Spatial intention–response compatibility

Ulrich Ansorge *

Department of Psychology, Bielefeld University, P.O. Box 100131, D-33501 Bielefeld, Germany

Received 15 January 2001; received in revised form 26 June 2001; accepted 27 June 2001

Abstract

In the current investigation the assumption that intentions and actions are represented in the same medium or code (common coding hypothesis of intention and action) was tested and confirmed [Q. J. Exp. Psychol. 52 (1999) 1; Eur. J. Cognit. Psychol. 9 (1997) 129]. In two experiments it is shown that the intention to produce a spatial consequence in the environment to an otherwise spatially neutral stimulus leads to a shorter response, if the responses and the intended consequences share relative positions compared to a situation where this is not the case. In two control experiments it is ruled out that this spatial intention–response compatibility effect is due to an intention-independent expectancy of the consequences of the correct responses. © 2002 Elsevier Science B.V. All rights reserved.

PsycINFO classification: 2340
Keywords: Reaction time; Intention; Spatial compatibility; Common coding

1. Introduction

Intensions to act comprise goals and rules to achieve them. Among the goals are the anticipated external consequences of the action in the environment (Elsner & Hommel, 2001; Prinz, 1997). For example, if someone intends to adjust a clock the final positions of the hands of the clock are such anticipated consequences. The concept of intention differs from the behaviouristic concept of response–effect contingency in at least two important ways. First, linking the anticipated
consequences to the preceding behaviour depends on the active intention of a goal. A mere passive expectancy of the behaviour-contingent environmental changes should be insufficient. Second, rather the logical content of the anticipated consequences than their emotional evaluation is studied for its functional relevance in the control of movements.

Several authors have claimed that intentions and actions are represented in the same medium or code (Elsner & Hommel, 2001; Jeannerod, 1999; Prinz, 1997). In line with this common coding hypothesis of intention and action the codes of external action consequences were shown to interact with those of overt responses (Beckers & De Houwer, submitted; Elsner & Hommel, 2001; Kunde, 2001). For example, Elsner and Hommel asked their participants to choose one of two alternative key presses freely in response to a white rectangle. In the training phase each of the alternative responses produced one specific auditory consequence, either a high- or a low-pitched tone. In the test phase the high and low tones were the imperative stimuli asking for responses that were either consistent with the mapping in the training phase (e.g., a tone that followed a right response in the training phase was to be answered by a right response in the test phase) or inconsistent (e.g., a tone that followed a right response in the training phase was to be answered by a left response in the test phase). It turned out that reaction times (RTs) were faster in consistent compared to inconsistent conditions. Elsner and Hommel ascribed these effects to the acquisition of response–consequence contingencies: During the training phase the tones as consequences were presumably associated with their preceding overt responses. Therefore, the tones tended to evoke the same responses more readily in the test phase. According to the authors the ability to intend specific consequences rests upon these associative mechanisms for linking actions and their consequences. In the present study the claim that intentions and actions are represented in the same medium was studied more directly by demonstrating a spatial intention–response compatibility effect.

1.1. Spatial compatibility

The usual spatial compatibility effects are determined by the spatial relations between different stimuli, between different responses, or between preceding stimuli and responses. For example, in compatible conditions the imperative stimuli and the responses share relative positions (often sides) in relation to the midline of the body, the centre of the field of gaze, the focus of attention, other stimuli, or parts of other stimuli (Fitts & Seeger, 1953; Proctor & Reeve, 1990). In compatible conditions the overt responses are faster or more accurate than in incompatible conditions, where the relative positions of stimuli and responses differ. Consider a stimulus presented to the right: It is responded to faster by a right- rather than a left-hand button press. This effect can be obtained even if the position of the target does not specify the required response, known for about 25 years as the “Simon effect” (for reviews see Lu & Proctor, 1995; Simon, 1990).
1.2. Spatial response–effect compatibility

There are good reasons to assume that at least some compatibility and Simon effects are due to the spatial content of the intended effects of an action: In everyday situations the spatial relations between the stimulus and the response, on the one hand, and between the response and the intended external consequence, on the other hand, are often confounded. As an example, consider that you want to grasp a cup. In this situation the location of the cup is compatible to the direction of the grasping movement, which would correspond to the usual compatibility between imperative stimulus and response. At the same time the response is compatible with the intended external effect or consequence. For example, the direction of the response would be compatible with the spatial content of your intention to see your own hand at the position formerly only occupied by the cup.

