Responding to object files: Automatic integration of spatial information revealed by stimulus–response compatibility effects

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Spatial information is assumed to play a central, organizing role in object perception and to be an important ingredient of object representations. Here, evidence is provided to show that automatically integrated spatial object information is also functional in guiding spatial action. In particular, retrieving nonspatial information about a previewed object facilitates responses that spatially correspond to this object. This is true whether the object is still in sight or has already disappeared. So, forming an object representation entails the integration and storage of action-related information concerning the action that the object affords.

Spatial information is of central importance for perception and action: Perceptual objects are defined by features appearing at the same location, and most of our actions are directed to a particular location in space. Therefore, it is hardly surprising that information about the spatial location of stimulus events exerts considerable effects on human perception and performance. For instance, providing people with preinformation about the spatial location of an upcoming stimulus has been shown to improve its detection (e.g., Posner, Snyder, & Davidson, 1980) and identification (Eriksen & Rohrbaugh, 1970), and providing preinformation about the spatial location of a manual response has been demonstrated to speed up its initiation (e.g., Miller, 1982; Rosenbaum, 1980). Hence, spatial location is, or at least can be, an important selection cue in both perception and action planning, which has led various authors to attribute to spatial representations a central, organizing function (e.g., Nissen, 1985; Rizzolatti, Riggio, & Sheliga, 1994; Schneider, 1995; Treisman & Gelade, 1980; Van der Heijden, 1992; Wolfe, Cave, & Franzel, 1989).

Further, and for present purposes more relevant, evidence for an important role of spatial information comes from studies on, what Kahneman, Treisman, and Gibbs (1992) have called "object files". These authors asked participants to name single letters appearing on a screen. Before the target display came on another, task-irrelevant, display (the so-called preview field) was presented, which contained two letters. When one of the previewed letters matched the target's identity, naming performance was consistently better if it also appeared in the same location, whereas repeating the identity yielded only a negligible effect. This superiority of identity-plus-location repetition over mere identity repetition has now been observed several times (Henderson, 1994; Henderson & Anes, 1994; Hommel, 1998; Treisman, 1993). It suggests that identity information (or, more precisely, information about the relevant stimulus feature: Hommel, 1998) is automatically integrated with location information, and the integrated code (or object file) is stored over time.

The automatic integration of spatial information makes sense for at least two reasons. One has been pointed out and extensively discussed by Kahneman et al. (1992) and Leslie, Xu, Tremoulet, and Scholl (1998). In a system that represents external events in a distributed fashion—like, for example, the primate visual system—perceiving an object as an enduring, coherent event over time and change (e.g., of perspective) requires some kind of integration or binding of the codes representing this object's features. However, binding requires some criterion of whether two given features do or do not belong to the same object, and (shared) location would be an excellent criterion in this respect—even though it need not be the only one or the best one under all conditions (Leslie et al., 1998). From this perspective, the integration of spatial information into coherent and enduring event representations might underlie, and perhaps even constitute, object constancy and our concept of external objects.

Second, the automatic integration of spatial and nonspatial object information may also subserve goal-directed action (cf., Tipper, Brehaut, & Driver, 1990). Although we often use immediate perceptual information to guide our actions, such as when reaching for a cup of coffee, we do not necessarily rely on it. For example, in the case of the reach, we may start moving in the cup's direction before we see or feel it, suggesting that retrieving information about the cup is accompanied by (re-) activating spatial information about where we have perceived it recently. Importantly, reactivating this information may not only be functional in mediating object perception but may also induce a tendency to perform an action towards this object. The present three experiments aimed at demonstrating that this is more than speculation.

Rationale of present study

The general idea underlying the present series of experiments was to use spatial stimulus–response compatibility or correspondence effects to index the (re-) activation of internal spatial codes. If stimuli and responses vary on the same (e.g., horizontal) dimension, performance is commonly observed to be better with spatial stimulus–response correspondence than with noncorrespondence, the so-called Simon effect (for overviews, see Lu & Proctor, 1995; Simon, 1990). Interestingly, correspondence effects also occur if the stimuli themselves are centrally presented but have a spatial left–right meaning (Eimer, 1995), appear in an intrinsically left or right part of an object (such as in one eye of a 90° rotated face: Hommel & Lippa, 1995), or have previously been associated with a particular map location (Tlauka & McKenna, 1998). That is, correspondence effects are not restricted to situations in which the location

itself is currently perceived, if only a response-congruent spatial code is somehow internally (re-) activated. This characteristic makes the effect a potentially useful indicator of the retrieval of spatial information as investigated here.

