This article was downloaded by:[Cohen-Kdoshay, Oshrit]
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Publisher: Psychology Press
Informa Ltd Registered in England and Wales Registered Number: 1072954
Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK

The Quarterly Journal of Experimental Psychology

Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t716100704

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Online Publication Date: 01 August 2007

To cite this Article: Cohen-Kdoshay, Oshrit and Meiran, Nachshon (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
To link to this article: DOI: 10.1080/17470210600896674
URL: http://dx.doi.org/10.1080/17470210600896674

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THE QUARTERLY JOURNAL OF EXPERIMENTAL PSYCHOLOGY
2007, 60 (8), 1140–1154

The representation of instructions in working memory leads to autonomous response activation: Evidence from the first trials in the flanker paradigm

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The authors examined whether instructions can lead to autonomous response activation even without practice. Eriksen and Eriksen's (1974) flanker compatibility paradigm was used to show that the flanker compatibility effect (FCE) is already present in the first trials following the stimulus–response instructions, before any of the stimuli have been repeated. This first-trials FCE was present even when participants were strongly motivated to ignore the flankers, and it disappeared under conditions of high working-memory (WM) load. The findings suggest that intention, formed by instructions, is involved in forming representations in WM that operate like a prepared reflex (Woodworth, 1938). The implications of the finding to intentionality and frontal lobe functions are discussed.

Consider a participant who is told to get ready to respond to faces by pressing the right key if the face presented is a happy face and the left key if it is a sad face. Consider further the fact that the participant has never reacted to faces in this manner beforehand. The type of situation just described is prevalent not only in the cognitive laboratory, but also in everyday life, whenever people must act according to instructions. It relates to a broader question: how people prepare themselves to react in a certain manner to a stimulus when they do not have prior experience with the task. In an attempt to answer this question, Hommel (2000), Kunde, Kiesel, and Hoffman (2003), Logan (1978), and Wenke, Gaschler, and Nattekemper (2005) have recently revived Woodworth's (1938) metaphor of a "prepared reflex" (PR). One reason for our choice to explore the implications of the PR is that, as is described below, it provides a powerful metaphor to describe the nature of the mechanism by which intention is translated into action, at least in the motor domain. Although this hypothetical mechanism would obviously be important, we argue that none of the existing evidence unequivocally demonstrates its existence.

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This research was supported by a grant to the second author from the Israel Science Foundation. We wish to thank Bernhard Hommel and Gordon Logan for helpful suggestions, and Rotem Eren-Rabinovich for English proofreading.

http://www.psypress.com/qjep
DOI:10.1080/17470210600896674

The prepared reflex

Historically, the insight for the idea of the *"prepared reflex"* came from Exner (1879). He assumed that stimuli can reflexively trigger the corresponding action based on instructions organized beforehand in preparation for the action. The concept itself was suggested by Woodworth (1938) in the early introspective studies on reaction time. He concluded that the major cognitive involvement seems to occur before the stimulus was presented and that the reaction itself was reflexive. "The reaction is involuntary, i.e., no new will impulse is needed after the entrance of the stimulus in order that the reaction shall follow. The only voluntary act is the preparation" (Woodworth, 1938, p. 305). Logan (1978) supports this idea in his investigation of the involvement of attention in mental operation. He concludes that "behavior in reaction time situations still appears to be nothing more than a prepared reflex" (p. 59). Recently, Hommel (2000) extended this metaphor. According to his extension, task preparation is an effortful holding of the instructed stimulus–response (S–R) link or task set, so that even a stimulus presented for the first time will reflexively elicit the appropriate response without any further effort of the will.

This metaphor has a few notable implications: First, a mental representation of the task mapping is created following the instructions. Second, the preparation of this representation demands intention and cognitive effort, and it operates within some form of working memory (WM). Third, this representation, once formed, can lead to autonomous processing. We adopted the criteria for autonomous processing suggested by Bargh (1989) and Tzelgov (1997; Tzelgov, Porat, & Henik, 1997; Tzelgov, Yehene, Kotler, & Alon, 2000). According to these authors, an autonomous process is one that runs to completion even when it is not a part of the task requirements. Take, for example, the flanker paradigm (e.g., Eriksen & Eriksen, 1974) in which participants are told to react to the central target and to ignore the flanking noise stimuli. In this paradigm, processing the flankers can be described as autonomous because according to the instructions, it is not a part of the task requirements. The final implication for the PR metaphor is that the autonomous processing should lead to response activation. The present paper reports a series of experiments that provided evidence for the PR, taking into account all of the four implications described above.

Review of relevant findings

Previous studies have shown that instructions affect relevant processes, including input selection ("attentional capture"), input organization in working memory, and response activation. Below we review these three lines of evidence.

Prepared reflex versus attentional setting

Emphasis on preparation is reminiscent of the idea of *"mental set"* mentioned already in the early attention literature (Ach, 1910; Gibson, 1941; Woodworth, 1938). According to this idea, attention sets the mind to respond in a certain way to particular aspects of stimulation. Stimulus presentation effectively releases the autonomic process comprising the set. The idea of mental set is also related to the literature on attentional control settings (e.g., Folk & Remington, 1998; Folk, Remington, & Johnston, 1992, 1993; Folk, Remington, & Wright, 1994; Remington & Folk, 2001). These works shows that attentional control settings allow only stimuli that are consistent with the current control setting to involuntary capture attention. Thus, the *attentional capture* is not purely a function of stimulus property but depends on the existence of a prior attentional set for the eliciting property. A similar idea was adopted in the field of singleton detection/search (e.g., Bacon & Egeth, 1994; Lamy & Tsal, 1999; Yantis & Egeth, 1999). These studies show that attention may be guided on the basis of top-down factors, meaning that stimulus-driven capture of attention depends on attentional control settings, which are a function of task demands. Along a similar line, Downing (2000) suggested that objects in the visual field compete for attention, and the strongest competition will be elicited by objects that have already had their representation activated in WM (cf. Desimone & Duncan, 1995; Duncan & Humphreys, 1989). Pratt and Hommel (2003) showed that overlearned stimuli (i.e., arrows) lead to covert movements of spatial attention in manners that reflect the current goal held in WM. Recently, Soto, Heinke, Humphreys, and Blanco (2005) have explored the interrelations between working memory and attention. The results also suggest that there can be early, involuntary top-down direction of attention to a stimulus that matches the contents of working memory.