Besides, in several studies response–effect compatibility was demonstrated: Actions and their consequences interacted. For example, Kunde (2001) has shown that responses were faster if their consequences were spatially compatible. His participants pressed one of four horizontally aligned keys in response to the colour of a visual stimulus that was presented at the centre of the screen. As a consequence of the key press one of four horizontally aligned boxes presented on the computer screen above the keys lit up. Responses were faster if the position of the key and the position of the box that lit up were compatible (e.g., when the rightmost box lit up as a consequence of pressing the rightmost key) than if the positions were incompatible (e.g., when a box on the left lit up as a consequence of pressing the rightmost key).

However, direct evidence for the influence of intentions on response–effect compatibility is sparse. In the majority of the studies of response–effect compatibility (a) mere passive expectancies of specific effects based on registered contingencies between actions and their consequences, and (b) intentions (as far as they existed) were confounded. As a result response–effect compatibility might have been due to the registration of the mere contingencies that existed between specific responses and their effects. For example, it is not clear whether Kunde’s (2001) participants actively intended the consequences of their actions or whether the passive expectancy of the consequences produced his response–effect compatibility.

The same holds for several instances of the Simon effect (Guiard, 1983; Riggio, Gawryszewski, & Umiltà, 1986; but see Hommel, 1993). For example, Guiard’s participants had to turn a steering wheel either to the right or to the left in response to a high- or a low-pitched tone that came from the right or from the left. As the wheel was sometimes operated by both hands initially placed on the 9 and 3 o’clock positions of the wheel, there was no compatibility in relation to (a) the initial position, and (b) the direction of the movement of the involved effectors in this condition. Nonetheless, a Simon effect resulted: Turning the wheel in the direction of the tone was faster than turning the wheel in the opposite direction. Again, this Simon effect might have been due to the spatial relation between the location of the target (left or right) and the intended effects (turning the wheel to the left or to the right), or the
Simon effect might have resulted from the passive expectancy of specific spatial consequences.

Presumably the only study to date that offers firm evidence for the impact of intentions on response–effect compatibility is the demonstration of Hommel (1993) that the intention to produce an effect on the side opposite to the responding hand (intention condition) led to an “inversion” of the Simon effect. In Hommel’s study targets were tones of different pitches presented to the left or to the right that required either a left- or a right-hand response. As usual, in a baseline condition responses were faster in the stimulus–response compatible than in the incompatible condition. In the intention condition participants were asked to turn on a light on the right side by pressing the left key, and to turn on a light on the left side by pressing the right key in response to the same stimuli. In this intention condition the usual Simon effect was turned into an advantage for the stimulus–response-incompatible compared to the compatible situation.

1.3. Purpose of the present study

The purpose of the present study was to produce further evidence for the common coding hypothesis of intention and action by demonstrating that codes of intentions and actions interact to produce an intention–response compatibility effect, and to control for influences of mere passive expectancies of specific action effects. The general design of the experiments corresponded to that of Kunde’s (2001) in many important respects: The intended consequences had differing spatial relations (compatible or incompatible) to the overt responses, while the imperative stimuli preceding the responses were presented spatially neutral, i.e., in the middle of the field of gaze, in the focus of attention, etc. Most importantly, to demonstrate that any response–effect compatibility was produced by intentions rather than by mere contingencies or passive expectancies, control experiments were run, in which the participants did not intend to produce the consequences, thereby eliminating the compatibility effects.

2. Experiment 1

In each trial one of the letters “H” or “T” was presented as the target in the screen centre. Half of the participants had to move the letter H to the left and the letter T to the right whereas this stimulus–response mapping rule was reversed for the other half of the participants. The spatial contents of the intended consequences, i.e., the target motions, were rendered compatible or incompatible to the overt responses by presenting a mapping cue approximately 2 s prior to the imperative letter at the same position. This signal was either the number 1 or 2. The number determined whether a leftward motion was produced by a left and a rightward motion by a right key press (intention–response compatible condition), or whether a leftward motion was produced by a right and a rightward motion by a left key press (intention–response incompatible condition). The assignment of the numbers to the
mappings was balanced across participants. It was expected that responses are faster in the intention–response compatible condition than in the intention–response incompatible condition. For example, if it was intended to move an H to the left the RT should be faster if a left-hand button press rather than a right-hand button press was given.