In particular, participants were presented with four-object displays (see Figure 1) containing a single response-relevant target object (target, in short) among three other irrelevant objects. The four objects always differed in colour, so that the target could be cued by accordingly changing the colour of the frame that surrounded the object configuration. The responses, left and right keypresses, were based on the target's shape, with circle and square indicating one or the other response key, respectively. Importantly, there were always two different shapes on either side, so that responses could not be selected before the target was cued by the frame's colour change.

According to Kahneman et al. (1992), perceiving the stimulus display should lead to the formation of (at least) four object files, one for each object, each one containing information about the features of the object (e.g., colour and shape) and its location. If then the colour cue is presented, the file of the target object should be addressed and its content reactivated or retrieved. This includes reactivating spatial codes representing the target's location which—according to the hypothesis under test should induce a tendency to react toward the target object, a correspondence effect. If so, responses consistent with this tendency should be easier to carry out than inconsistent responses. For instance, if the colour cue indicates a target object that appears on the left side of the display, responding to this target by pressing a left key should be easier (i.e., faster and more accurate) than responding by pressing a right key. In other words, retrieving nonspatial information about an object was expected to facilitate the spatially corresponding response.
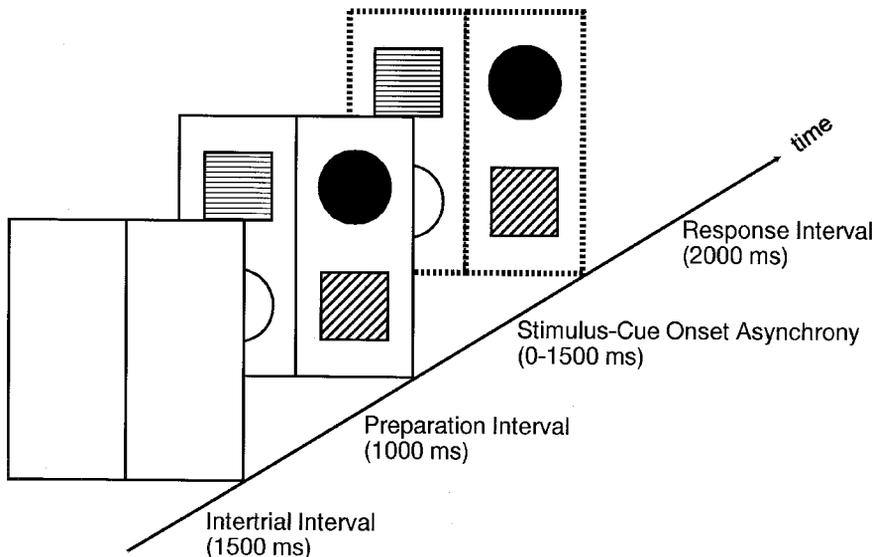

Figure 1.   Diagram of the stimulus display and the timing of events in Experiment 1. Diagonally opposite corners were always occupied by elements of the same shape. Each element had a different colour which changed from trial to trial.

EXPERIMENT 1

Experiment 1 studied the time course of object-file formation in the four-object task by vary-ing the interval between presentation of the objects and the colour cue (stimulus-cue onset asynchrony or SCOA) from 0 to 1500 ms. With an SCOA of zero the task is similar to the stan-dard Simon task (Simon & Small, 1969), which also requires spatial responses to nonspatial attributes of spatially varying stimuli. As already mentioned, this task is known to produce better performance with spatial correspondence than with noncorrespondence between stim-ulus and response—the Simon effect. However, the Simon effect is also known to disappear if reaction times (RTs) are longer than about 500–600 ms (Eimer, Hommel, & Prinz, 1995; Hommel, 1993), most likely due to the quick, automatic decay of the irrelevant spatial code and/or the response tendency it induces (De Jong, Liang, & Lauber, 1994; Hommel, 1993, 1994). Given that the present task yielded much longer RTs, a Simon effect was unlikely, especially with the longer SCOAs.

