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Attention, instruction, and response representation

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A two-dimensional Simon-type task was devised to investigate the impact of task requirements and explicit instructions on spatial action coding. Subjects performed actions that were defined on two spatial dimensions: horizontal (left–right) or vertical (top–bottom). The relevant stimulus feature was nonspatial but the stimuli varied on the horizontal and the vertical dimension, so that horizontal and vertical S–R compatibility effects could be measured separately. Implicit task requirements were manipulated by having the subjects perform an unrelated task before the Simon task—a task in which only one of the two spatial dimensions was relevant. Instructions were varied by describing the responses in the unrelated priming task and/or in the Simon task in spatial terms or by referring to nonspatial features of the response keys. Priming a particular dimension increased the Simon effect on that dimension, whereas instructions had no differential effect. These findings suggest that, first, drawing attention to a particular dimension leads to a stronger contribution to event representation of those features defined on that dimension (intentional weighting) and, second, that instructions do not affect action coding if the manipulation does not change the task goal.

Even though humans are equipped with only limited motoric means, they can perform an infinite number of different actions. The same stimulus, such as a glass of water, may give rise to very different actions. When thirsty the glass may be used for drinking, whereas in a different context it may be used for watering plants. That is, human actions are not controlled exclusively by environmental stimuli, but behaviour is flexibly controlled by taking situational constraints, such as task demands and current goals into account. This flexibility of perception and action suggests that perceived events (stimuli) and produced events (actions) are not represented in a unitary, invariant fashion but, rather, by distributed networks of feature codes that are tuned to the current task goals and the relevant situational constraints (Barsalou, 1999; Cohen, Braver, & O'Reilly, 1998; Hommel, Müsseler, Aschersleben, & Prinz, 2001; Meiran, 2000). We may

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thus tailor our cognitive representations of perceived and produced events to the task at hand.

People may flexibly adapt to the current situation by what Hommel et al. (2001) have called ‘‘intentional weighting’’. The idea is that those stimulus and response features or feature dimensions that are crucial for realising a goal are ‘‘emphasised’’ and endogenously primed by increasing the internal weights of the representational units coding them. Among other things, this increases the perceiver/actor’s ‘‘attention’’ to these features or feature dimensions when processing an event and, thus, increase their impact on perceptual representation (of external events or one’s own actions) and action control. In the present study we focused on intentional weighting in spatial response coding. There are several indications suggesting that response coding can be affected by task constraints and action goals. Hommel (1993) instructed subjects to either ‘‘press a left or right key’’ or to ‘‘switch on a right or left light’’ in response to the pitch of a tone signal that occurred randomly on the left or right side. As pressing the left and right key switched on the right and left light, respectively, both groups of subjects actually carried out the same task. And yet, key instruction produced a key-related Simon effect (i.e., reactions were faster if the tone appeared on the same side as the key; for an overview, see Hommel & Prinz, 1997; Lu & Proctor, 1995), whereas light instruction produced a light-related Simon effect (i.e., reactions were faster if the tone appeared on the same side as the to-be-produced light). Apparently, then, describing a response in terms of key pressing increased the contribution of key location to defining the action’s location, whereas describing it in terms of light switching increased the contribution of light location to that definition: instruction-induced weighting of response features.

Another, more recent example of apparent response-code weighting comes from Ansorge and Wühr (2004). They used a two-dimensional Simon task, in which stimuli and responses could vary on the horizontal and the vertical dimension. If responses differed on both spatial dimensions (e.g., top-left vs. bottom-right key) Simon effects were found for both axes, that is, pressing a key was faster if its horizontal location matched the horizontal location of the stimulus and if its vertical location matched the vertical location of the stimulus. Interestingly, however, using responses that differed with respect to one dimension only (e.g., top-left vs. bottom-left key) eliminated the Simon effect on the other axis. As Ansorge and Wühr argue, this suggests that response features are coded (and matched against corresponding stimulus codes) only if they discriminate in the given task context: task-induced weighting of response features.

