(1, 110)=9.85$, $p=.002$, $\eta_p^2=.082$. Responses were faster in Experiment 1, for which the handle-incompatible session was the second session, than in Experiment 2, for which it was the first session, indicating a benefit of practicing the task of responding to the spoon stimuli, even though practice was with the tip-incompatible mapping. Experiment also interacted with block, $F(3, 330)=10.91$, $p<.001$, $\eta_p^2=.090$, reflecting a larger decrease from Block 1 to Block 2 in Experiment 2 (see Figure 4, left panel). This locus of the interaction was confirmed by a similar analysis that excluded Block 1, for which the main effect of experiment was significant, $F(1, 110)=6.83$, $p=.010$, $\eta_p^2=0.058$, but the interaction of block and experiment was not, $F(2, 220)=1.74$, $p=.183$, $\eta_p^2=.016$. The longer RT for Block 1 in Experiment 2 again likely is due to it being the first trial block experienced, whereas in Experiment 1, 80 practice trials of the task had already been performed.

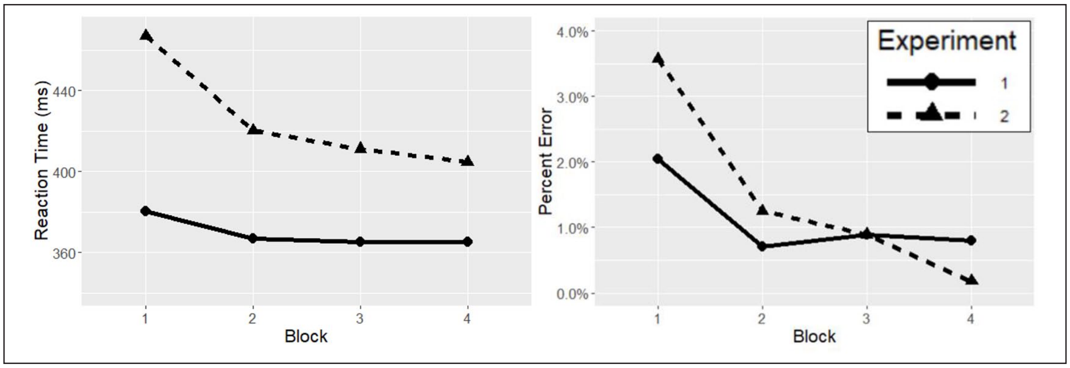

Figure 4. Handle-incompatible mapping for Experiment 1, Session 2, and Experiment 2, Session 1: Mean reaction time (left panel) and percent error (right panel) as a function of block.

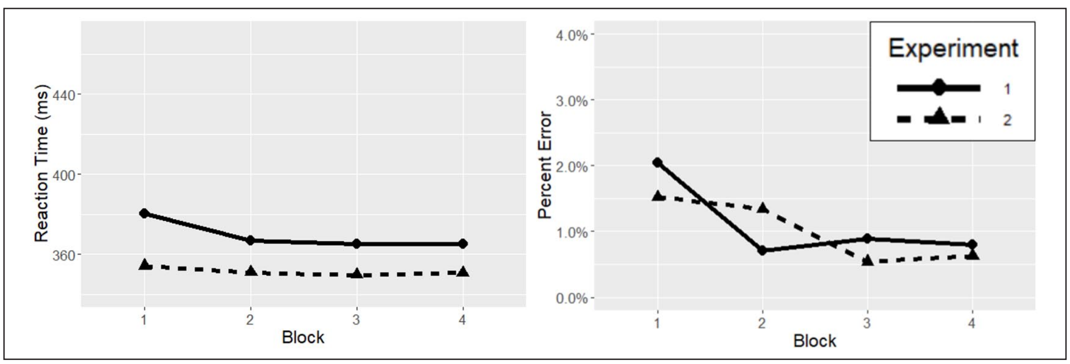

Figure 5. Handle-incompatible mapping for Experiment 1, Session 2, and Experiment 2, Session 2: Mean reaction time (left panel) and percent error (right panel) as a function of block.

