The Representation of Instructions Operates Like a Prepared Reflex

Flanker Compatibility Effects Found in First Trial Following S–R Instructions

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Abstract. The prepared reflex (PR) metaphor (Woodworth, R. S. (1938). *Experimental psychology.* New York: Holt, Rinehart and Winston) suggests that stimulus–response (S–R) instructions held in working memory (WM) can lead to autonomous response activation even *without any practice*. Cohen-Kdoshay and Meiran (Cohen-Kdoshay, O., & Meiran, N. (2007). The representation of instructions in working memory leads to autonomous response activation: Evidence from the first trials in the flanker paradigm. *The Quarterly Journal of Experimental Psychology, 60* (8), 1140–1154) showed that the flanker compatibility effect (FCE) is found in the eight trials following S–R instructions supporting the PR hypothesis. Nonetheless, performance in the first trials forms long-term memory (LTM) traces which link abstract categories with responses and the retrieval of these LTM traces may be the reason for the autonomous response activation seen in the FCE. This account predicts FCEs to be absent in the *first trial* and present afterwards. The authors show that the FCE was present in the first trial immediately following the instructions, thus providing unequivocal support for the PR metaphor.

Keywords: instructions, autonomous processing, prepared reflex, intention, flanker compatibility, task set

The metaphor of the *prepared reflex* (PR) was presented almost seven decades ago by Woodworth (1938; see also Hommel, 2000; Kunde, Kiesel, & Hoffman, 2003; Logan, 1978; Wenke, Gaschler, & Nattekemper, 2007). This metaphor suggests that stimuli can reflexively trigger the corresponding action based on instructed or planned stimulus–response (S–R) information, even without any prior practice. It also implies that the S–R links or task set is prepared and activated in working memory (WM) in advance of performance, so that even a stimulus presented for the first time will educe the appropriate response. Such a mechanism is likely to contribute to the enormous flexibility of humans in adapting to new situations.

Although previous studies support the PR idea, their main limitation is that the experiments were lengthy and the relevant effects could be due to the accumulation of long-term memory (LTM) traces during the experiment rather than due to the active WM representation of the S–R rule created following the instructions (see Cohen-Kdoshay & Meiran, 2007, for review). Only a handful of studies examined the pure effect of the instructions on action activation. Wenke et al. (2007) used a paradigm in which participants (a) were given instructions for a choice task, (b) performed a size task while holding the choice instructions in mind, and (c) performed the choice task. Importantly, the choice task instructions (e.g., if the letter is N, press the right key, if it is K, press the left key) changed in every trial. While holding these instructions in mind, the participants judged which one of two simultaneously presented letters was physically bigger. The critical results concern the size task and show faster responses when the letter display corresponded with the choice task instructions (e.g., the letter N presented on the right and the letter K presented on the left). After ruling out a potential spatial confound in the experiments, a reliable 6 ms instruction compatibility effect was found.

One problem with this demonstration is that one cannot rule out an alternative explanation that the moderate facilitation observed resulted from the semantic match/mismatch between the two successive displays (the task instructions and the size-task display) rather than from response activation (see Kahneman, Treisman, & Gibbs, 1992; Milliken, Tipper, & Weaver, 1994, for the effect of match/mismatch).

In De Houwer, Beckers, Vandorpe, and Custers's (2005) study, the participants were given three types of instructions. They were informed that the words "left" and "right", a left and a right arrow, and blue and green squares would appear on the screen. Their task was to respond vocally with the nonsense syllable "bee"/"boo" depending on the color of the squares, or according to the direction indicated by the words or the arrows. Importantly, the colored squares were presented on the right or on the left, despite the fact that color, and not position, was relevant. In the most relevant Experiment 2, the participants performed only the color task. Despite the fact that the participant never executed the location tasks, a significant Simon effect was found. Specifically, reactions were quicker when the colored square required a "bee"/"boo" response that corresponded with the

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(irrelevant) location of the square. Importantly, arrows and words were presented at the screen's center, whereas colored squares were presented to the left or to the right of the screen center. That is, location was task-irrelevant in the color task. The authors concluded that *short-term* associations that were created based on the instructions underline the Simon effect. Although the results are suggestive in supporting the PR hypothesis, another alternative explanation still remains possible. Specifically, the Simon effect could have resulted from the match/mismatch between the location and the declarative knowledge held in WM. Namely, what could have driven the results was the mismatch between the "bee" response and the left position on the one hand and the declarative knowledge associating "bee" with the right position in the instructions of the location tasks on the other hand. Note that according to this alternative account, the WM content does not result in autonomous response activation.