The crucial difference between the studies listed above and Woodworth's (1938) PR idea, as we see it, is that the former refer to how input is selected, whereas the PR metaphor refers to how responses are activated and selected. Because many cognitive theories hold that input selection and response selection are different processes (e.g., Logan, 2002; Pashler, 1998), it is unclear at present whether motor responses can also be activated in a reflex-like fashion after the intention to respond has been encoded.

Input organization in working memory

Previous studies have shown that instructions not only affect the direction of attention and how stimuli in the environment capture it, but also affect the organization of WM objects. A relevant example comes from Wheeler and Treisman's (2002) study. These authors found that whether stimulus information in WM will reflect feature binding or not depends on the instructions given to the participants.

Instructions effects on response activation

Many studies already showed that instructions can modulate the manner in which stimuli activate the corresponding responses. These studies show, for example, that instructions can reverse the Simon effect (for reviews, see Lu & Proctor, 1994; Simon, 1990), so that stimuli presented on the right, for example, would prime the left-hand response instead of the right-hand response as usually found (e.g., Hommel, 1993a; Tagliabue, Zorzi, Umiltà, & Bassignani, 2000). To explain such reversals, some authors have suggested a distinction between two types of memory links, STM (short-term memory) links and LTM (long-term memory) links. STM links are established in accordance with task instructions, are arbitrary, are short lived, and are set up to perform the task at hand and then decay. In contrast, LTM links are preexisting S–R associations that do not depend on the immediate instructions. They are not related to the task to be performed and do not decay over time. Considering the Simon task, for example, the LTM links are spatial in nature and connect the location of the stimulus with the location of the spatially corresponding response. STM links are nonspatial in nature and connect the task-relevant, nonspatial feature of the stimulus with the location of the required response. Another example of the effects of instructions with the Simon task is demonstrated in experiments in which two stimuli are simultaneously presented on both sides, and one of them is designated as relevant by its colour (Hommel, 1993b), shape (Grice, Boroughs, & Canham, 1984), or meaning (O'Leary & Barber, 1993). In addition, Wenke and Frensch (2005) show that response labels used in the instructions directly determine the codes that are used to control responding in dual-task settings. Another study supporting the idea of the prepared reflex was conducted by Kunde et al. (2003, see also Eimer & Schlaghecken, 1998, for a related finding). These authors showed that subliminally presented stimuli triggered actions even when these stimuli were not encountered beforehand as targets, as shown by the compatibility between the prime indicated response and the target's indicated response (Experiment 1). In this study the participant's task was to judge whether a number was larger or smaller than five. In each trial, a subliminally presented prime stimulus (numbers 1–9 excluding 5, or neutral stimulus) was followed by a target number (1, 4, 6, or 9). Prime–target compatibility effects were found also for primes that were never presented as a target (e.g., "2" as a prime followed by "4" as a target).

All the above evidence, while suggestive, cannot be regarded as conclusive support for the PR because the experiments were lengthy. Consequently there was stimulus repetition. Therefore, it is conceivable that the automatic response triggering resulted from the accumulation of LTM traces. This holds equally for Kunde et al.'s (2003) work, in which practice could have resulted in strengthening the LTM link between the semantic categories *high* and *low* and the respective responses. The formation of such LTM traces would be sufficient to support performance capitalizing on the preexisting associations between the numerals and the categories that were present in LTM preexperimentally. Such a proposal fits theories positing that S−R links are not direct, but may be mediated by abstract categories (e.g., Abrams, Klinger, & Greenwald, 2002; Campbell & Proctor, 1993). Therefore, what is lacking still is an examination of performance that immediately follows the instructions and occurs before any practice has been given, which is what we did in the current study.

In our opinion, the strongest support for the PR idea, one that cannot be attributed to a build-up of new associations in LTM, comes from a recent study by Wenke et al. (2005). These authors 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 Wenke et al. (2005) 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 the present study, we tried to provide unequivocal support for the PR by a unique modification made to the widely studied flanker paradigm. First, we introduced a new set of stimuli and stimulus−response instructions in each experimental block. This allowed us to examine the flanker effect in the first trials following the instructions, under conditions in which there was no target repetition, a feature that rules out the possibility that the effect was LTM based. Second, we investigated how the flanker effect developed or changed over time, a feature that allowed us to separate LTM-based effects from PR-based effects. Third, we explored the flanker effect that we obtained under WM load condition in order to support the idea that the PR is based on processes occurring within WM. Finally, we were concerned with the size of the effect reported by Wenke et al. (2005), which may be too small to allow studying of how the effect is modulated by experimental manipulations. We conjectured that the small effect found in Wenke et al. (2005) could have resulted from a lack of full task commitment, which led to weak representation of the instructions in WM. Such a lack of task commitment is likely to be found when task instructions change frequently (Monsell, Sumner, & Waters, 2003). To encourage fuller task commitment, we asked the participants to use the same instructions in the entire block of 120 trials before the next block and new instructions came.