2.1. Method

2.1.1. Participants
16 students (10 female) of Bielefeld University participated in Experiment 1. The participants had a mean age of 25.9 years and normal or corrected-to-normal vision. They received 6 DM (approximately US$ 3) for their participation.

2.1.2. Apparatus
The experiment was controlled by a 486 PC. Stimuli were presented on a 15 in. colour monitor (MGA type DX15). The responses were registered via a serial mouse. Latency was measured from the beginning of the target to the nearest millisecond. The participants were seated in a dimly lit room 65 cm in front of the screen with their line of gaze straight ahead.

2.1.3. Procedure
The sequence of events in a trial is depicted in Fig. 1. The stimuli were displayed dark (<1 cd/m²) on a bright background (40 cd/m²). The digits and the letters were all of the same height and presented in an area subtending a visual angle of 0.25° length times 0.39° height. Each trial started with the presentation of one of the two digits, a 1 or a 2, for 1000 ms in the middle of the screen. 100 ms after the digit was turned off a small rectangle (0.15° × 0.15° in size) was presented at the same position for another 1000 ms to keep the gaze and the attention fixated at the location of the upcoming target. 100 ms after the fixation rectangle was turned off one of the two letters, an H or a T, appeared at the screen centre until a response was given. A button press led to the disappearance of the target at the screen centre and its reappearance spatially shifted by 3.92° of visual angle either to the left or to the right. For half of the participants, in conditions signalled by a 1, a leftward leap was produced by a left button press and a rightward leap was produced by a right button press, and in conditions signalled by a 2, a right button press led to a leftward leap and a left button press to a rightward leap of the target. This mapping was reversed for the other half of the participants. In both conditions the target was presented for 700 ms at its new position. Finally, if the response was wrong the sentence “Wrong button!” (“Falsche Taste!”), and if the response was too slow (>1000 ms) the sentence “Please respond faster!” (“Bitte schneller reagieren!”) were presented in German for 700 ms on the screen.

The participants were asked to move the letter H to the left and the letter T to the right or vice versa by pressing one of the two mouse keys, either the left key with their left index finger or the right key with their right index finger. Which mouse
key produced the required response depended on the digit presented at the beginning of the trial. The participants had to react as fast and as accurately as possible.

Each letter and each digit was presented with the same frequency, and the digits 1 and 2 were followed by the letters H and T equally often. The resulting four conditions (2 digits × 2 letters) were repeated 30 times in a random sequence leading to 120 trials in sum. Together with a training of the task (approximately 40 trials) prior to the data acquisition and a short interview about the intentions and the strategies of the participants at the end, the whole experiment took about 30 min.

2.1.4. Analysis

RTs <100 ms were excluded. The individual median latencies of correct responses and the arcsine transformed error percentages were submitted to separate ANOVAs with the factor compatibility (intention–response compatible vs. incompatible).

2.2. Results and discussion

As expected, there was a strong effect of compatibility in the RT data due to the faster responses in the compatible compared to the incompatible condition (see Table 1 for the results of all experiments). There was no effect in the error data. The observed RT compatibility effect tentatively confirmed the hypothesis of a common representational medium for overt responses and intentions. However, it could have been due to the spatial relation between the correct responses and their expected consequences. This possibility was checked in Experiment 2.
3. Experiment 2

Experiment 2 was similar to Experiment 1, but now the participants were not asked to move the targets. The participants only responded to the identity of the letters, that is, they pressed the right key in response to the H and the left key in response to the T, or vice versa. The mapping cue told them which of these two rules was to be applied in the current trial. As the letters still moved and as the final positions of the letters were again either spatially compatible to the response or not, a compatibility effect between an expected spatial consequence and a response would have been possible. However, if the compatibility effect in Experiment 1 was due to the intention to move the letter it should be eliminated.