Recently, we (Cohen-Kdoshay & Meiran, 2007) used a unique modification of the flanker paradigm (Eriksen & Eriksen, 1974) in order to provide further support to the PR metaphor. The participants made speedy classification of centrally presented target stimuli and responded with a right or a left key press. The targets were flanked by visually dissimilar noise stimuli that, due to the instructions given beforehand, were either compatible (indicating the same response according to the instructions) or incompatible (indicating the opposite response according to the instructions) in relation to the target stimulus. Critically, in that study, we introduced a new set of S–R instructions and new stimuli in each experimental block. The blocks were made of mini-blocks in which none of the target stimuli were repeated. This design allowed us to show that the flanker compatibility effect (FCE) was large and significant already in the first mini-block of eight trials that immediately followed the instructions under conditions that prevented prior practice with the S–R instructions and target repetition. We also showed that this effect was eliminated under WM load, thus demonstrating its dependence on this limited capacity buffering system.

Although our previous results provide support to the PR metaphor, an important alternative explanation remains possible. We will describe this explanation in reference to one set of instructions from Cohen-Kdoshay and Meiran's (2007) experiments as an example. The exemplar task required the participants to classify letters according to whether they belonged to the beginning or to the end of the alphabet. Because the instructions linked the stimuli to the responses through an abstract category (e.g., "beginning of the alphabet"), it is quite reasonable to assume that response selection was mediated by the selection of this category (e.g., Logan, 1990), which in turn was linked to the physical response (see further, Meiran & Kessler, 2008; Pashler & Baylis, 1991, in reference to WM processes). This mapping could be described as IF [beginning of the alphabet] THEN [press the right key]. Furthermore, the link of a specific stimulus (e.g., the letter D) to an abstract category ("beginning of the alphabet") was not novel and presumably existed in semantic LTM prior to the experiment. In other words, the instructed association was between the abstract category, and the response, and not between specific instances of the abstract category (e.g., the letters, B, C, and D) and the response. This processing instance could be recorded accordingly, namely, as an episode linking the abstract category (e.g., the beginning of the alphabet) and the response (right key press). If this explanation were correct, it would have been sufficient to encounter the abstract category once, and all the subsequent trials could, in principle, be based on the retrieval of past episodes. Moreover, because we observed the first-trial FCE in the first mini-block of eight trials, it is completely conceivable that the autonomous response activation evident in the FCE was based on episodic retrieval, rendering our demonstration of PR completely useless. Importantly, this LTM-based account predicts that FCEs will be absent in the *first trial* that follows the S–R instructions (because LTM traces were not yet formed) and will be present afterwards, when LTM traces have already been formed. Arguably, this trend was masked by the averaging across the first mini-block in Cohen-Kdoshay and Meiran's report.

The above-mentioned LTM account is supported by some theories (e.g., Anderson, 1982; Fitts, 1964), which suggest that direct connections between stimuli (S) or stimulus categories and responses (R) are built up gradually, as a result of task execution. Similarly, in Logan's (1988) instance theory of automaticity, automatic S–R translation results from the accumulation of multiple memory traces built during previous task executions. These theories seem to imply that, without having executed the task beforehand, response activation is entirely controlled.