   Time has also been found to be important for the emergence of object files—object-file formation takes time. For instance, Kahneman et al. (1992) observed benefits of identity-plus-location repetition over mere identity repetition after 550 ms but not after 400 ms, and Hommel (2002) found evidence for the binding of stimulus features after 250 ms but not earlier. Therefore, the stimulus information may not yet be integrated completely with short or zero SCOAs, suggesting that target–response correspondence effects may be observed only with longer SCOAs. In Experiment 1A, four SCOAs were used, ranging from 0 to 1500 ms, in steps of 500 ms. It turned out that the results markedly differed between the zero and the nonzero SCOA conditions, which might have been due to some peculiarities associated with simultaneous presentation of display and cue. To rule that out, Experiment 1B was run with SCOAs of 0, 250, and 500 ms. As will be seen, the 250-ms condition produced very much the same results as the 0-ms condition, this pointing to the emergence of object files over time.

Method

As described, the task required responding to the shape of one of four differently coloured stimuli by pressing a left or right key, the relevant target stimulus being signalled by a colour cue. Stimulus presen-tation and data acquisition were controlled by an IBM-compatible microcomputer. Responses were made by pressing the left or right shift key of the computer keyboard with the corresponding index fin-ger. Stimulus displays consisted of two squares (0.85 × 0.85 cm) and two circles (0.85 cm in diameter) surrounded by a rectangular frame, positioned as shown in Figure 1. Objects of the same shape were diagonally arranged, so that each side contained one square and one circle. Each object had a different colour (red, green, blue, and yellow, equated in intensity). The colour of the relevant stimulus object was balanced across blocks, whereas the three remaining colours were randomly assigned to the three irrele-vant objects in each trial. The frame appeared first in white (on black background), followed by the pre-sentation of the four objects. After an SCOA of 0, 500, 1000, or 1500 ms (in Experiment 1A) or 0, 250, or 500 ms (in Experiment 1B) the frame changed to the colour of the relevant stimulus object. A total of 8 and 12 adults (in Experiments 1A and 1B respectively) worked through 64 practice trials and three blocks of 128/96 experimental trials, with each block comprising all randomly ordered combinations of the two shapes, four locations, four colours, and four (or three) SCOAs. Trials with incorrect responses, response omissions (RT > 2000 ms), or anticipations (RT < 150 ms) were repeated.

Results and discussion

After excluding trials with response omissions (0.2%) or anticipations (0.04%), RTs (measured from cue onset) and percentages of error (PEs) were computed for each combination of horizontal target–response correspondence and SCOA (see Figure 2). The significance criterion was set to $p < .05$.

In Experiment 1A, RT decreased with SCOA, $F(3, 21) = 12.81$, and was lower with target–response correspondence than with noncorrespondence, $F(1, 7) = 12.04$, an effect that was also found in PEs, $F(1, 7) = 19.65$ (0.9% vs. 2.7%). Most interestingly, the RT correspondence effect increased with SCOA, $F(3, 21) = 5.50$, with all but the 0-ms condition producing a significant effect in separate, planned comparisons. Closer inspection showed that the numerical effects were rather evenly distributed in the zero SCOA condition—that is 3 participants showed negative and 5 showed positive correspondence effects.

Experiment 1B yielded similar results: RTs decreased with SCOA, $F(2, 22) = 69.84$, and was lower with correspondence than with noncorrespondence, $F(1, 11) = 11.05$, the latter being also true for error rates, $F(1, 11) = 7.91$ (2.1 % vs. 3.2%). Again, the correspondence effect increased with SCOA, $F(2, 22) = 3.93$, and was significant with the longest SCOA only. With the two shorter SCOAs, 5 participants showed negative and 7 positive numerical effects.