The observations of Hommel (1993) and Ansorge and Wühr (2004) support the assumption that action representations are shaped by attentional processes induced by instructions or task requirements but systematic research along these lines is lacking (Wenke, 2003). In particular, it is not clear whether instructions and task requirements do the same thing, that is, whether they affect response coding in the same way. This issue is particularly relevant in view of findings demonstrating that instructions do not always work as expected. For instance, having subjects cross their arms, so that the left hand operates the right key and vice versa, consistently produces a key-related Simon effect, that is, subjects are faster if stimulus and key location correspond (Wallace, 1971). Interestingly, this is not only the case if subjects are instructed in terms of key locations (as the weighting account leads one to expect) but also if instructions refer to the anatomical status of the effectors (Roswarski & Proctor, 2003). Likewise, instructing subjects to ''switch on lights'' that differ in colour but not in location does not eliminate the effect of stimulus–key correspondence (Hommel, 1996a). Both observations suggest that instructions do not directly determine action coding but only suggest particular weightings of action features—which however can be overruled (i.e., ''outweighed'') by weightings in favour of more familiar or more salient (Reeve, Proctor, Weeks, & Dornier, 1992) features of the given action.

The present study sought to analyse the impact of implicit task requirements and explicit task instruction on action coding by manipulating both factors concurrently. To manipulate the first factor we made use of the dimensional-priming technique employed by Memelink and Hommel (in press). They had subjects perform a two-dimensional Simon task, that is, a task that requires responses varying on the horizontal and the vertical dimension (e.g., top-left vs. bottom-right) to nonspatial attributes of a stimulus that also varies on the horizontal and the vertical dimension (i.e., randomly appear at the top-left, top-right, bottom-left, or bottom-right of a display). As already mentioned, such tasks produce Simon effects for both spatial dimensions, that is, faster responses if stimulus and response correspond on the horizontal and/or on the vertical dimension (Ansorge & Wühr, 2004; Rubichi, Nicoletti, & Umiltà, 2005). Before carrying out this Simon task, Memelink and Hommel's subjects worked through a priming task, which required discovering a spatial stimulus–response rule. In one group of subjects, this rule was horizontally defined, that is, stimuli appearing in left and right locations required pressing a left and right response key, respectively, whereas the vertical location of stimuli or responses did not matter. In a second group of subjects, the rule was vertically defined, that is, stimuli appearing in top and bottom locations required pressing a top and bottom response key, whereas horizontal stimulus or response locations played no role.

Memelink and Hommel (in press) expected that this manipulation should induce different intentional-weighting tendencies in the two groups: Discovering and working on a horizontal rule should induce a heavier weighting of left–right codes than top–bottom codes (on top of other, possible weighting biases, such as left–right prevalence: Rubichi et al., 2005), whereas working on a vertical rule should induce heavier weighting of top–bottom than left–right codes. If so, and if intentional weighting would (''unintentionally''!) transfer to the Simon task, the horizontal-rule group should show a relative increase in the horizontal Simon effect while the vertical-rule group should exhibit a relative increase in the vertical Simon effect. This is indeed what the data showed. Rules biased dimension-specific Simon effects even in a within-subjects task version, in which horizontal and vertical rules frequently changed between Simon blocks—which excludes long-term learning effects of the sort observed by Tagliabue, Zorzi, Umiltà, and Bassignani (2000) on a one-dimensional Simon task.

In the present study, we again attempted to affect dimension-specific Simon effects by means of a dimensional-priming task, that is, we manipulated implicit task requirements. To test the impact of explicit instructions we combined the priming manipulation with an instruction manipulation in an orthogonal design. Three different instructions were compared. In one group (P&S), the response keys were explicitly labelled according to the primed dimension in both the priming task and the Simon task. For example, if a subject was horizontally primed and was using a top-left and a bottom-right response key, the instruction for both the priming and the Simon task would describe the responses as ‘‘left’’ and ‘‘right’’. In a second group (P only), the response keys were explicitly labelled in the priming task but were labelled in a spatially neutral manner in the Simon task. Finally, in a third group (neutral), the response keys were labelled in a spatially neutral manner in both the priming task and the Simon task. Regarding the priming manipulation, we expected a (conceptual) replication of Memelink and Hommel's (in press) finding that the dimension emphasised in the priming task affects the relative sizes of horizontal and vertical Simon effects. Regarding the instruction manipulation, the question was whether instruction differences would matter at all and, if they do, whether they would increase the priming effect to the degree that they emphasise the primed spatial response dimension (i.e., P&S > P only > neutral).