In the present experiment, we contrasted the PR metaphor against the alternative LTM-based explanation listed above. To this end, we examined the FCE in the very first trial following the instructions. The predictions according to the PR hypothesis are that the FCE will be found in the *first trial* following the instructions, while the alternative LTM-based account predicts that the FCE will be absent in the first trial and will appear only in subsequent trials. To test this prediction, we needed to change the procedure of our previous study (Cohen-Kdoshay & Meiran, 2007). In the previous study, we chose instruction sets for which we could produce eight trials in which the flankers never served as targets, and there was no item repetition. This created serious constraints on the type of stimuli that could be used and consequently, there were only 5–6 different sets of stimuli (and instructions). Since half of the trials were compatible and half were incompatible, there were only 2–3 first trials of each (compatible or incompatible) in the entire experiment, making the examination of the current predictions practically impossible. Given these considerations, Cohen-Kdoshay and Meiran (2007) chose to conduct the analyses at the level of mini-blocks rather than at the levels of individual trials. For that reason, we were also concerned in that study with the stability of the estimates at the level of the mini-blocks, which is why we chose such high restrictions that included no target repetition and used different stimuli as targets and as instructions.

Our main goal was to collect stable estimates at the level of individual trials (rather than at the level of mini-blocks). As we were less interested in the analyses at the level of mini-blocks, we relaxed our constraints regarding target repetition by enabling mini-blocks of only four trials. This made it possible to use many more sets of stimuli (and instructions), which made it possible to conduct our analyses at the level of individual trials. The objective of this change was to collect a sufficiently large number of *first trials* which followed their respective S–R instructions for the sake of the statistical analyses. As in our previous paper, there was no stimulus repetition between experimental blocks. We reasoned that a demonstration of FCE in the very first trial following the S–R instructions would consist of an especially strong support for the PR metaphor.

Another unique aspect of the current study is that we show, at least to our knowledge, for the first time autonomous response activation which results from *category–response* instructions rather than stimulus-specific instructions. This feature contrasts with De Houwer et al. (2005) and Wenke et al. (2007) who used stimulus-specific instructions.

Method

Participants

Twenty Ben-Gurion University of the Negev freshmen took part in the experiment in exchange for a course credit. All reported having normal or corrected-to-normal vision and being unaware of the goal of the experiment, as indicated by a post-experimental questionnaire.

Apparatus and Stimuli

The stimuli were presented on a 17 in. color monitor controlled by a Pentium III computer. The display of target and flankers (each 1.1×0.9 cm^2) was presented within a frame. The target was always flanked by two identical noise elements, and the distance between the target and noise elements was 1.0°. The general instructions included a general description of the task (i.e., "In each trial, you will be presented with three stimuli. You need to respond only to the stimulus in the center and ignore all other stimuli"), followed by an example of possible categorization that was not used in the experimental blocks (i.e., odd and even digits mapped to the right and left key, respectively) and a picture of a keyboard indicating the mapping (with no specific exemplars). These slides were used only in the practice block in order to present the participants with the general procedure. The experimental blocks started with the instruction of the new category mapping. The last slide of the instructions indicated that "In the next step you will start. Prepare yourself. Press the space bar when ready". During the instructions, the participants were asked to avoid simulating any button presses, and the experimenter carefully watched them during this phase. Each experimental block was associated with a new stimulus set and new S–R instructions. Each instruction set applied to a set of 8–12 stimuli, half mapped to one response and half to the other response. We controlled the stimuli by using *only eight stimuli* from the instructions set in the first four trials and the other stimuli were used as fillers, appeared always after the first four controlled trials, and were not analyzed (see Figure 1). The reason to use fillers is that in this study we needed more category–response rules in comparison to our previous work. This caused a situation in which we had a small number of stimuli for some of the rules (e.g., only four stimuli for each response compared with eight stimuli in our previous work). When only very few stimuli are used for a given category, it might be beneficial for the participants to remember specific S–R rules rather than using categorical representations. In order to discourage this strategy, we added stimuli in some of the categories and used them as fillers. One half of the stimuli were used as targets and the other half were used as flankers, meaning that stimuli that served as flankers never served as targets in order to ensure that their influence was entirely based on instructions. This feature additionally ensured that the effect would not result from presenting flankers that were physically identical to the targets.