As expected, the spatial correspondence between cued target and response affected performance, but not over the whole time range. In particular, no reliable effect was obtained with SCOAs below 500 ms. Although it is obvious that something different was happening in the conditions with short and long SCOAs, respectively, it is important to distinguish between two aspects of this pattern, as they are presumably of differing theoretical relevance.
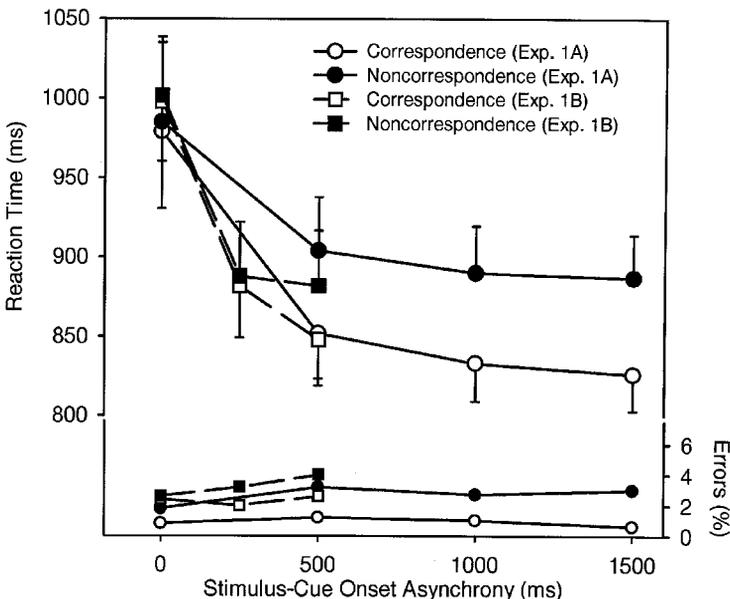

Figure 2.   Reaction time and error results from Experiments 1A (solid lines and circles) and 1B (dotted lines and squares), as a function of spatial target–response correspondence and the interval between stimulus onset and cue onset. Error bars show standard errors for reaction times.

The first, presumably less interesting observation is that the correspondence effect was entirely absent at zero SCOA. As already mentioned, correspondence effects under standard conditions (i.e., with immediate action on the appearing stimulus) strongly depend on the RT level, in the sense that the effect gets smaller the longer the reaction takes. The common explanation of this pattern assumes that the relevant stimulus feature is processed in parallel to stimulus location but the code of the latter decays rather quickly (presumably within half a second), so that any delay in processing the relevant feature diminishes the (facilitating or interfering) contribution of the irrelevant spatial code to response selection (De Jong et al., 1994; Hommel, 1993). Accordingly, correspondence effects decrease and even disappear if the task is made more difficult, be it in terms of stimulus identification (Hommel, 1993, 1994) or response selection (Hommel, 1995), or if the response is delayed by other means (Simon, Acosta, Mewaldt, & Speidel, 1976). Compared to the standard Simon task with single, easily discriminable stimuli, the present task involves a substantial increase in the demands on stimulus processing and target selection, so that it is not surprising that even in the zero SCOA condition no correspondence effect showed up. However, the dependency of correspondence effects on RT level also implies that if we would decrease those demands and/or find other means to manipulate the temporal relationship between processing the relevant stimulus information and location information, small but reliable correspondence effects might be obtained with zero SCOA. A control experiment that was conducted suggests that this might be possible indeed. In that experiment, the present zero SCOA condition was paired with two other conditions in which the SCOA was negative—that is, the colour cue preceded the four objects by 500 or 1000 ms, the expectation being that this might motivate participants to process the colour cue before the four objects even with zero SCOA. If so, this would delay the point at which both the relevant and irrelevant features of the four objects would be coded, which should increase the impact of the (now presumably less decayed) spatial code on response selection. Indeed, the correspondence effect was still very small (11 ms) but now significant, and distribution analyses confirmed that the effect was bigger in fast than in slow responses (i.e., more pronounced in the lower tail of the distributions)—an observation that was not made in corresponding analyses of the data from the present experiments. In other words, the correspondence effect at zero SCOA can be expected to be very small, but whether it is statistically significant or not is likely to depend on the particular task setting and individual processing strategies.

The second aspect of the present findings is more relevant for our purposes. Significant or not, it is clear that the size of the correspondence effect is of an entirely different magnitude if the colour cue is delayed by more than 250 ms—that is, if people have at least 500 ms for processing the stimulus display before selecting the target. According to an object-file account, this huge increase is likely to reflect the now more or less completed integration of spatial and other information into a coherent object file, so that retrieving the relevant target led to the activation of the associated location information, which then primed the spatially corresponding response. Indeed, this interpretation fits with previous findings suggesting that object-file formation takes around 250–500 ms (Hommel, 2002; Kahneman et al., 1992). In sum, Experiment 1 provides evidence that, first, spatial information is spontaneously integrated with nonspatial object information into some coherent associative structure, and that, second, reactivating this structure exerts a rather direct impact on response selection.