THE PRESENT STUDY AND THE FLANKER PARADIGM

The PR metaphor suggests that task sets (or the task-related S−R mappings) are created and activated before performing the task. If this were the case, one would predict that presenting participants with stimuli associated with conflicting responses would result in a competition between responses and a consequent response slowing. Moreover, this slowing should take place even in trials immediately following the instructions. To investigate this question, we used a flanker task (e.g., Eriksen, 1995; Eriksen & Eriksen, 1974; Eriksen & Schultz, 1979) in which a target appeared in the centre of the screen and was surrounded by compatible, incompatible, or neutral noise stimuli. Reaction time (RT) in compatible trials is typically faster than that in incompatible trials, revealing the "*flanker compatibility effect*" (FCE). We suggest that an FCE revealed in the very beginning stages of performance, immediately after the instructions were given, would indicate that the instructed mapping operates autonomously. However, in order for the flankers to activate a response, the visual information must not be blocked by peripheral means such as focusing visual attention. To reduce the chances for this scenario, we added a black frame around the entire display so that the target and flankers were positioned within a single visual object (cf. Duncan, 1984). It can be claimed that using a frame around the entire display might cause some attention to spill over onto the irrelevant flankers (e.g., Yantis & Johnston, 1990). Our results show that in the present study this was not the case, as elaborated below.

Early studies assumed that the source of the FCE is mainly perceptual (e.g., Harms & Bundesen, 1983; Kramer & Jacobson, 1991). Following Miller's (1991) study that showed convincingly that the source of the FCE is not at the perceptual level, it is commonly believed today that the source of the effect arises mostly from response competition that occurs at the response selection or response activation stage. Arguably, responses compete with each other so that the incorrect response is inhibited, and the correct response is delayed (e.g., A. Cohen & Shoup, 1997; Eriksen & Eriksen, 1974, 1979; Eriksen & Hoffman, 1973; Eriksen & Shultz, 1979; Grice & Gwynne, 1985; Grice, Nullmeyer, & Spiker, 1977). A similar conclusion was adopted in research that used psychophysiological measures (e.g., Coles, Gratton, Bashore, Eriksen, & Donchin, 1985) and is also reflected in parallel distributed processing models (e.g., Botvinick, Braver, Barch, Carter, & Cohen, 2001; J. D. Cohen, Servan-Schreiber, & McClelland, 1992). These studies support the idea that the source of the FCE reflects response activation. Thus, showing that the FCE is present immediately following the instructions would constitute important support for the PR hypothesis, in that it would show that instructions lead to autonomous response activation. The novel aspect of our design was the change in mapping instructions and the stimulus set in each block of trials, which allowed us to accumulate the first trials following the instructions from the different experimental blocks. As a result there were sufficient first trials to observe a reliable FCE before practice with the particular instructions took place. If the entire instructed category–response or S–R mapping is activated prior to performance, as predicted by the PR hypothesis, the FCE should be observed immediately following the instructions. On the other hand, if it is necessary to perform the task in order to create associations or traces in LTM, then the FCE should show up only after some practice.

EXPERIMENT 1

Method

Participants
The participants were 25 Ben-Gurion University freshmen who took part in the experiment in exchange for a course credit or 25 NIS (roughly $5), all reporting having normal or corrected-to-normal vision and being unaware of the goal of the experiment, as indicated by a postexperimental questionnaire.

Apparatus and stimuli
The stimuli were presented on a 17″ colour monitor controlled by a Pentium III computer. The display (Figure 1) of target and flankers (each 1.1 × 0.9 cm) was presented within a frame. The target was always flanked by two

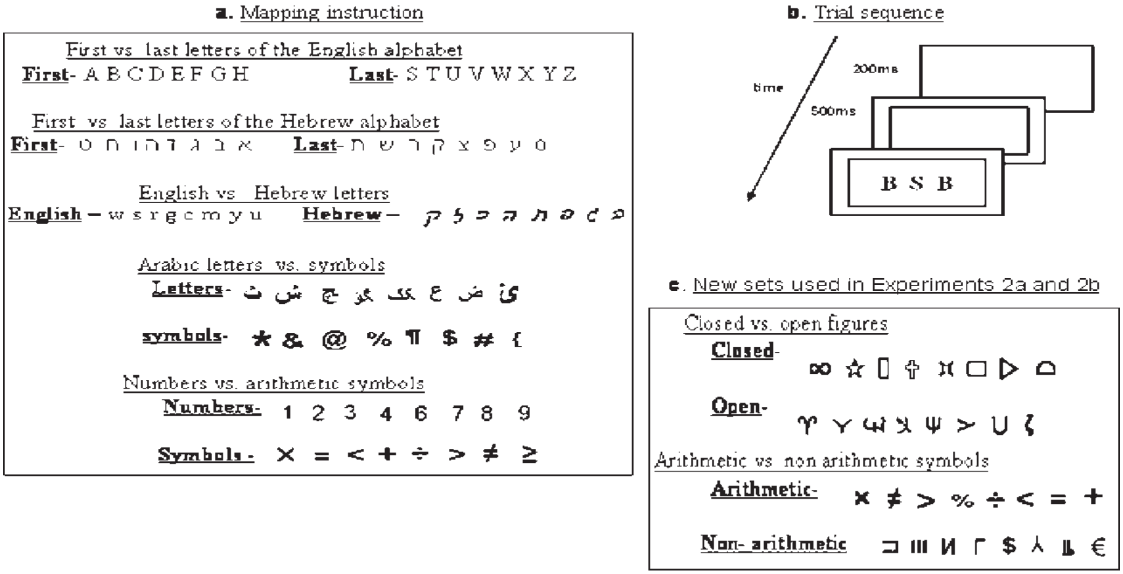

Figure 1. *(a) Stimulus–response mappings. Each mapping served in one block of 120 trials and began with the following slides: (i) mapping instructions (e.g., "In the following trials use this rule: If the target is one of the first letters of the alphabet, press the right key. If the target is one of the last letters of the alphabet press the left key"); (ii) the list of the stimuli mapped to each response; and (iii) a "get ready" slide. (b) The trial sequence: Each trial began with an intertrial interval of 200 ms (only for Experiments 2a and 2b), followed by a black frame presented in the centre of the screen, followed by the display that remained visible until the response was given. (c) The new stimulus mapping used in Experiments 2a and 2b, replacing the sets of Arabic letters versus symbols and numbers versus arithmetic symbols.*

identical noise elements, and the distance between the target and noise elements was either 0.5° or 1.0°. Since this distance manipulation did not have any effect, we do not discuss it any further. 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 centre and ignore all other stimuli"), followed by an example of possible categorization that was not use 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. 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 press. Each experimental block was associated with a new stimulus set. Each instructions set applied to a set of 16 stimuli, 8 mapped to the one response and 8 to the other response (see Figure 1). 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 further ensure that their influence was entirely based on instructions. This feature additionally ensured that the effect would not result from a match or mismatch at the perceptual level in the case that the flankers were physically identical with the targets.