Procedure

Each participant completed seven blocks of 60–90 trials (the block length depended on the stimulus set size, which dictated the number of fillers). Each block began with the mapping instructions, followed by a list of the stimuli belonging to each of the two response categories, followed by the "get ready" slide. Although all the trials were presented in succession, the block was divided from the experimenter perspective into 15 mini-blocks of 4 controlled trials. One or two filler trials were presented after the four controlled trials. Within each mini-block, there were two compatible trials and two incompatible trials. The compatible trials involved flankers that were visually different from the target, but were mapped to the same response via the instructions. We collected one trial from each instruction set/block, resulting in a total of 7 "first trials" (7 Blocks × 1 Trial) for each participant. Of these seven trials, about half were compatible and the rest were incompatible, although this number was not controlled because stimulus selection was completely pseudo-randomized individually. The order in which the sets of instructions were given was counterbalanced by a Latin square.

Participants were tested individually in one session, lasting approximately 40 min. Testing took place in a dimly lit room, and the participants were seated about 50 cm from the computer monitor. In the beginning of the experiment, the participants executed one block to familiarize themselves with the task structure in order to be sure that in the subsequent blocks the location of the flankers and the target are clear. This block was based on a set of instructions and stimuli that were not used in the subsequent blocks, and this was considered as practice and was not analyzed. It included 32 *incompatible* trials to ensure that the participants adopt the strategy of focusing on the target. Moreover, if the participant committed an error during these practice trials,

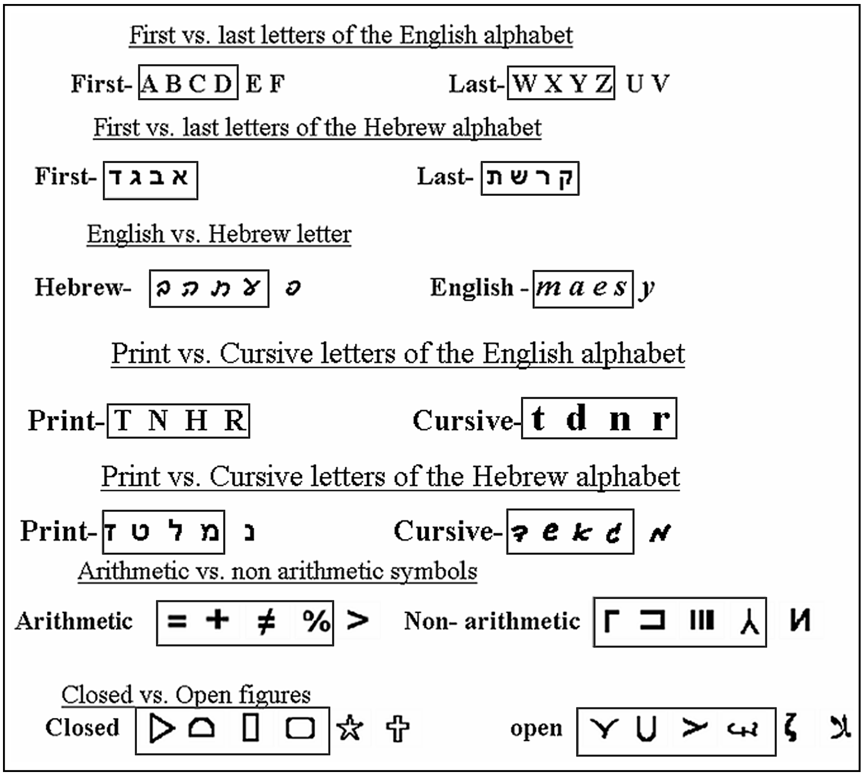

Figure 1. S–R mappings: Framed stimuli used as experimental stimuli and the other stimuli used as fillers.

an error message appeared in red letters, accompanied with a 350 Hz beep presented for 250 ms. In a further attempt to discourage flanker processing, we explicitly told the participants that the aim of using the flankers was to confuse them. In addition, after each block we provided feedback with the mean accuracy level. Because responding to flankers rather than to targets would result in errors for these conditions, emphasizing high accuracy further discouraged any attempt to use flanker information in making decisions about the targets. The trial sequence was as follows: At the beginning of each trial, a black frame was presented on a white background. After 500 ms, the target and flankers were presented within a frame. The display remained visible until the participant responded. Responses were made by pressing the "z" (left) and "/" (right) keys on a standard computer keyboard, with the left and right index fingers, respectively. The mapping of the response category to the response key was counterbalanced across participants. We used an inter-trial interval of 200 ms.