EXPERIMENT 2

The increase of correspondence effects with SCOA in Experiment 1 suggests that stimulus information was automatically integrated and stored during the preview interval. However, as the stimulus display was visible until the response was executed, the evidence that it actually was memory codes, not perceptual codes, that produced the correspondence effect is indirect. Clearly, if the correspondence effect was really generated by spatial memory codes, it should not depend on whether or not the display is perceptually available at the time the cue comes up. Accordingly, Experiment 2 tested whether an effect can be obtained even without the display being present at that time. The cue always appeared long after display onset, and it was the interval between display offset and cue onset that varied. In one condition, the cue appeared 500 ms before the display was masked. This condition resembles the long-SCOA conditions in Experiment 1 and, thus, was expected to produce a reliable correspondence effect. In a second condition, the cue appeared simultaneous with display offset, and in two more conditions the cue was presented 500 or 1000 ms after the display was masked. If memory codes are able to produce a correspondence effect, substantial effects should be obtained even in the absence of perceptual information and hence be independent of cue delay.

Method

The method differed from that in Experiment 1 in the following ways. One second after the onset of the white frame, the four coloured objects appeared and stayed for 2000 ms. Then the objects were deleted by two 28-ms intensity masks (bright white rectangles covering the area occupied by the two objects on either side of the central line), in order to prevent after-images. The temporal relationship between stimulus offset and frame-colour change (i.e., cue onset) varied randomly. The colour change could precede stimulus offset by 500 ms (stimulus–cue delay = – 500), so that there was overlap of stimulus objects and cue, or it could appear simultaneously with stimulus offset (delay = 0), or follow stimulus offset by 500 or 1000 ms (delay = 500 or 1000). A total of 16 adults worked through 64 practice trials and three blocks of 128 experimental trials, composed as in Experiment 1A.

Results and discussion

Response omissions (0.4%) and anticipations (0.01%) were rare. As shown in Figure 3, RT decreased with stimulus–cue delay, $F(3, 45) = 42.33$, and was lower with correspondence than with noncorrespondence (621 vs. 637 ms), $F(1, 15) = 8.39$. The PEs showed a similar pattern with significant main effects of delay, $F(3, 45) = 11.93$, and correspondence (3.5% vs. 5.1%), $F(1, 15) = 7.13$.

The results clearly demonstrate that reliable effects of target–response correspondence can be obtained even when perceptual stimulus information is not available and the stimulus is selected from memory. This provides further evidence that correspondence effects can be mediated by short-term memory codes and, thus, supports the suggested memory-code construction interpretation of the increase of effect size with preview obtained in Experiment 1.
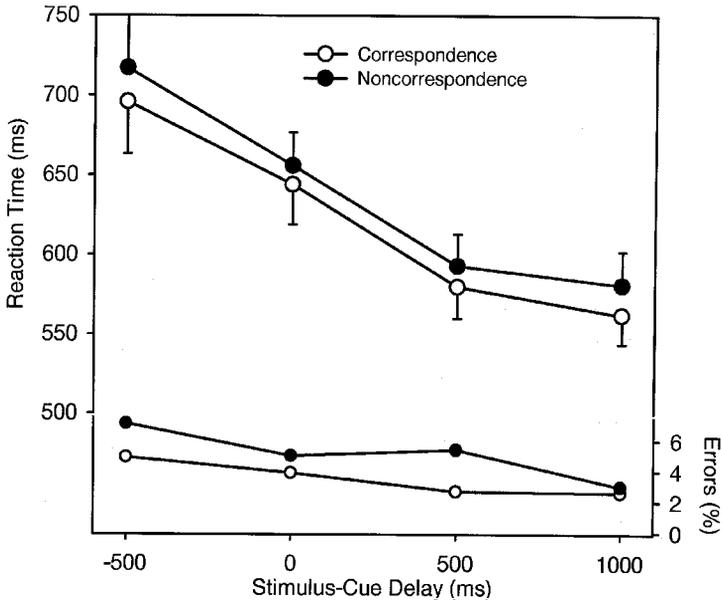
Figure 3.   Reaction time and error results from Experiment 2, as a function of stimulus spatial target–response correspondence and the interval between stimulus offset and cue onset. Error bars show standard errors for reaction times.