Procedure

Each participant completed five blocks of 120 trials each, which 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. Each block was divided into 15 miniblocks of 8 trials each. Within each miniblock, there were four compatible trials and four incompatible trials. The compatible trials involved flankers that were visually different from the target, but were mapped to the same response via the instructions. Within each such miniblock, each stimulus was presented as a target only once, meaning that the first miniblock did not involve any stimulus repetition. We collected eight trials from each instruction set/block and therefore a total of 40 "first trials" (5 blocks × 8 trials) for each participant. As a result of these settings, the sequential miniblock number also represents the number of times that any given stimulus was repeated in the experiment. Stimulus selection was completely pseudorandomized individually. The order in which the sets of instructions were given was counterbalanced by a Latin square. Participants were tested individually in one session, in a dimly lit room, and 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. This block was based on a set of instructions and stimuli that were not used in the subsequent blocks. It was considered as practice, included 42 trials, and was not analysed. 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 the standard computer keyboard with the participants' left and right index fingers, respectively. The mapping of the response category to the response key was counterbalanced across participants.

Results and discussion

Mean RTs were calculated as a function of compatibility, miniblock, and block sequential order. We adopted an $\alpha = .05$ in all the analyses. Response latencies quicker than 100 ms or exceeding 3,000 ms were discarded as deviant (2%) and were only analysed for accuracy.

Significant main effects were found for compatibility, $F(1,\ 24) = 6.70$, $\eta^2 = .22$, indicating an FCE, and miniblock, $F(14,\ 336) = 15.25$, $\eta^2 = .39$, reflecting practice. The interaction between compatibility and miniblock was marginal, $F(14,\ 336) = 1.69$, $p = .054$. FCE for the first miniblock (53 ms) was greater than that in the remaining miniblocks (6 ms), but the corresponding focused contrast was only marginally significant, $F(1,\ 24) = 3.5$, $p = .06$. When we analysed the FCE for each stimulus set, separately, we revealed that one stimulus set (Arabic letters vs. symbols) did not show an FCE, and this trend held throughout the respective blocks. Possibly, the lack of the effect was due to the fact that Arabic letters that were used as stimuli were unfamiliar to the participants, and therefore they made the decision based on complimentary judgement (this stimulus is not a recognized symbol). However, we do not make the claim that PR exists for any particular set of instructions. We only wish to demonstrate that PR exists at least in some cases. Therefore, we replaced this stimulus category in the subsequent experiments (see Figure 1).

Because it is conceivable that after the first block, participants learned to attend to the flankers that were compatible in 50% of the trials, we examined the FCE separately for the first miniblock within the first block. FCE in this block was 90 ms and the corresponding planned contrast was marginally significant, $F(1,\ 24) = 4.20$, $p = .051$. This result suggests that the first-trial FCE (FTFCE) does not result from a strategy (e.g. focusing on distracters) that developed in the course of the experiment.

EXPERIMENT 2

In order to further ensure that the FCE does not result from an attempt to improve task performance through attending to the flankers (as would be the case for compatible trials) we made two changes in the design of the experiments. First, we increased the distance between the target and flankers from 0.5° to about 1.17° (see Eriksen & Eriksen, 1974). In addition, we replaced one set of stimuli (numbers vs. arithmetic symbols) because the stimuli belonging to each of these response categories were very different, perceptually, and it is possible that this aspect encouraged processing of the task based on shallow perceptual differences (curved shapes vs. straight-lined shapes). Furthermore, the practice block included only incompatible flankers, and a high level of accuracy (achieved only if one does not respond to the flankers) was strongly encouraged. It was reasoned that, because attending to the flanker stimuli, which were incompatible, would result in producing errors, emphasizing high accuracy would greatly discourage intentional attempts to process these flankers.

Method

Participants

A total of 18 students, similar in attributes to those in Experiment 1, took part in the experiment in exchange for a course credit.

Apparatus, stimuli, and procedure

The only changes relative to Experiment 1 aside from those listed above were that there were six sets of instructions (and blocks) rather than five, and that we replaced two stimulus sets with other sets (see Figure 1). The practice block included 16 incompatible trials to encourage the participants to ignore the flankers. In addition, after each block, we provided feedback with the mean accuracy level. To increase participants' motivation to prepare for the task before each set of stimuli, we offered a monetary bonus of 10 NIS (approximately $2) if their RT and error rate would fall below the group average. In order to maintain the participants' level of arousal and reduce the chance that the instructions from previous blocks would affect performance, we presented a verbal joke or a funny caricature between the experimental blocks. The only change in the trial sequence was adding an intertrial interval of 200 ms.

In the postexperimental questionnaire, the participants reported that in one set of stimuli, the discrimination between the two categories was difficult and unclear. The categories were curved figures versus round figures. Separate investigation by instructions-type revealed that the FCE pattern on this block was reversed (558 and 540 ms for the compatible and incompatible conditions, respectively). Consequently, we discarded this instruction set from the subsequent analyses.