3.1. Method

3.1.1. Participants

16 students (seven female) of Bielefeld University participated in Experiment 2. The participants had a mean age of 27.8 years and normal or corrected-to-normal vision. They received 6 DM (approximately US$ 3) for their participation.

<table>
<thead>
<tr>
<th></th>
<th>Compatible</th>
<th>Incompatible</th>
<th>ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment 1</td>
<td>Reaction times</td>
<td>541</td>
<td>625</td>
</tr>
<tr>
<td></td>
<td>Percentage errors</td>
<td>8.8</td>
<td>8.4</td>
</tr>
<tr>
<td></td>
<td>F(1,15) = 10.35, p &lt; 0.01</td>
<td>F(1,15) = 0, p = 1</td>
<td></td>
</tr>
<tr>
<td>Experiment 2</td>
<td>Reaction times</td>
<td>593</td>
<td>588</td>
</tr>
<tr>
<td></td>
<td>Percentage errors</td>
<td>6.7</td>
<td>5.7</td>
</tr>
<tr>
<td></td>
<td>F(1,15) = 0.01, p = 0.91</td>
<td>F(1,15) = 2.8, p = 0.61</td>
<td></td>
</tr>
<tr>
<td>Experiment 3</td>
<td>Reaction times</td>
<td>641</td>
<td>752</td>
</tr>
<tr>
<td></td>
<td>Movement times</td>
<td>968</td>
<td>1153</td>
</tr>
<tr>
<td></td>
<td>Percentage errors</td>
<td>3.1</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td>F(1,7) = 6.22, p &lt; 0.05</td>
<td>F(1,7) = 24.4, p &lt; 0.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F(1,7) = 2.18, p = 0.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment 4</td>
<td>Reaction times</td>
<td>812</td>
<td>789</td>
</tr>
<tr>
<td>Movement times</td>
<td>1296</td>
<td>1279</td>
<td></td>
</tr>
<tr>
<td>Percentage errors</td>
<td>14.3</td>
<td>10.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F(1,7) = 0.12, p = 0.75</td>
<td>F(1,7) = 0.06, p = 0.81</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F(1,7) = 3.04, p = 0.13</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Given are the mean reaction times in milliseconds (ms) of correct responses and the mean errors in percent in response–effect compatible vs. incompatible conditions of the four experiments. The compatibility effect only resulted when the consequences were intended (Experiments 1 and 3). Therefore, the effect is best denoted as an intention–response compatibility effect. Reaction times and movement times in Experiments 3 and 4 refer to the times of start key release and target key press, respectively. The values printed bold in Experiment 4 are derived from the 50% fastest responses of each participant in this experiment. This analysis was included to check whether the absence of a compatibility effect in Experiment 4 was simply due to the longer absolute reaction times. This was not the case. (ANOVA: Results of analyses of variances with the single two-step within-subject factor of response–effect compatibility (compatible vs. incompatible) on mean correct reaction times and mean arcsine transformed error scores.) For further information see text.
3.1.2. Apparatus, procedure, and analysis

These were the same as before with the exception of a changed instruction. Half of the participants were asked to press the left key in response to an H and the right key in response to a T if the digit 1 was presented prior to the letter, and to change the rule, that means, to respond to the letter H with the left and to the letter T with the right key, in case of the prior presentation of the digit 2. For the other half of the participants these mappings were reversed, that means, the first rule was to be applied after the presentation of the digit 2 and was to be changed after the presentation of the digit 1.

3.2. Results and discussion

There was no effect of the factor compatibility in the RT and in the error analysis (see Table 1). Therefore, the compatibility effect in Experiment 1 was most likely due to the intention to produce specific spatial consequences, and not to the mere passive expectancy of these consequences. At least two different explanations for the intention–response compatibility effect of Experiment 1 are conceivable. First, as the representation of the overt responses and their external consequences presumably shared codes, the computation of the intention may have been faster in compatible than in incompatible conditions. Determining the spatial content of the intended response might have been shorter if the prior determination of the external effect had a more or less similar spatial content (in the compatible condition) than if this was not the case (in the incompatible condition). Second, according to Lotze (1852) observed and imagined external motion induces a tendency in the observer to move in the direction of this motion. Consequently, especially if the intended external consequences (the letter motions) were imagined, this might have induced a response tendency that corresponded to the overt response or not. In contrast to the first explanation, this influence of an intended spatial consequence would be restricted to situations of intended motions. Which of the two explanations is more appropriate was tested in Experiment 3.