EXPERIMENT 3

Experiment 2 provides evidence that correspondence effects can be mediated by codes of objects that are no longer perceptually available at the time the target object is selected. However the interval between the offset of the perceptual information and object selection from memory was one second, at most, which was rather short for a presumably memory-based phenomenon. Clearly, if object information had been integrated and stored during the preview interval, it should have been available and potent enough to affect response choices for a longer time.

A radical way to test this prediction is to present a single stimulus configuration only once at the beginning of each task or session and then leave it to the cue to signal the relevant object in a larger number of trials. However, it would be very obvious and easy to recode the perceptual information in terms of colour-response mappings (e.g., "respond left to red or yellow and right to blue or green"), if only the display would be exposed sufficiently long. This might alter the internal representation of the task completely, so that it would not be particularly informative if under these circumstances no correspondence effect is obtained. Experiment 3 was a compromise of these considerations. On the one hand, it did employ sequences of cue presentation without intervening stimulus displays, to make sure that participants really responded on the basis of memory codes, not of perceptual information. On the other hand, however, there were also many different, changing stimulus configurations to preclude recoding strategies, or to work against them at least. More specifically, the experiment comprised several miniblocks of four trials each, where each miniblock started with the presentation of a new object configuration, followed by four trials where only the cue appeared to signal the relevant

object. Although even a memory code may decay over time, thus producing a decrease of correspondence over trials, one would clearly expect that correspondence effects are not restricted to the very first trial only, but occur in later trials as well.

Method

The method was as that in Experiment 1, with the following exceptions. The frame's central horizontal line appeared only during presentation of the object configuration, but was omitted when the frame was used as a cue. Each four-trial miniblock began with presentation of the white frame for 1000 ms, after which the four stimulus objects appeared within the frame. Participants then memorized the display for 6000 ms, after which the display was deleted by 28-ms intensity masks. Next, there were four trials, separated by intertrial intervals of 1500 ms, where only the target cue but no stimulus appeared. Again, the white frame appeared first and then signalled the target object by changing to red, green, blue, or yellow, after 1000 ms. A total of 12 adults worked through a single block of 16 randomly drawn practice trials and five blocks of 64 experimental trials (16 four-trial miniblocks). The type of trial within each miniblock was randomly determined, except that the possible combinations of stimulus shape, horizontal stimulus location, and position within a miniblock were fully counterbalanced. As a consequence, trials with response errors were not repeated.

Results and discussion

Response omissions were rare (0.3%), and anticipations were not observed. As Figure 4 shows, RT decreased from the first to the fourth trial, $F(3, 33) = 17.04$, and was lower with correspondence than with noncorrespondence (598 vs. 620 ms), $F(1, 11) = 22.89$. However,
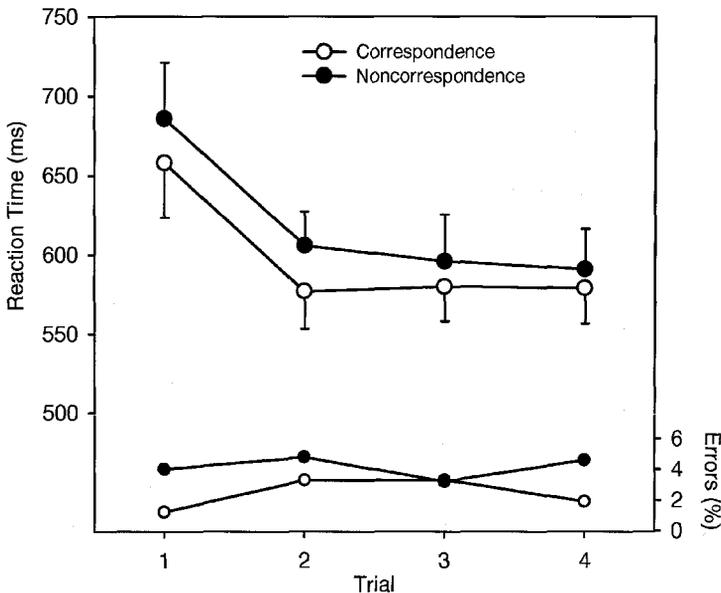

Figure 4.   Reaction time and error results from Experiment 3, as a function of stimulus spatial target–response correspondence and trial position. Error bars show standard errors for reaction times.

the interaction was far from significant ($p < .5$). In the PEs, only the correspondence effect was significant (2.4% vs. 4.1 %), $F(1, 11) = 11.90$.