Results and discussion

One response was discarded as deviant. Significant main effects were found for compatibility, $F(1, 17) = 21.99$, $\eta^2 = .56$, indicating FCE, and miniblock, $F(14, 238) = 17.08$, $\eta^2 = .50$, reflecting practice. The interaction between compatibility and miniblock was also significant, $F(14, 238) = 1.98$, $\eta^2 = .22$. The same pattern of FCEs was found as that in Experiment 1 (44 ms in the first miniblock vs. 13 ms in the remaining miniblocks), but this difference was only marginally significant as indicated by a focused contrast, $F(1, 17) = 3.54$. The focused contrast examining the FCE in the first miniblock of the first block was also significant, $F(1, 17) = 5.16$, $\eta^2 = .23$, indicating a significant FCE (85 ms) from the outset.

EXPERIMENT 3

In this experiment, further attempts were made to discourage participants from intentionally processing the flankers.

Method

Participants

A total of 10 participants of similar attributes to those tested beforehand took part in the experiment.

Apparatus, stimuli, and procedure

The only changes relative to Experiment 2 were that there were five sets of instructions (and blocks). As noted before, the participants in Experiment 2 reported that one set of instructions confused them, and we excluded it from this experiment. 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, the practice block included 120 incompatible trials to ensure that the participants adopted the strategy of focusing on the target. Moreover, if the participant committed an error during these practice trials, an error message appeared in red letters accompanied by a 350-Hz beep. We believe that such an extended practice period strongly discouraged the participants from focusing on the flankers.

Results and discussion

Using the same cut-offs as before, no responses were discarded as deviant. Significant main effects were found for compatibility, $F(1, 9) = 7.43$, $\eta^2 = .45$, indicating FCE, and miniblock, $F(14, 126) = 10.02$, $\eta^2 = .53$, reflecting practice. The interaction between compatibility and miniblock was also significant, $F(14, 126) = 2.46$, $\eta^2 = .21$. The same pattern of FCEs was found as that in the former experiments (87 ms in the first miniblock vs. 10 ms in the remaining miniblocks), and this difference was significant as indicated by a focused contrast, $F(1, 9) = 5.36$, $\eta^2 = .37$.

We analysed the FCE in the first miniblock, the one immediately following practice, and found a significant first-trials FCE (FTFCE) of 117 ms, $F(1, 9) = 9.93$, $\eta^2 = .52$, indicating FCE from the outset. This pattern of results was also found in Experiment 1 and Experiment 2. It is hardly likely that eight trials (including only four compatible trials) provided sufficient time for a strategy change.

Errors were rare (see Table 1), and there was no indication of a speed–accuracy trade-off.

Across-experiment comparisons

An additional analysis examined whether the FTFCE changed in the course of the experiment. Learning to ignore the flankers or to attend to them in the course of the experiment is predicted to result in a decrease or an increase, respectively, in the FTFCE across the experiment. In fact, the interaction between block-order and FTFCE was nonsignificant, $F(4, 96) = 0.379$; $F(4, 68) = 0.217$; $F(4, 36) = 0.197$, in Experiments 1 through 3, respectively. This conclusion is strengthened in the next experiment.

Table 1. *Proportion of errors as a function of compatibility, miniblock, and experiment*

	Miniblock			
	1		*2–15*	
Experiment	*Compatible*	*Incompatible*	*Compatible*	*Incompatible*
1	.01	.03	.01	.02
2	.01	.02	.01	.01
3	.01	.02	.01	.02
4	.01	.00	.00	.01

In order to further investigate the difference between the first miniblock and the remaining miniblocks, we conducted an across-experiments analysis. In this analysis, the interaction between compatibility and the miniblock contrast (first block vs. the remaining blocks) was significant, $F(1, 50) = 10.92$, $\eta^2 = .18$, while the triple interaction with experiment was nonsignificant (see Figure 2).

EXPERIMENT 4

All of the evidence above supports the idea of the PR. It seems that some kind of task set or task goal presentation is activated prior to performance and following the instructions. We argue that the FTFCE reflects the fact that flanker information was processed at the level of response identity based on representation of the whole mapping in WM. In order to support this idea, we designed the final and fourth experiment in which we added to the primary flanker task a secondary task in an effort to load WM.

As pointed out by one reviewer, the response latencies for the first miniblock were slow compared to the remaining miniblocks, and this could perhaps account for the larger FCE in that block. The fourth experiment addresses this issue as well: If the slower responses in the first miniblock explain the former results, large FCE is predicted to be found in the first miniblock in spite of the WM load.

Importantly, the literature suggests that WM reflects attentional control and that top-down control signals from object representation in WM can bias selection in favour of the object whose features have been preactivated (e.g., Desimone & Duncan, 1995; Downing, 2000;