METHOD

Subjects

Sixty undergraduate students from Leiden University participated as paid volunteers, twenty in each instruction group. Ten subjects of each instruction group were randomly assigned to the horizontal priming task and the other ten to the vertical priming task. All reported having normal or corrected-to-normal vision and were unaware of the purposes of the experiment.

Apparatus and stimuli

The experiment was conducted in a small dimly lit room. All testing was performed in front of a 17 inch monitor connected to an IBM-compatible PC. The software was written in Experimental Run Time System (ERTS) version 3.28 (Beringer, 1999). The viewing distance was about 60 cm.

The stimuli in the dimensional priming task consisted of a light grey plus sign serving as a central fixation point and of four pictures of different animals. Each picture was rotated so that four orientations were obtained amounting to 16 stimuli pictures. The size of the pictures was approximately 4 $\times$ 4 cm. The orientations of the animals were diagonally at angles of approximately 45°, 135°, 225°, and 315°. Auditory feedback stimuli for errors consisted of tones of 880 Hz and 300 ms.

For the Simon task a two by two grid was displayed in the middle of the screen. The grid was a light grey on a black background 5.2 $\times$ 5.2 cm. Targets consisted of either the letter O or the letter X appearing in light grey in the middle of the cell. The size of the target letter was 24 points.

Responses were given by pressing one of two diagonally arranged keys of the computer keyboard. Half the subjects were assigned to a top-left, bottom-right configuration for their responses. The other half was assigned to a top-right, bottom-left configuration. The keys used in these configurations were the Esc key (top-left), the right control key (bottom-right), the F12 key (top-right), and the left control key (bottom-left). Each participant used the left index finger to press the button on the left side of the keyboard and the right index finger to press the button on the right side of the keyboard. To provide a nonspatial reference feature, one key was marked with a yellow and the other with a blue sticker.

Procedure

An experimental session consisted of the dimensional priming task followed by the Simon task. For the dimensional priming task the fixation point was presented for 1000 ms followed by a picture of an animal in one of the four orientations. For horizontal groups the rule was to press the left button when an animal had its face directed toward the left side of the screen, irrespective of its vertical orientation, and pressing the right button when an animal had its face directed toward the right side of the screen, again irrespective of its vertical orientation. For vertical groups the rule was to press the top button when the animal had its face pointing to the top of the screen, irrespective of its horizontal orientation, and to press the bottom button when the animal pointed with his face to the bottom of the screen, irrespective of its horizontal orientation. The picture remained on screen until a response was given. The maximum time to respond was 2000 ms. The dimensional priming task consisted of one block of 48 trials.

There were three types of instructions. P&S instructions referred to response keys in spatial terms, that is, response keys were specifically named after the dimension the subject was primed on (''left'' and ''right'' [in Dutch] for horizontally primed subjects and ''top'' and ''bottom'' [in Dutch] for vertically primed subjects). P-only instructions described response keys in spatial terms only once at the beginning of the instruction for the priming task, but from then on only with reference to their colour. Neutral instructions described response referred to response keys only in terms of their colour.

After completing the dimensional priming task the instructions for the Simon task followed. For the Simon task the X was mapped to one button and the O to another button, balanced between subjects. After the instruction for the Simon task (see above) the subject received one block of 16 practice trials followed by eight blocks of 32 experimental trials. Between the third and the fourth block subjects were again confronted with one block of 16 trials of the dimensional priming task, in order to refresh and update their codes. In the Simon task the maximum time to respond was 2000 ms. After the response was given the new stimulus appeared after 1000 ms. All testing was done within a half-hour session.