4. Experiment 3

In each trial the participants had to respond to one out of eight possible, centrally presented numbers (0, 3, 6, 9, 12, 15, 18, or 21). The numbers were to be interpreted as times, and the participants had to mark the position of that time on a schematic clock face. For example, the uppermost position was to be marked in response to a 0 or to a 12, the rightmost position was to be marked in response to a 3 or to a 15, and so on (see also Fig. 2). One half of the numbers required a response that was spatially compatible to the content of the intention (either the morning hours 0–9, or the midday to evening hours 12–21) – for example, a finger movement upwards from a central home key to a target key above to mark the upper position if a 12 was presented. The corresponding other half of the numbers required a response that was spatially
incompatible to the content of the intention – for example, a finger movement downwards from the central home key to a target key below to mark the upper position if a 0 was presented. Again, spatial consequences (i.e., schematic clock faces with one marked position) were presented only after the response.

Experiment 3 allowed one to test whether a spatial intention–response compatibility effect can be produced by intending to produce motions only, because the intended spatial consequences now were non-moving. The intention–response compatibility effect should be absent if motions are necessary for the effect. However, if any intended spatial consequence can lead to an intention–response compatibility effect, such an effect should show up.

Fig. 2. Stimuli and succession of events in Experiments 3 and 4, starting from the bottom. In the frames the contents of the computer displays are shown. Black keys indicate active (pressed or released) keys, light grey keys indicate possible alternative keys (possible valid responses), dark grey keys indicate irrelevant keys. Depicted are examples of a correct (on the left: the target key below the home key is shown in black) and of an incorrect (on the right: the target key above the home key is shown in black) key press to the number 12, when this number required a response that was incompatible to its consequence. As a consequence of the target key press a schematic clock face consisting of four squares appeared centred on the screen. Three squares were white (depicted black), and one was red (depicted white) depending on the response. The arrows indicate mutually exclusive events in the last frame (top left and middle). Top left: If the response was correct, the red square marked the position of the hour hand, corresponding to the number (time). For example, the upper square was red after a 12. Top middle: If the response was wrong, the position opposite to the corresponding hour hand location was marked. For example, the lower square was red after a 12. Eight imperative numbers were used, four with compatible, and four with incompatible spatial consequences of the response. For further information see text.
4.1. Method

4.1.1. Participants

Eight students (five female) of Bielefeld University participated in Experiment 3. The participants had a mean age of 25.3 years and normal or corrected-to-normal vision. They received 6 DM (approximately US$ 3) for their participation.

4.1.2. Procedure

The sequence of events in a trial is depicted in Fig. 2. The stimuli were presented bright (40 cd/m²) on a dark background (<1 cd/m²). A trial started with a rectangular fixation mark until the participant pressed the home key (number 5) in the middle of the numeric field of the standard keyboard with her right index finger. This started the presentation of the imperative stimulus, a number signifying a time, at the centre of the screen. Each digit subtended a visual angle of 0.25° length times 0.39° height. The participants had to mark that one out of four possible positions which corresponded to the position of the tip of the hour finger on an analogue clock for that time. To that end they had to press one of the four target keys with their right index finger, either the key above (number 8), to the right (number 6), below (number 2) or to the left (number 4) of the home key. (No special mention was made of the numbers denoted by the keys, only the spatial relations to the home key were mentioned in the instruction.) In the compatible condition the direction of the response was in the same direction as the intended effect; for example, pressing the key above the home key led to the marking of the position above the screen centre. In the incompatible condition the direction of the response was to the opposite in relation to the direction of the intended effect; for example, pressing the key below the home key led to the marking of the position above the screen centre. Half of the participants had to give spatially intention-compatible responses to the morning hours (0–9), and spatially intention-incompatible responses to the midday-to-evening hours (12–21). This mapping was reversed for the other half of the participants.