For PE, the primary ANOVA again showed no main effect of experiment, $F(1, 110) = 1.31$, $p = .254$, $\eta_p^2 = .012$, but an interaction of experiment with block, $F(3, 330) = 2.975$, $p = .032$ (0.056 with Huynh–Feldt adjustment), $\eta_p^2 = .026$. The PE was higher in Experiment 2 than in Experiment 1, primarily in the first trial block. With that block removed, unlike RT, there was not tendency towards a main effect of experiment, $F < 1.0$, but the interaction with block was in the indeterminate range of $.10 > p > .05$, $F(2, 220) = 2.55$, $p = .081$, $\eta_p^2 = .023$, reflecting a tendency for PE to decrease further across Blocks 2–4 in Experiment 2 than in Experiment 1.

A second ANOVA compared Session 2 of both experiments, which would be after practice with the tip-incompatible mapping in Experiment 1 and after practice with the handle-incompatible mapping in Experiment 2. This comparison allows assessment of whether there is any specific benefit of practice with the same two mappings in both sessions. The RT data showed a significant effect of block, $F(3, 330) = 3.07$, $p = .034$, $\eta_p^2 = .003$, indicating a small decrease in RT across blocks (see Figure 5, left panel). However, neither the experiment main effect, $F(1, 110) = 1.60$, $p = .208$, $\eta_p^2 = .013$, nor interaction with block, $F(3, 330) = 1.03$, $p = .372$, was significant.

The PE data for Session 2 showed an effect of block, $F(3, 330) = 4.98$, $p < .001$, $\eta_p^2 = .097$, but not experiment, $F < 1.0$, or their interaction, $F(3, 330) = 1.28$, $p = .282$, $\eta_p^2 = .011$. PE decreased across blocks (see Figure 5, right panel), with little difference between experiments.

Performance analyses with strategy use as a factor. In Experiment 2, participants indicated at the end of Session 1 and the end of Session 2 whether they had used a strategy. For Session 1, 43 of the 56 participants (77%) stated that they adopted a strategy of responding compatibly to the location of the spoon tip. Of the remaining participants, two indicated that they adopted a strategy focusing on the left or right side and basing their response on which part appeared to that side, two specified that they visualised crossing diagonal lines from the handle locations to the responses, and nine participants indicated that they used no strategy. We were interested in comparing persons who adopted the tip-compatible strategy in Session 1 without being told to do so to those who indicated that they did not adopt a strategy but said that they did adopt the tip-compatible strategy in Session 2. However, we were expecting a larger number of participants in the latter category than

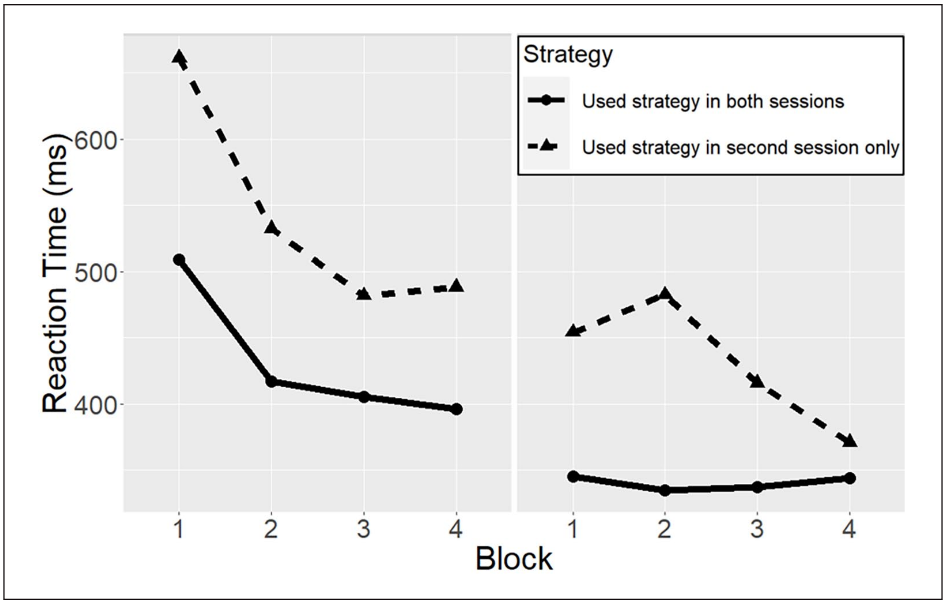

Figure 6. Mean reaction time of Session 1 (left panel) and Session 2 (right panel) as a function of block and use of the tip-compatible strategy in Experiment 2.

was obtained, so we report this analysis only as an exploratory one.