Results

The first analysis was conducted to see if we replicated the results of our former study. Mean reaction times (RTs) were calculated as a function of Compatibility and Mini-Block. The first mini-block was compared to the other mini-blocks. Response latencies quicker than 100 ms or exceeding 3,000 ms were considered as deviant (1.8%) and discarded. Errors were rare (< 1%), and there was no evidence for speed accuracy tradeoff. Significant main effects were found for Compatibility, $F(1, 19) = 25.7$, $\eta_P^2 = .57$, indicating a FCE, and Mini-Block, $F(1, 19) = 12.2$, $\eta_P^2 = .39$, reflecting practice. The interaction between Compatibility and Mini-Block was also significant, $F(1, 19) = 15.2$, $\eta_P^2 = .44$, indicating larger FCE in the first mini-block (85 ms) compared with the remaining mini-blocks (27 ms). This pattern of results is a replication to our former study and, although not new, it is important to show that the procedural changes we made (including the introduction of new stimulus sets and new S–R instructions) were not critical.

The second analysis, which was the main interest of the present study, focused on the first four trials in the first mini-block following its respective instructions. These results are, of course, averaged across the seven blocks (and instruction sets). We calculated the number of compatible and incompatible trials, in the first trial within each subject across the seven blocks. The individual participants' results are based on 3.5/3.5 compatible/incompatible trials per position on average. Only in 3 of 20 participants, the number of trials per compatible/incompatible condition was one. This feature made it more difficult to support our predictions because it lowers the reliability of the measurement, thus reducing the statistical power. Since the critical finding was significant (see below), the potential lack of statistical power (which, by definition, can produce only Type II errors) becomes irrelevant.

Mean RT was calculated as a function of Compatibility and Trial Position (Trials 1–4) only for the first mini-blocks

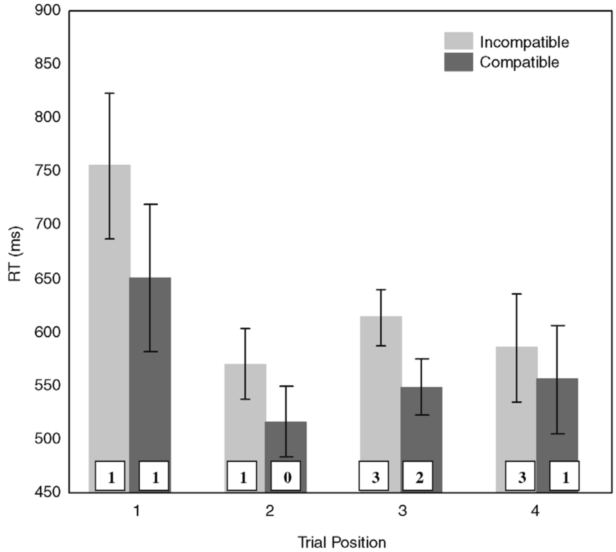

Figure 2. Mean RT (ms) according to Compatibility and Trial Position for the first mini-block. Number of errors is presented within each column. (Bars indicate standard errors for the focused contrast for the FCE in each Trial Position.)

of each instruction set in which no target repetition took place. We used the same cutoff as before, excluding deviant trials (2.3%) and errors (2.01%) from the RT analysis. Significant main effects were found for Compatibility, $F(1, 18) = 18.1$, $\eta_P^2 = .50$, indicating an FCE for the first mini-block, and Trial Position, $F(3, 54) = 23.13$, $\eta_P^2 = .56$, indicating that RT for the first trial was longer than that in the remaining trials in the first mini-block. The interaction between these variables was not significant $F(3, 54) = 0.8$, $\eta_P^2 = .046$, indicating that the FCE was statistically the same size for all trials in the first mini-block in spite of being numerically largest in the first trial (see Figure 2). Despite the non-significant interaction, we computed a focused contrast on the *first* Trial Position and found that the FCE was significant, $F(1, 18) = 4.89$, $\eta_P^2 = .21$.