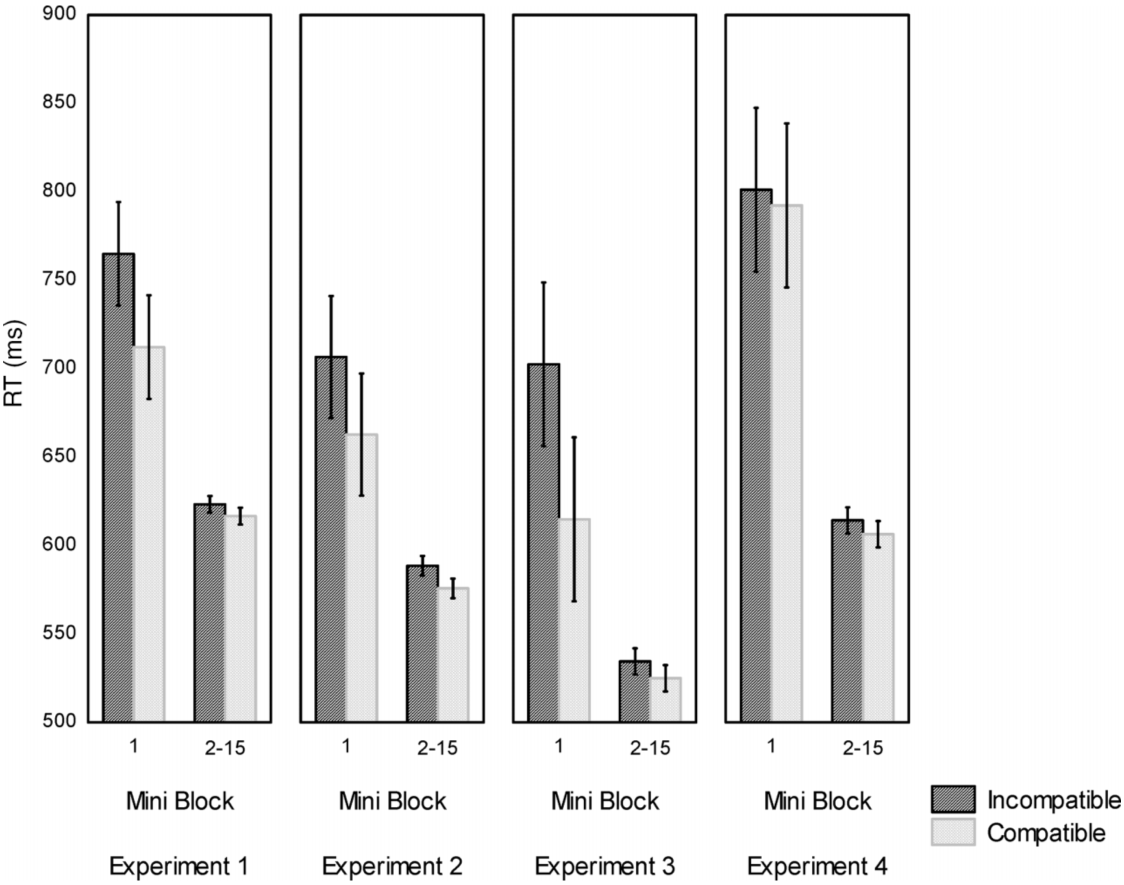

Figure 2. *Mean reaction time (RT; in ms) according to compatibility, experiment, and miniblock. Error bars indicate a 95% confidence interval for the compatibility contrast.*

Pratt & Hommel, 2003; Soto et al., 2005). Therefore, loading WM should reduce attentional control resources (e.g., De Fockert, Rees, Frith, & Lavie, 2001). De Fockert et al.'s study is especially relevant here because they showed larger interference effects from distractors under conditions of high memory load. Accordingly, one would predict that loading WM should result in a greater rate of trials in which the flankers, instead of the target, are processed (e.g., Lavie, Hirst, De Fockert, & Viding, 2004; Ste-Marie & Jacoby, 1993) and increase the FTFCE. However, if the FTFCE represents a prepared reflex held in WM as the PR hypothesis holds, loading WM should reduce or eliminate it.

Method

Participants

A total of 10 students with similar attributes to those tested so far took part in this experiment.

Apparatus, stimuli, and procedure

The procedure was the same as that in Experiment 3, with the following exception: The practice block included 48 trials, which were divided into two parts and were not analysed further. The first 24 trials were identical to the corresponding trials in the former experiments, and the second part included the WM task. The task used to load WM was a go/no-go task in response to numbers (e.g., press the space bar only when you see a number that is divisible by 4). One go/no-go WM trial was given in a randomly chosen position within each miniblock. This trial consisted of a fixation point, presented for 500 ms, followed by a target number, which remained visible until the participant responded or until 3 s had elapsed. A feedback with the mean accuracy level was presented only after the practice block. To ensure that the go/no-go task information is held in WM and not in LTM, we introduced a new set of instructions for the WM task in each experimental block. We also changed the font used to display the numbers and the number words in every block. After each block, we asked the participants to recall the WM task instructions, thus making sure that this information was held in WM during the block.

Results and discussion

Using the same cut-offs as before, one response was discarded as deviant. The error rate was less than 1% (0.005%). In order to eliminate task-switching influence on the results, we did not analyse the flanker task trials that immediately followed the WM task. As would be expected, the mean RT was longer than that in the previous experiments, indicating an effect of WM load (see Figure 2). All the participants correctly recalled the instructions for the go/no-go WM task and did so in all the blocks. In terms of performance, 4 participants made one error in the go/no-go task, and 1 participant made two errors. None of these errors was at the first miniblock, which allows us to conclude that the information for the go/no-go task was held in WM while performing this critical miniblock. The only main effect was for miniblock, $F(14, 126) = 42.33$, $\eta^2 = .82$, reflecting practice. The main effect of compatibility was nonsignificant, and numerically the FCE was only 8 ms. The FCE in the first miniblock was 9 ms and was nonsignificant as well, $F(1, 9) = 0.12$. Thus, the presently used WM load task eliminated the FTFCE. The experiment lends further support to the argument that the FTFCE stems from WM representations rather than from LTM representations. It is important to note that although the FTFCE was eliminated, the participants managed to complete the task. This suggests that the PR mechanism reflects the operation of a default strategy, based on holding instructions in a specific WM component when possible. When this WM component becomes unavailable, the information is held in other components of that system, and the WM component does not have PR characteristics. Cowan's (1988) and Oberauer's (2001, 2002) model may explain this result. According to this model, WM consists of activated (and linked) LTM, which is not a severely limited resource, and the focus of attention, which is limited. Accordingly, one possibility is that the participants who were given a WM load kept the S–R mapping information as activated LTM. We currently pursue this issue in an effort to clarify the exact nature of the WM systems supporting PR.

Finally, the same pattern of RT facilitation due to within-block practice was found in all the four experiments. Still, the FTFCE disappeared under WM load. These results rule out the possibility that the FTFCE was merely due to the initially slower responses in the beginning of the block.