Of the nine participants who reported not using a strategy in Session 1, two indicated that they did not use a strategy in Session 2 and two reported adopting a strategy of attending to one side and responding based on which part of the spoon appeared there. We compared performance of the remaining participants who reported switching to the tip-compatible strategy in Session 2 (n=5) with that of the persons who stated they used them in both sessions (n=43).

For Session 1, an unequal n ANOVA revealed main effects of block, $F(3, 138)=20.05$, $p<.001$, $\eta_p^2=.304$, and strategy, $F(1, 46)=4.49$, $p=.040$, $\eta_p^2=.089$. The latter indicates that participants who reported using the tip-compatible strategy responded faster than those who said they did not (Figure 6, left panel). The block × strategy interaction was not significant, $F(3, 138)=2.03$, $p=.116$, $\eta_p^2=.042$. PE showed a main effect of block, $F(3, 138)=5.36$, $p=.002$, $\eta_p^2=.104$, but no main effect or interaction with strategy, $Fs<1.0$ (Figure 7, left panel).

For Session 2, RT evidenced main effects of block, $F(3, 138)=5.70$, $p<.002$, $\eta_p^2=.110$, and strategy, $F(1, 46)=5.70$, $p=.021$, $\eta_p^2=.110$, and the two factors interacted, $F(1, 46)=7.30$, $p<.001$, $\eta_p^2=.137$. As apparent in Figure 6 (right panel), the primary pattern producing the interaction is that the participants who reported not using a strategy in Session 1 had much longer RT in the first two blocks than those who indicated that they had used a strategy, but the differences in Blocks 3 and 4 were much less. The Session 2 PE data showed a significant block effect, $F(3, 138)=5.56$, $p<.002$, $\eta_p^2=.108$, but also both a strategy main effect, $F(1, 46)=5.38$, $p=.025$, $\eta_p^2=.105$, and a block × strategy interaction, $F(3, 1138)=4.63$, $p=.006$, $\eta_p^2=.091$ (Figure 7, right panel).

Discussion

Overall, participants' performance responding in the handle-incompatible mapping condition improved throughout Session 1 and was relatively stable in Session 2. There was a large decrease in RT from the fourth block of Session 1 to the first block of Session 2, performed only a few minutes later, which is likely due to participants being queried between the sessions about strategy use in the first session. A total of 77% of participants reported using the tip-compatible strategy in Session 1, and only 16% reported using no specific strategy. Use of the strategy was more frequent than we had expected on the basis of Experiment 1. That the percentage of participants adopting the strategy was larger than when the handle-incompatible condition followed the tip-incompatible condition in Experiment 1 could be a consequence of having acquired inappropriate associations of the tip locations to the responses. Alternatively, it could be a consequence of the question asked in Experiment 1 not being specifically about strategy use. Regardless, the large percentage of participants who volunteered that they responded compatibly to the spoon tip in Session 1 of Experiment 2 indicates that being instructed to attend to the tip previously is not necessary for the compatible tip-response relation to be evident when instructed to respond incompatibly to the less salient handle location.

Because we anticipated more participants to indicate not using a strategy than did, our analysis of the participants who did and did not use the tip-compatible strategy