The results are very clear in showing that effects of irrelevant stimulus–response correspondence are not restricted to perceptually available objects, but occur with memorized objects as well. Although the effect decreases in size from the second to the fourth trial, this reduction is not reliable. Moreover, the effect is virtually identical for the first two trials, which demonstrates that there is nothing special to the trial that immediately follows stimulus presentation.

GENERAL DISCUSSION

The purpose of the present study was to find out whether the spontaneous integration of features of external objects (object-file formation) also includes action–related spatial information—that is, spatial codes the retrieval of which directly affects action planning. If such information would become an ingredient of object representations, the retrieval of object information (i.e., access to an object file) can be expected to induce a tendency to perform actions directed towards (or associated with) the respective object. Indeed, the present experiments demonstrated that retrieving nonspatial information about an object leads to the facilitation of responses that spatially correspond to this object. This suggests that spatial and nonspatial object information is automatically integrated into a coherent, durable object representation, and that this representation might subserve both object perception and the guidance of action.

Experiment 1 provided evidence that the construction of action–related object representations takes time. Under the present display conditions, correspondence effects were observed not earlier than 500 ms from display onset, suggesting that construction time lies between a quarter to half a second. As already pointed out, this estimate fits with previous observations of Hommel (2002) and Kahneman et al. (1992), who observed effects of identity–location conjunctions to emerge after about 250–500 ms. Experiment 2 made sure that perceptual information, which in Experiment 1 was available until the response, is not responsible or necessary for correspondence effects after preview. Correspondence effects were obtained irrespective of whether the target was cued during display presentation or up to 1 s after the display was masked. That is, correspondence effects can be produced by stimuli selected from short-term memory, demonstrating that memory retrieval of object information automatically induces a spatial bias in action control and response selection. Experiment 3 extended these findings to a longer temporal range and across up to four trials. Although the correspondence effect slightly decreased from the second to the fourth trial (which might suggest some loss of spatial information over time), the effect was reliable and constant—as one would expect from a memory code.

The automatic integration of spatial information—although completely irrelevant to the task—points to a central, organizing role of space in the emergence of cognitive representations. In object perception, location codes are likely to subserve the cross–referencing of feature information by indicating whether or not two features belong to the same object. In fact, most current theories of attention assume that spatial information mediates both feature binding (i.e., the construction of perceptual objects) and attentional object selection (e.g., Schneider, 1995; Treisman, 1988; Van der Heijden, 1992; Wolfe et al., 1989). This "early",

organizing role of spatial information in the coordination of distributed feature information may be a basic prerequisite for perceiving our environment in terms of stable, enduring objects instead of mere feature bundles.

The present study suggests a further role of spatial information. Enriching object representations by automatically integrating location information does not only serve later recognition of the object, it is also functional in planning an action associated with this object. Even if actual action may often rely on immediate perceptual input—especially with high-precision movements—the inclusion of location information into enduring object representations helps to plan a goal-directed action before the goal object comes in sight. In a sense, then, object representations entail information about what actions they afford (Gibson, 1979). Technically speaking, this does not necessarily call for a major revision of the object-file approach; in fact, the present experiments may be taken to represent just another way to demonstrate what Kahneman et al. (1992) have already claimed with respect to the automatic integration of location information. However, hitherto investigations of feature integration have been motivated mainly by pointing to its role for perception, whereas the present observation that accessing integrated object features directly impacts on response selection points to a further role for action planning—no contradiction, but an important extension of the object-file perspective.