GENERAL DISCUSSION

The goal of this study was to establish unequivocal support for the PR metaphor. We reasoned that such supporting evidence needs to meet the following criteria: (a) It should indicate response activation; (b) this activation should be autonomous; (c) it should not be LTM based; and (d) dependence on WM should be established. Previous studies failed to meet at least one of these requirements, as elaborated in the Introduction. To address these shortcomings, we used a variant of the commonly used 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 miniblock before any of the stimuli repeated. We report three novel results. First, there was a FTFCE, which probably does not reflect focusing failures or strategic attempts to focus on the flankers. Second, the FTFCE was larger than the FCE present in the remaining trials in the block, and finally, the FTFCE (as well the usual FCE) was eliminated when we loaded WM by an additional go/no-go task that changed in every block. These results meet all the four requirements that we listed: They indicate response activation, which was autonomous, and resulted from WM representations and not LTM representations. Below we discuss some additional features of the present results.

It seems unlikely that the participants attended to the flankers instead of attending to the targets. First, error rate was very low (2%, 1%, and 1% in Experiments 1 through 3, respectively), which shows that participants did not process the flankers completely. Had they processed them completely, the error rate in incompatible trials should have been 100%. The results of Experiment 4 further weaken the possibility that the effect was due to poor segregation of flankers and targets, because WM load should have increased the FCE but it in fact eliminated it. Second, the FTFCE was found for the first miniblock at the first block, the one immediately following practice, where the participants were strongly encouraged to ignore the flankers (see especially Experiment 3).

Another possible explanation of the results is that there was semantic priming from the flankers to target. This explanation is unlikely to be correct because in most of the instruction sets in our study, the response categories were ad hoc categories taken from the same semantic category. An example is the decision between the first and last letters of the alphabet. In this case, all the stimuli belong to the same semantic category (they were letters), and their category was determined by the instructions.

Interestingly, the FCE was larger in the first miniblock than in the remaining miniblocks. It therefore seems that immediately after the instructions, participants are ready to perform the task in a different mode than they perform it after having executed it for a few times. This pattern of result fits with theories that assume that, with practice, participants learn to ignore task-irrelevant information (e.g., Haider & Frensch, 1996, 1999).

We note that the FCE is usually between 5 and 60 ms (e.g., A. Cohen & Shoup, 1997, 20–60 ms; Eriksen & Eriksen, 1974, about 20 ms for the critical comparison; Flowers & Wilcox, 1982, 5–40 ms; Yantis & Johnston, 1990, 11 ms). The size of the FCE for the late mini blocks in this study corresponded to the lower end of this range. This small effect may be due to the procedural changes such as using new instructions in each block and preventing any overlap between targets and flankers. Because our focus in this paper is on the first trials, we did not pursue this issue any further.

Broader implications

In terms of the neurological processes, the characteristics of neurons in the prefrontal cortex make them likely candidates for the mechanism subservient to the PR. These characteristics include the ability to maintain task-relevant information (e.g., Goldman-Rakic, 1987), to integrate diverse sources of information (e.g., Fuster, 1995), and to change their representation according to the task at hand (White & Wise, 1999).

The results are also related to studies in social psychology, where it has been proposed that goals can be activated outside awareness and then run to completion without conscious intervention (e.g., Bargh, 1990; Bargh & Gollwitzer, 1994; Bargh, Gollwitzer, Lee-Chai, Barndollar, & Trötschel, 2001). According to these authors, whenever a goal is activated (consciously or unconsciously), it will operate effectively to guide a person's goal-relevant cognition, affect, and behaviour from that point on.

Original manuscript received 20 December 2005
Accepted revision received 27 June 2006
First published online 11 September 2006

REFERENCES

Abrams, R. L., Klinger, M. R., & Greenwald, A. G. (2002). Subliminal words activate semantic categories (not automated motor responses). *Psychological Bulletin & Review, 9*, 100–106.

Ach, N. (1910). *Über den Willensakt und das Temperament*. Leipzig, Germany: Quelle & Meyer.

Bacon, W. F., & Egeth, H. E. (1994). Overriding stimulus-driven attentional capture. *Perception & Psychophysics*, *55*, 485–496.

Bargh, J. A. (1989). Conditional automaticity: Varieties of automatic influence in social perception and cognition. In J. S. Uleman & J. A. Bargh (Eds.), *Unintended thought* (pp. 3–51). New York: Guilford Press.

Bargh, J. A. (1990). Auto-motives: Preconscious determinants of thought and behavior. In E. T. Higgins & R. M. Sorrentino (Eds.), *Handbook of motivation and cognition* (Vol. 2, pp. 93–130). New York: Guilford Press.

Bargh, J. A., & Gollwitzer, P. M. (1994). Environmental control of goal directed action: Automatic and strategic contingencies between situations and behavior. *Nebraska Symposium on Motivation*, *41*, 71–124.

Bargh, J. A., Gollwitzer, P. M., Lee-Chai, A., Barndollar, K., & Trötschel, R. (2001). The automated will: Nonconscious activation and pursuit of behavioral goals. *Journal of Personality and Social Psychology*, *81*, 1014–1027.

Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., & Cohen, J. D. (2001). Conflict monitoring and cognitive control. *Psychological Review*, *108*, 624–652.

Campbell, K, C., & Proctor, R. W. (1993). Repetition effects with categorizable stimulus and response set. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*, 1345–1362.

Cohen, A., & Shoup, R. (1997). Perceptual dimensional constrains in response selection process. *Cognitive Psychology, 32*, 128–181.

Cohen, J. D., Servan-Schreiber, D., & McClelland, J. L. (1992). A parallel distributed processing approach to automaticity. *American Journal of Psychology, 105*, 239–269.

Coles, M. G. H., Gratton, G., Bashore, T. R., Eriksen, C. W., & Donchin, E. (1985). A psychophysiological investigation of the continuous flow model of human information processing. *Journal of Experimental Psychology: Human Perception and Performance*, *11*, 529–553.