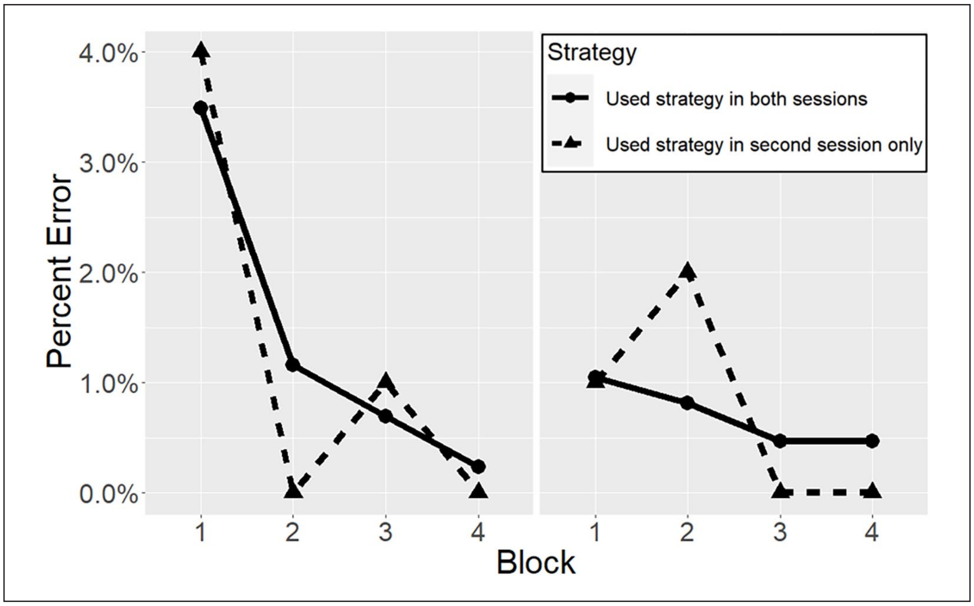

Figure 7. Mean percentage error of Session 1 (left panel) and Session 2 (right panel) as a function of block and use of the tip-compatible strategy in Experiment 2.

in the first session should be taken to be exploratory. In any case, participants who said they used the tip-compatible strategy in Session 1 responded faster in that session than those who did not. The participants who indicated that they switched to the tip-compatible strategy in Session 2 continued to show longer RT in the first two trial blocks, although the difference decreased over the third and fourth blocks. Their PE in the first two blocks of Session 2 increased compared with the last block of Experiment 1, and was also larger than that for the group continuing to use the tip-compatible strategy. Those results suggest that these participants indeed followed the instruction to try to find a strategy that would improve performance and found it as the session progressed. Another qualifier on these interactions with block in Session 2 is that the participants who began using the tip-compatible strategy in Session 1 may have been restricted in the amount of improvement they could show due to their performance approaching asymptote.

The comparisons of Experiments 1 and 2 mainly indicate a cost in RT and PE for the first 20 trials of performing the handle-incompatible condition. This cost is apparent both when the condition follows the tip-incompatible condition (Experiment 1) and when it is the first session of the experiment (Experiment 2).

On the whole, the results of Experiment 2 suggest that using a strategy, such as responding to the spoon tip, is evident to many participants even when there has not been prior practice with instruction to attend to the tip. The fact that participants were more inclined to respond to the spoon tip than the handle even though it was not mentioned in the handle-incompatible instructions implies that visual salience of the tip and compatibility of the mapping are the dominant factors on which participants rely when making their speeded decisions.

General discussion

The two experiments showed that performance in the first session improved with practice for the tip-incompatible condition (Experiment 1) and the handle-incompatible condition (Experiment 2). The majority of improvement was over the first 20-trial block, but RT (and in Experiment 2, PE) tended to decrease further over the remaining three trial blocks. These practice effects in this spoon-orientation reaction task are similar to those found in other choice-reaction tasks (e.g., Proctor & Dutta, 1993; Proctor & Lu, 1999).

The second session of Experiment 1, in which participants performed with all combinations of the tip or handle as the relevant part and compatible or incompatible mapping to responses, showed results qualitatively similar to those obtained by Xiong et al. (2019, 2021) when participants did not receive prior practice with the tip-incompatible mapping (see Table 2). The tip-compatible condition showed the best performance and a substantial benefit in comparison to the tip-incompatible condition. In contrast to this typical SRC effect, the handle-incompatible condition yielded better performance than the handle-compatible condition, that is, the handle showed a reverse compatibility effect. The tip compatibility effect was 65 ms in the present study compared with 45 and 43 ms in Xiong et al.'s experiments. If the associations of the tip locations to incompatible responses were affecting performance in the second

Table 2. Mean reaction time in the test session with all combinations of the tip or handle as the relevant part and compatible or incompatible mapping to response in the current Exp. 1 and Exp. 1 of Xiong et al. (2019) and Exp. 1 of Xiong et al. (2021).