The idea that object representations include action-related information receives further support from a couple of recent findings. As briefly mentioned earlier, Tlauka and McKenna (1998) asked subjects to study a real or verbally described simple map, in which elements were located on the left or right side. Later, participants carried out choice responses to those elements, which were now centrally presented. As it turned out, performance was better if the response side corresponded to the original location of the element on the map than if it did not. This suggests that participants had associated objects and location codes in the study phase and were able to make use of these associations when selecting responses in the choice task. Also working with visual maps, Hommel and Knuf (2000) asked subjects to perform choice responses to the flashing of particular houses on a map-like array. After acquiring the correct house-response mappings, participants verified statements regarding the spatial relationship between pairs of houses. As the results show, pairs were judged faster if the two members shared the same response in the acquisition phase, irrespective of whether or not the map was visible during verification. This suggests that response-related information became associated with the houses' cognitive representations (i.e., integrated into their object files), so that accessing one member of a pair for comparison spread activation to the other via the shared response code. Finally, Richardson and Spivey (2000) presented participants with short video clips appearing in various locations, each clip showing a speaker talking about a particular topic (e.g., plays of Shakespeare). When later asked about facts related to these topics, participants often looked at the location where the respective clip was presented. Not only does this suggest that the clips' representations comprised information about where they had been seen, retrieving clip-related information also had a direct effect on eye-movement control—much like retrieving object information affected manual actions in the present study.

Although the present experiments did not aim at investigating spatial correspondence effects but merely used them as indicators for feature integration, the obtained findings do have implications for the basis of correspondence effects, especially of the Simon effect. In particular, the findings contribute to providing rather tight constraints on theoretical

conceptualizations of the processing routes along which those effects emerge. A common basis of virtually all current accounts of Simon and Simon-like effects is the distinction between two information-processing pathways (e.g., De Jong et al., 1994; Hommel, 1993; Kornblum, Hasbroucq, & Osman, 1990): on the one hand a highly controlled, task-specific route responsible for translating the relevant stimulus feature into the correct response, on the other a more or less automatic route along which, however, quickly decaying spatial stimulus information directly activates the corresponding response. The theoretical challenge is, of course, to characterize further those routes and their biological underpinnings. Although none of the available models ever made this connection, it is tempting to relate the two-route model to the two-processing-streams framework as developed by Milner and Goodale (1995) and others. According to Milner and Goodale, visuomotor transformations between primary visual cortex and motor cortex proceed along to separate channels, a ventral stream mainly concerned with object-related features like colour, shape, or object-intrinsic spatial relations and a dorsal stream responsible for the supply of action-relevant, mainly egocentrically coded information. Interestingly, only the ventral stream is claimed to have access to consciousness and to stored information, whereas the dorsal stream is assumed to be an unconscious online channel without any memory. At first sight, these characterizations fit well with what is known about the two processing routes presumably involved in the Simon effect, which raises the question of whether the automatic route inducing the Simon effect can be identified with the dorsal stream.

However, there are three reasons to question this possibility. First, Simon and other spatial compatibility effects do not rely much on egocentric coordinates, the assumed reference frame of the dorsal stream. Rather, such effects can be obtained if both "left" and "right" stimuli appear in the same visual hemispace (Umiltà & Liotti, 1987), if both responses are located on the same side of the body (Heister, Ehrenstein, & Schroeder-Heister, 1987), and even if left and right are defined with respect to object-intrinsic (Hommel & Lippa, 1995) or effector-intrinsic (Lippa, 1996) coordinates. Second, according to Milner and Goodale's (1995) approach information processed via the ventral stream can be haunted by all sorts of visual illusions and other top-down effects, whereas the dorsal stream is assumed to be cognitively impenetrable and to deliver pure and valid information about action-relevant aspects of the environment. However, Kerzel, Hommel, and Bekkering (2001) were able to produce Simon effects by illusory visual displacement—that is, by moving a rectangle that surrounded the target stimulus. This suggests that the Simon effect is induced along the same neural pathway that is responsible for cognitive illusions. Third, the present demonstration of a memory-based Simon effect, together with the previously mentioned converging observations, rule out that it was produced via a memory-less processing route. This discounts the dorsal stream as a candidate—at least if conceptualized along the lines of Milner and Goodale—but, rather, points to the ventral stream. Taken altogether, these observations do not support the idea that the automatic route thought to mediate stimulus–response compatibility effects of the Simon type can be identified with the dorsal stream, at least if that is conceptualized as a memory-less and cognitively impenetrable processing route restricted to egocentric codes (Milner & Goodale). Rather, voluntary and more automatic contributions to action planning seem to share and make use of the same processing stream and the same representational domain (Hommel, Müsseler, Aschersleben, & Prinz, in press; Kerzel et al., 2001).

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