As a consequence of the target key press the schematic clock face was presented. It consisted of four squares that appeared for 700 ms centred on the screen, one above (corresponding to the 0 and 12 o’clock position), one to the right (corresponding to the 3 and 15 o’clock position), one below (corresponding to the 6 and 18 o’clock position), and one to the left of the centre (corresponding to the 9 and 21 o’clock position). One of these squares was red, the other three squares were white. If the response was correct, the red square was in that position which corresponded to the location of the tip of the hour hand for the actually presented time. For example, the upper square was red after a 12. If the response was wrong, the position opposite to that of the tip of the hour hand that would have been appropriate for the actual time was red. For example, the lower square was red after a 12. Moreover, if the response was not correct the sentence “Wrong button!” (“Falsche Taste!”) was presented in German for 700 ms on the screen.

The participants were told to take their time before initiating the next presentation of an imperative stimulus, and to lift their finger from the home key just prior to the target key press, that is, when the correct response was already determined.
After a short training phase comprising two to four repetitions of each of the eight conditions (corresponding to the eight imperative stimuli) participants worked through 20 repetitions of each condition presented in a random order. Again, the participants were briefly asked about their strategies and their intentions after the experiment.

4.2. Results and discussion

Like in Experiment 1, there was a strong effect of compatibility in the RT data. RT was faster in the compatible than in the incompatible condition (see Table 1). There was no effect in the error data. Tentatively, the spatial intention–response compatibility effect seemed not to be restricted to situations where motions were intended. However, at least two problems need to be discussed. First, in previous research mixing spatially compatible and incompatible conditions within one block led to a diminution of compatibility effects (Duncan, 1978; Stoffels, 1996). Compared to the RT obtained in blocks consisting of only compatible or incompatible trials, RT increased in mixed blocks, but this increase was stronger for compatible than for incompatible conditions. It is an interesting question (but beyond the scope of the present study) whether such a diminution of the compatibility effect was present in the results of Experiments 1 and 3. There, compatible and incompatible conditions were mixed within one block. Note, however, that, if anything, this would have meant that the compatibility effects of the current study were obtained under (unnecessarily) conservative conditions.

Second, using numbers as the imperative stimuli might have been unfortunate. Numbers and responses were shown to have different degrees of compatibility that could have been quite independent of the actual intentions of the participants. For example, Fitts and Deininger (1954) presented digital numbers/times to their participants and found that a response in the direction of that time on a clock face (e.g., moving a stylus upwards in response to a target “12:00”) was faster than in the opposite direction (e.g., moving a stylus downwards in response to a “12:00”). Whether the compatibility effect of Experiment 3 was indeed due to the spatial relation between the responses and the intended consequences, or to either the compatibility between the numbers and the responses, or the spatial relation between the correct responses and their merely expected consequences was still to be tested.

5. Experiment 4

Experiment 4 was similar to Experiment 3, but the participants were no longer asked to produce the spatial consequences in response to the numbers. The participants had to press the same keys in response to the numbers as before, but the spatial consequences of the key presses, although still present, were no longer part of the task. Again, like in Experiment 2, as the spatial consequences were either spatially compatible to the response or not, an influence of spatial response–effect compatibility would have been possible. Moreover, as the same numbers required the same
responses as before, the compatibility between the numbers and the responses was also still a possible potent factor. Contrary to these explanations, if the compatibility effect in Experiment 3 was due to the intention to produce the spatial consequences it should be eliminated in Experiment 4.

5.1. Method

5.1.1. Participants

Eight students (five female) of Bielefeld University participated in Experiment 4. The participants had a mean age of 26 years and normal or corrected-to-normal vision. They received 6 DM (approximately US$ 3) for their participation.

5.1.2. Procedure

The sequence of events in a trial was exactly the same as in Experiment 3. After the presentation of the fixation mark the participants had to press (1) the home key to initiate the presentation of the imperative number, and (2) one out of the four target keys. The number-to-response mapping rules were the same as before. Note that, because the four squares, one marked red, were again presented as a consequence of the responses, the correct responses produced either a compatible or an incompatible effect to the preceding responses.

5.2. Results and discussion

Like in Experiment 2, there was no effect of compatibility in the RT and in the error analysis (see Table 1). As the mean RT was somewhat longer than in Experiment 3, the same analyses were conducted on the basis of the 50% fastest responses of each participant to rule out that a compatibility effect was present in the faster responses only: Once again the effect was non-significant (see Table 1). This means that the compatibility effect in Experiment 3 was presumably not solely due to the compatibility between numbers and responses, but that the intentions were necessary to produce the effect.