Practice	Exp.	Tip			Handle		
		Comp (ms)	Incomp (ms)	SRC (ms)	Comp (ms)	Incomp (ms)	SRC (ms)
Yes	Exp. 1	350	415	**65**	409	378	**−31**
No	Exp. 1 of Xiong et al. (2019)	336	381	**45**	389	374	**−15**
	Exp. 1 of Xiong et al. (2021)	429	472	**43**	491	474	**−17**

Comp: Compatible; Incomp: Incompatible; SRC: stimulus-response compatibility effect.
In Xiong et al.'s (2021) Experiment 1, with 2D images as in this study, the longer RTs were due to having the display blocked by liquid crystal occlusion glasses for an intertrial interval of 10 s, after which the glasses opened to show the display, to allow comparison to a 3D condition with real spoons as stimuli.

session, the SRC effect would be expected to be smaller than in the previous experiments for which there was no prior practice with the tip-incompatible mapping. The evidence thus implies that those associations were not influencing performance. For the handle-relevant conditions, the reverse handle-compatibility effect (favouring the incompatible mapping) was 31 ms in Experiment 1 compared with 15 and 17 ms in the prior experiments. One possible reason for this difference is that at least some participants who practised with the tip-incompatible mapping continued to use a tip-incompatible strategy when instructed to respond compatibly to the less salient handle. Another possibility is that there was a relative benefit of attending to the tip in the practice session when it now was mapped compatibly to the response in the handle-incompatible condition.

When the participants were asked at the end of Experiment 1 whether they noticed anything about the experiment, and then were queried further, several who were instructed to respond to the handle indicated that they adopted specific strategies. Eight participants in the handle-incompatible condition indicated that they responded to the spoon tip instead (for which the mapping was compatible), as did one participant in the handle-compatible condition (for which the tip mapping remained incompatible, as in the practice session). The other strategy mentioned by two participants, also for the handle-compatible condition, was to look at one side of the screen and code the responses based on whether the tip or handle appeared there.

That several participants reported using a strategy of responding compatibly to the salient tip in the handle-incompatible condition led us to explore this strategy further in Experiment 2 by having participants perform the handle-incompatible condition in both sessions. No reference was made to a strategy for the first session, after which more specific questions about strategy use were asked and participants were instructed to adopt a strategy if they had not been done so previously. They were again questioned after the second session. With this explicit questioning, 43 of 56 participants indicated that they used the tip-compatible strategy in Session 1 and only 5 indicated not using it in Session 1 but adopting it in Session 2. These results suggest that the strategy is relatively obvious to many participants instructed to respond incompatibly to the handle, most likely because the spoon tip is the salient feature changing from left to right location across trials (Xiong et al., 2019). Moreover, participants who reported using the strategy in Session 1 performed better than those who did not report using it, both in Session 1 and the first two trial blocks of Session 2, after which the performance of those who switched to the strategy improved across the last two trial blocks. Thus, even when it diverges from instructions, participants can determine that the tip location is the inverse of the handle location and, in the case of handle-incompatible mapping, allows for faster and more accurate responding.

This tendency to identify and use a strategy that departs from instructions is different from results obtained when responses are made with a steering wheel for which the hands are placed at the bottom. In that case, responses can be defined in terms of direction of the wheel rotation (right or left turn) or direction of hand movement (left or right direction). With neutral instructions, an approximately equal number of participants tend to adopt each reference frame (Guiard, 1983). Proctor et al. (2004, Experiment 2) found that when participants were instructed in terms of hand-movement direction, the results implied that they coded the responses relative to the hand-movement frame even when it was incompatible with the left or right location of a tone (move hands left to a tone on the right) and would have been compatible with an alternative wheel-based coding (rotate the wheel to the right to a tone on the right). A likely reason why participants in that study did not adopt a strategy of using the alternative response coding is that the two ways of coding the responses are of relatively equally salience. Consistent with this salience interpretation, when the wheel controlled the direction of movement of a salient visual cursor in Proctor et al.'s (2004) study, responses were coded relative to this salient action effect even when that coding resulted in an incompatible spatial mapping.