Discussion

In this experiment, we contrasted two accounts for the FCE that was found in the first mini-block following the S–R instructions (Cohen-Kdoshay & Meiran, 2007). According to the PR metaphor, this effect resulted from the representation of the S–R instructions in WM and the fact that these instructions are capable of leading to autonomous response activation. According to an alternative account, performance in the very first trials following the instructions results in forming LTM representations that link abstract response categories such as "beginning of the alphabet" to their respective responses such as "press the right key". Furthermore, these LTM representations are the reason for the FCE and not the WM representations. The two accounts generate differential predictions regarding the FCE in the very first trial that follows the instructions, with the FCE predicted only according to the PR metaphor. In order to investigate this issue, we used a variant of the flanker paradigm, in which we changed the stimulus set and the instructions in each block, used flankers that never served as targets and examined the FCE in the *first trial* from each experimental block. Our results show a significant FCE already in the first trial following the instructions. In fact, the FCE that we found in the first trial was numerically larger than that in the remaining trials in that mini-block. The FCE represents autonomous processing in the sense described by Bargh (1989), Tzelgov (1997), Tzelgov, Porat, and Henik (1997), and Tzelgov, Yehene, Kotler, and Alon (2000). Namely, it indicates that the flankers activated the instructed response in spite of the instructions to ignore them and in spite of using a procedure that strongly discouraged their processing. The present results unequivocally support the PR notion and are incompatible with the LTM-based account that we presented beforehand.

Our results seem to contrast those of a recent study by Waszak, Wenke, and Brass (2008), in which no instruction-based compatibility effect was found. They used task switching paradigm and the tasks were to decide between color and shape. In the instructions, they presented six different colors and shapes, but used only four of them as targets. In the relevant condition, involving *bivalent* stimuli, the participants reacted to one dimension (color or shape), and the distractor was color or shape that was used only in the instruction phase. Under this condition the RT was longer but no response compatibility effect was found. Namely, RT was not shorter when the distractor was compatible with the correct response as compared to when it was incompatible with it. One way to reconcile the differences is in referring to the similarity between switching conditions in the study of Waszak et al. and the load manipulation used by Cohen-Kdoshay and Meiran (2007, Experiment 4). In the latter study, WM load led to the elimination of the FCE. As we argued in our previous study, under condition of WM load, which was the case for both these experiments, task execution cannot be based on the PR because the PR operates as representation held in limited capacity WM. When this resource becomes unavailable, the information is held in other components of the cognitive system, and performance does not have the PR characteristics.

In this paper, we made a distinction between LTM traces and WM representations. An apparently similar distinction between short-term and long-term links has been proposed in the literature (e.g., De Houwer, 2004; Proctor & Vu, 2002; Tagliabue, Zorzi, Umiltà, & Bassignani, 2000). According to this distinction, long-term links are associations that participants had before taking part in the experiment such as the association between right–left spatial position of stimuli and right–left manual responses. Short-term links are those that were formed during the experiment. Demonstrations of short-term links are typically associated with executing the newly formed instructions. Therefore, the short/long-term distinction is different from our distinction because according to our conception, short-term links may be newly formed LTM. The representations which support the PR are even shorter-term than the short-term links described by these theories in that they are formed by the instructions alone and exist prior to actual task performance. In a sense, they are the cognitive equivalent of the *intention* to react in a certain manner to a given stimulus or stimulus category.

The PR metaphor provides a powerful tool to describe how intentions (operationalized as S–R instructions) translate into action. According to this metaphor, a newly formed intention to respond in a given manner to a stimulus is associated with transient representations that drive behavior in the first trials. Subsequent trials may later be guided by the accumulated experience in LTM (e.g., Logan, 1978). Very similar ideas were suggested by Gollwitzer (1999), who described the preparation of goal-directed responses in terms of "implementation intention", which is a simple mental plan that links a particular stimulus or stimulus feature with a specific goal-directed response.

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