RESULTS

Trials with missing responses were excluded from analysis as well as responses slower than 1000 ms and anticipations (responses faster than 100 ms); this was less than 1.2 % of the data. Mean reaction time (RT) and percentage of errors (PE) were calculated for each condition and analysed by means of a 2 (compatibility: horizontal vs. vertical) $\times$ 2 (dimensional priming: horizontal vs. vertical) $\times$ 3 (instruction) ANOVA—the last two factors being varied between subjects. (See Table 1.)

Simon task

In RTs, the main effect of horizontal compatibility, $F(1, 54) = 97.68$, $p < .001$, was boosted by horizontal priming, $F(1, 54) = 17.69$, $p < .001$, and the main effect of vertical compatibility, $F(1, 54) = 60.19$, $p < .001$, was boosted by vertical priming, $F(1, 54) = 14.25$, $p < .001$. No interaction involving instruction was found, $p > .28$ and no higher order interactions were obtained. (See Figure 1.)

In the PEs, the main effects of horizontal compatibility, $F(1, 54) = 44.46$, $p < .001$, and of vertical compatibility, $F(1, 54) = 14.89$, $p < .001$, were not modified by priming but entered into a three-way interaction with priming, $F(1, 54) = 5.67$, $p < .05$, and a four-way interaction, $F(1, 54) = 3.41$, $p < .05$. The latter indicated that under neutral instruction (the only condition where the three-way interaction was reliable) vertical priming caused subjects to make more errors on completely compatible trials than on those trials that were only horizontally compatible, whereas in all other conditions the completely compatible trials always yielded the fewest errors.

TABLE 1
Reaction times (RT), percentages of errors (PE), and effect sizes (Δ) as a function of horizontal and vertical compatibility, priming, and instruction

	Horizontal compatibility											
	Horizontal priming						*Vertical priming*					
	Compatible		*Incompatible*		Δ		*Compatible*		*Incompatible*		Δ	
	RT	*PE*	*RT*	*PE*	*RT*	*PE*	*RT*	*PE*	*RT*	*PE*	*RT*	*PE*
Vertical compatibility												
Instruction P&S												
Compatible	429	1.3	464	4.8	35	3.5	431	2.5	449	5.0	18	2.5
Incompatible	440	3.5	468	6.0	28	2.5	459	3.1	473	5.0	14	1.9
Δ	11	2.2	4	1.2			28	0.6	24			
Instruction P only												
Compatible	431	2.5	468	8.3	37	5.8	454	1.3	466	4.4	12	3.1
Incompatible	446	4.8	472	8.5	26	7.3	484	4.2	483	6.5	1	2.3
Δ	15	2.3	4	0.2			30	2.9	17	2.1		
Instruction neutral												
Compatible	413	1.5	446	7.3	33	5.8	447	5.4	465	6.9	18	1.5
Incompatible	420	4.4	449	6.9	29	2.5	464	4.0	480	11.5	16	7.5
Δ	7	2.9	3	0.4			17	1.4	15	4.6		

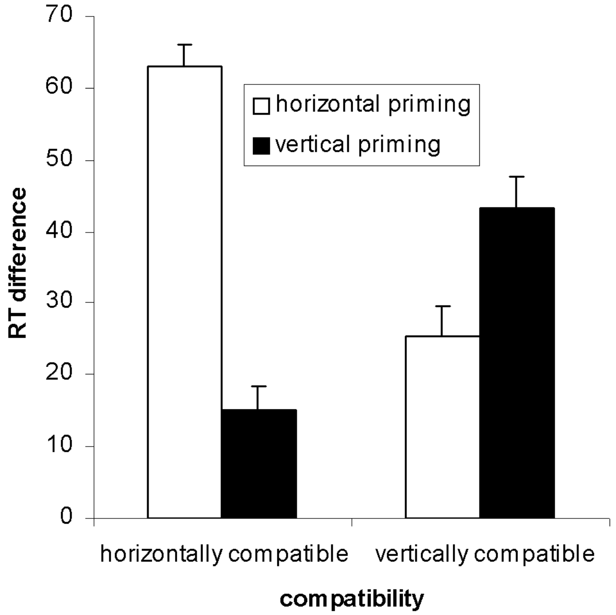

Figure 1. Compatibility effect sizes (incompatible minus compatible) as a function of dimension and priming.