The relative lack of evidence for transfer of the incompatible tip-response mapping to the other three conditions in Experiment 1 is a different result from that obtained when transfer is to variations of the Simon task, for which stimulus location is irrelevant. On the left–right spatial dimension, the Simon effect is absent or reversed after an amount of practice with a spatially incompatible mapping similar to that provided in the present study (Proctor et al., 2009; Tagliabue et al., 2000; Vu, 2007), with this transfer effect seemingly absent only when the Simon task was performed as a baseline prior to the SRC task (D'Ascenzo et al., 2021).

In contrast to the numerous studies of transfer to the Simon task, studies in which spatial mapping is varied within subjects usually counterbalance the order of the mappings, without examining the order effects. An exception is Experiment 1 of Proctor and Dutta (1993) in which different groups of participants practised a two-choice spatial reaction task with the same mapping (compatible or incompatible) for 3 days of 300 trials each, during which RT decreased. They then performed the same task in a fourth session but with the mapping being the same or different from the practised mapping. With normal hand placement, the SRC effect for the groups who continued to practice with the same mappings was 382 − 321 = 61 ms, whereas that for the groups who switched from the prior mapping was 434 − 364 = 70 ms. These data illustrate that the SRC effect was relatively unaffected by the change in mapping, but the change produced an increase in mean RT of 47 ms. Overall RT for the groups with switched mapping was at the level of the first practice session, 447 − 342 = 105 ms, although the compatibility effect was smaller, implying that the transfer effect from the incompatible to compatible mapping was more deleterious than the alternative.

In the present study, the first session was only a total of 80 trials. This amount of practice with an incompatible mapping is sufficient to produce transfer to a Simon task that counteracts the tendency to make the spatially corresponding response. However, it may not be enough to induce transfer to a task for which location is still relevant but the mapping has changed. For example, the participants in Proctor and Dutta's (1993) experiment showing an apparent influence of the prior mapping on performance with the alternative mapping had 900 practice trials with the initial mapping. Although the visual salience of the spoon tip and the ease of responding with a compatible mapping of it to the responses seems to have overridden any effect of the practice with an incompatible tip mapping, strengthening of the incompatible spatial associations through 600 or 900 trials might enable transfer to be more evident.

Alternatively, the association of the salient spoon tip with the spatially corresponding response may be sufficiently strong that even a large amount of practice with an incompatible mapping will not reduce the benefit of a subsequent compatible mapping. A reviewer suggested that such may be the case due to the tip's functional significance, citing a study by Scerrati, D'Ascenzo, et al. (2020) in which stimuli with a functional component to the opposite side of the handle seemed to eliminate an 8 ms benefit of the handle location. However, this finding was obtained with a Simon task (respond whether the pictured object is plastic or metal) and is likely due to the opposing spatial properties of the functional end and the handle (Cho & Proctor, 2011).

Another recent study by Pilacinski et al. (2021) purported to show automatic direction of saccadic eye-movement responses towards the functional end of objects with handles. They used a task in which participants responded with a left or right eye movement to a target location, depending on the colour of a small circle at fixation. A tool image that onset prior to the imperative stimulus provided a background on each trial, and reaction times were shorter overall when the eye-movement direction corresponded with the functional end of the tool than when it did not. No information was provided as to whether the tool images were object- or pixel-centred, although it was likely the former. Regardless, because the stimuli included multiple objects with distinct physical properties in both oblique and horizontal orientations, it is difficult to assess whether the results reflect only the relative salience of the functional end, averaged across all of the objects. Because the eye movements were left and right responses, they most likely were subject to the same causal factors as left and right keypresses.

To summarise, in the present experiments, a compatible mapping of the salient spoon tip to keypress responses dominated effects of prior practice with an incompatible mapping of the tip to responses. Moreover, when instructed in terms of an incompatible mapping of the spoon handle to responses, many participants realised that they could respond compatibly to the salient spoon tip to improve their performance. When the goal of a choice-reaction task is to respond as fast and accurately as possible, some participants will attempt to achieve the goal by adopting strategies that deviate from the specific instructions provided for the completion of the task.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval

All procedures performed in the experiments involving human participants were in accordance with the ethical standards of the Purdue University Institutional Review Board and with the 1964 Helsinki declaration and its later amendments.

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ORCID iDs

Aiping Xiong https://orcid.org/0000-0001-7607-0695

Robert W Proctor https://orcid.org/0000-0002-0149-8352

Supplementary material

The supplementary material is available at qjep.sagepub.com.

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