Interestingly, several participants of Experiment 4 reported that they were aware of the contingencies between at least some of their responses and the external consequences. Thus, although a part of the consequences were expected, the spatial content of the expectancies had not the same influence as that of the intentions. In sum, the comparisons of Experiments 1 and 2, and Experiments 3 and 4, led to the same conclusion: An intention to produce the spatial consequences was a necessary precondition for the observed compatibility effect.

6. General discussion

In the current investigation an intention–response compatibility effect was demonstrated in two experiments. In Experiment 1 moving letters to one side was faster if the key was in the direction of the intended motion than if it was not. Experiment 2
did show that this compatibility effect was eliminated if the motions were not intended, although the same motions resulted as a consequence of the key presses. In Experiment 3 marking positions on a schematic clock face was faster if the responses were in the direction of the intentionally marked position than if not. Experiment 4 confirmed that this compatibility effect was abolished if the marking was not intended, although the same positions on the schematic clock face were marked as a consequence of the responses. In sum, the experiments supported the common coding hypothesis of intention and action by demonstrating that the codes underlying intentions and actions interacted (Jeannerod, 1999; Prinz, 1997).

The intention–response compatibility effect can be explained best by assuming that processing time is saved if two codes of the underlying information processes (one code corresponding to the intention of the external consequence, the other code to the preparation of the overt response) contain comparable spatial information. At least two explanations in terms of common coding for intentions and actions are conceivable. First, an intention of external consequences might depend on the same motor or pre-motor processes that are responsible for overt responses. The repeated use of similar spatial information in the computation of the intended effect and in the computation of the overt response might then reduce the processing time in the compatible condition compared to the incompatible condition, in which the spatial content of the intended effect and that of the overt response are dissimilar, so that spatial content must be computed two times. Indeed, some authors have argued for a role of motor or pre-motor processes in intentional processes such as voluntary thinking and image formation (Cohen, 1986; Demarais & Cohen, 1998; Wexler, Kosslyn, & Berthoz, 1998; Wohlschläger & Wohlschläger, 1998). For example, Wexler et al. found that the time to mentally rotate an image in one direction was longer when a simultaneously executed open response was in the opposite direction (incongruent condition) than when it was in the same direction (congruent condition). Second, the intention–response compatibility might be due to the common codes underlying different mental images. The repeated use of comparable spatial information in the computation of two mental images (one of the response and one of the intended environmental consequences) could have shown up as an RT reduction, too, for the same formal reasons as are described above. Interestingly, mental images seem to produce Simon effects in relation to overt responses (Tlauka & McKenna, 1998).

Whatever the exact causes of the obtained intention–response compatibility effect, the results of the present study indicate that intentions have effects beyond those of the mere presence of response–effect contingencies. One likely reason for this difference is that only intentions can guarantee that response–effect contingencies can be achieved and applied in a wide range of natural situations. For example, in many skill-learning situations the novice will not necessarily produce and experience consistent effects by his/her own overt actions from the beginning. An intention based on the anticipated consequences of the same overt actions as obtained from observing experts during their performance of the task might help to improve the skill in phases where the experts are not present, and failure by the novice to produce the same consequences by the novice would soon lead to an extinction of the memorable consequences. Likewise, certain consequences of actions are rare and therefore not
expected due to other influences besides one’s own overt behaviour. Intentions might help to keep track of goals in such situations, too. Finally, intentions might be also useful in detecting certain response–effect contingencies, for example, by directing attention to aspects of the produced effects that are so non-salient that they would otherwise remain unregistered.

Acknowledgements

Supported by Grant No. 366/6-1 from the Deutsche Forschungsgemeinschaft to Odmar Neumann. Thanks to Bernhard Hommel, Maurits van der Molen, an anonymous reviewer, Elena Carbone, Heike Hartwig-Jakobs, Manfred Heumann, Werner Klotz, Ingrid Scharlau and Odmar Neumann for helpful comments on earlier drafts of the current paper, and to Carmen Kropat and Ulf Kirse for help in running the experiments.

References