Priming task

For the sake of completeness, the data of the priming task were analysed as a function of primed dimension (horizontal vs. vertical), instruction (P&S, P only, and neutral), and compatibility in the irrelevant dimension (i.e., vertical compatibility in the horizontal-priming groups and horizontal compatibility in the vertical-priming groups). The main effect of compatibility was significant in RTs, $F(1, 54) = 14.98$, $p < .001$, and PEs, $F(1, 54) = 4.19$, $p < .05$, and the latter effect interacted with instruction, $F(1, 54) = 4.14$, $p < .05$. The main effects were due to faster RTs and less errors in the compatible than the incompatible condition (629 vs. 653 ms, 4.5% vs. 5.7%), and the interaction indicated that subjects made more errors under neutral (5.9%) or P only (6.1%) than under P&S instruction (3.3%). This finding suggests that emphasising the spatial response features indeed affected response coding in a way that made the task easier—presumably by increasing the compatibility with the relevant stimulus feature.

DISCUSSION

The purpose of this experiment was to compare the impact of implicit task requirements and explicit instruction on the intentional weighting of spatial action codes—as indicated by variations in the relative sizes of horizontal and vertical Simon effects. Regarding the impact of task requirements, the findings are clear in replicating Memelink and Hommel's (in press) observation that making the horizontal or vertical dimension relevant in another, unrelated task carried out before increases the Simon effect on the corresponding dimension. Before turning to the impact of instructions, let us first consider two alternative interpretations of this effect of dimensional priming: the intentional-weighting account based on which we predicted the transfer effect originally and an associative account.

Associative accounts of transfer effects assume that practising a particular stimulus–response mapping leads to the acquisition of short-term (and, if consolidated, long-term) associations between stimuli and responses (Proctor & Lu, 1999; Tagliabue, Zorzi, & Umiltà, 2002). Once acquired, these associations contribute to stimulus-based response priming, so that processing a particular stimulus would automatically prime the response it was mapped upon previously. On first sight, this does not seem to be an option in our case because the stimuli in the priming task and in the Simon task were very different and appeared in different, nonoverlapping locations. However, one might argue that the stimuli in the priming task had intrinsic spatial features that were at least symbolically related to the extrinsic horizontal and vertical dimensions on which the Simon stimuli varied. Accordingly, participants may have acquired associations between the respective symbolic spatial codes (which may also underlie the intermodal transfer of spatial stimulus–response associations as demonstrated by Vu, Proctor, & Urcuioli, 2003) and responses in the priming task, which then contributed to performance in the Simon task. For example, repeatedly pressing a left key to a leftward-oriented picture might have created an association between an abstract LEFT code and the left response, and the same would apply to a hypothetical RIGHT code and the right response. If so, these associations would, in the Simon task, contribute to priming left and right response upon processing left and right stimuli, irrespective of the vertical stimulus or response dimension. As a consequence, the impact of horizontal stimulus–response compatibility would be stronger, simply because the horizontal but not the vertical Simon effect would be enhanced by the acquired associations. In other words, it may be possible to consider the present outcome as reflecting the same sort of short-term stimulus–response associations as tapped into by Proctor and Lu (1999), Rubichi, Gherri, Nicoletti, and Umiltà (2005 this issue), and Tagliabue et al. (2002). Indeed, whereas Proctor and Lu administered as many as 900 trials for practice, Tagliabue et al. found transfer effects after 72 trials only—still more than our 48 priming trials but arguably in the same ball park.

However, there are at least two reasons that make us doubt that our effects are due to associative learning. One is that such learning was also possible with respect to the unprimed dimension, namely, in what we called the compatible (in irrelevant dimension) trials. Considering these trials, and the possible associations acquired in them, would reduce the associative advantage for the primed over the unprimed dimension to 24 trials, a number that has not yet been shown to allow for transfer effects. Another reason for us to be sceptical is that we were able to demonstrate priming effects from an unrelated, interleaved task in which the spatial stimulus–response rules changed every four trials—a condition that should have prevented any systematic association (Memelink & Hommel, in press).

As an alternative, at least for the present findings, we suggest that making one of the two spatial dimensions more relevant to the priming task induced a bias towards that dimension, which then affected the coding of the responses or, in the Simon task, the coding of the spatial relationship between stimuli and responses. As suggested by Hommel et al. (2001; Memelink & Hommel, in press), relating the horizontal or vertical dimension to the action goal might increase the intentional weight of features coded on that dimension, which again may be considered to direct more attention to it. Accordingly, a top-left key press would be represented as more ''left'' than ''top'' under a horizontal rule but as more ''top'' than ''left'' under a vertical rule. If this bias would transfer to the Simon task, the response would thus be more sensitive to stimulus information from the primed dimension and, hence, be more activated by spatial stimulus codes that do or do not match on this dimension.

It is interesting to realise that the transfer of biases or sets from the priming to the Simon task was neither necessary nor helpful and, hence, of no adaptive value. That means that our findings reveal the inner workings of what we consider an actually adaptive mechanism by showing one of its nonadaptive side effects. Apparently, then, adopting a particular set of code weighting patterns to maximise performance on the current task is sufficiently inert to affect a later task, even if that is of no use. This fits with Allport, Styles, and Hsieh's (1994) claim that task sets can outlive the task they were set up and implemented for, and with corresponding observations of Meiran (2000). In contrast, transfer of what one may call an attentional set across tasks does not seem to be consistent with strictly top-down models of action control like Logan and Gordon's (2001) ECTVA. This model assumes that preparing for a task involves the specification of attentional parameters by a high-level control system. To account for the present findings, one would need to assume that the control system is for some reason reluctant to change these parameters when preparing for a new task so that, paradoxically, control would actually reflect the system's past preferences rather than being dictated by current adaptivity considerations.

The second important outcome is that instructions did not have any reliable impact on the Simon task, even though they did affect performance in the priming task—suggesting that the manipulation as such has worked. That is, literally speaking, instructions did not add anything to whatever the priming manipulation achieved. Given that instruction effects on action coding have been observed on other occasions (Hommel, 1993, 1996b), the failure to find an effect in the present experiment and in other studies (Hommel, 1996a; Roswarski & Proctor, 2003) supports the idea that instructions only suggest but do not unequivocally determine coding stimuli and responses in a particular fashion. More generally speaking, it seems that action coding is mainly driven by (present or past) task requirements and less sensitive to instructional hints—at least if the latter have no direct implications for the overall goal of the task (as was the case in the study of Hommel, 1993).

A final observation is worth mentioning, even though it is not related to the main aims of our study. In the priming task we obtained a compatibility effect for the irrelevant dimension, that is, pressing a left key, say, in response to a leftward-oriented picture was easier if the vertical orientation of the picture matched the vertical location of the response key. Clearly, this effect can considered to be an ''intrinsic'' variant of the more standard Simon effect obtained with left and right responses to a nonspatial feature of left and right stimuli (Hommel & Lippa, 1995). Although the presence of such an effect may not seem surprising it would be difficult to predict from attentional accounts of the Simon effect (Notebaert, Soetens, & Melis, 2001; Rubichi, Nicoletti, Iani, & Umiltà, 1997; Stoffer & Umiltà, 1997). Attentional accounts claim that a spatial shift of attention is necessary for the Simon effect to occur. It is not obvious in which sense such a shift was required in our priming task, where all stimuli appeared at the centre of the display. Minimally, an attentional account of our observation would need to assume that oriented objects can induce attentional shifts, which then prime the corresponding response. However, the direction of such shifts would depend on the identity of the object and, hence, presuppose its identification, which would turn the processing logic underlying the available attentional approaches (shifting → identification) upside-down.

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