Cowan, N. (1988). Evolving conceptions of memory storage, selective attention, and their mutual constraints within the human information-processing system. *Psychological Bulletin, 104*, 163–191.

De Fockert, J. W., Rees, G., Frith, C. D., & Lavie, N. (2001). The role of working memory in visual selective attention. *Science, 291*, 1803–1806.

Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience, 18*, 193–222.

Downing, P. E. (2000). Interaction between visual working memory and selective attention. *Psychological Science*, *11*, 467–473.

Duncan, J. (1984). Selective attention and the organization of visual information. *Journal of Experimental Psychology: General*, *113*, 501–517.

Duncan, J., & Humphreys, G. W. (1989). Visual search and stimulus similarity. *Psychological Review*, *96*, 433–458.

Eimer, M., & Schlaghecken, F. (1998). Effect of masked stimuli on motor activation: Behavioral and electrophysiological evidence. *Journal of Experimental Psychology: Human Perception and Performance, 24*, 1737–1747.

Eriksen, C. W. (1995). The flanker task and response competition: A useful tool for investigating a variety of cognitive problems. *Visual Cognition*, *2*, 101–118.

Eriksen, B., & Eriksen, C. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics*, *16*, 143–149.

Eriksen, C. W., & Eriksen, B. (1979). Target redundancy in visual search: Do repetitions of the target within the display impair processing? *Perception & Psychophysics*, *26*, 195–205.

Eriksen, C. W., & Hoffman, J. E. (1973). The extent of processing of noise elements during selective encoding from visual displays. *Perception and Psychophysics*, *14*, 155–160.

Eriksen, C. W., & Schultz, D. W. (1979). Information processing in visual search: A continuous flow conception and experimental results. *Perception and Psychophysics*, *25*, 249–263.

Exner, S. (1879). Physiologie der Grosshirnrinde. In L. Hermann (Ed.), *Handbuch der Physiologie* (Vol. 2, pp. 189–350). Leipzig, Germany: Vogel.

Flowers, J. H., & Wilcox, N. (1982). The effect of flanking context on visual classification: The joint contribution of interactions at different processing levels. *Perception & Psychophysics*, *32*, 581–591.

Folk, C. L., & Remington, R. W. (1998). Selectivity in distraction by irrelevant featural singletons: Evidence for two forms of attentional capture. *Journal of Experimental Psychology: Human Perception and Performance*, *24*, 847–858.

Folk, C. L., Remington, R. W., & Johnston, J. C. (1992). Involuntary covert orienting is contingent on attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance*, *18*, 1030–1044.

Folk, C. L., Remington, R. W., & Johnston, J. C. (1993). Contingent attentional capture: A reply to Yantis (1993). *Journal of Experimental Psychology: Human Perception and Performance*, *19*, 682–685.

Folk, C. L., Remington, R. W., & Wright, J. H. (1994). The structure of attentional control: Contingent attentional capture by apparent motion, abrupt onset, and color. *Journal of Experimental Psychology: Human Perception and Performance, 20*, 317–329.

Fuster, J. M. (1995). *Memory in the cerebral cortex*. Cambridge, MA: MIT Press.

Gibson, J. J. (1941). A critical review of the concept of set in contemporary experimental psychology. *Psychological Bulletin, 38*, 781–817.

Goldman-Rakic, P. S. (1987). Circuitry of primate prefrontal cortex and regulation of behavior by representational memory. In F. Plum & V. Mountcastle (Eds.), *Handbook of physiology: Section 1. The nervous system: Volume V. Higher functions of the brain: Part 1* (pp. 373–417). Bethesda, MD: American Physiological Society.

Grice, G. R., Boroughs, J. M., & Canham, L. (1984). Temporal dynamics of associative interference and facilitation produced by visual context. *Perception & Psychophysics, 36*, 499–507.

Grice, G. R., & Gwynne, J. W. (1985). Temporal characteristics of noise conditions producing facilitation and interference. *Perception & Psychophysics*, *37*, 495–501.

Grice, G. R., Nullmeyer, R., & Spiker, V. A. (1977). Application of variable criterion theory of choice reaction time. *Perception & Psychophysics, 22*, 431–449.

Haider, H., & Frensch, P. A. (1996). The role of information reduction in skill acquisition. *Cognitive Psychology, 30*, 304–337.

Haider, H., & Frensch, P. A. (1999). Information reduction during skill acquisition: The influence of task instruction. *Journal of Experimental Psychology: Applied, 5*, 129–151.

Harms, L., & Bundesen, C. (1983). Color segregation and selective attention. *Perception & Psychophysics, 33*, 11–19.

Hommel, B. (1993a). Inverting the Simon effect by intention: Determinants of direction and extent of effects of irrelevant spatial information. *Psychological Research, 55*, 270–279.

Hommel, B. (1993b). The role of attention in the Simon effect. *Psychological Research, 55*, 208–222.

Hommel, B. (2000). The prepared reflex: Automaticity and control in stimulus–response translation. In S. Monsell & J. Driver (Eds.), *Attention and performance 18: Control of cognitive processes* (pp. 247–273). Cambridge, MA: MIT Press.

Kahneman, D., Treisman, A., & Gibbs, B. (1992). The reviewing of object files: Object-specific integration of information. *Cognitive Psychology, 24*, 175–219.

Kramer, A. F., & Jacobson, A. (1991). Perceptual organization and focused attention: The role of objects and proximity in visual processing. *Perception & Psychophysics, 50*, 267–284.

Kunde, W., Kiesel, A., & Hoffmann, J. (2003). Conscious control over the content of unconscious cognition. *Cognition*, *88*, 223–242.

Lamy, D., & Tsal, Y. (1999). A salient distractor does not disrupt conjunction search. *Psychological Bulletin & Review, 6*, 93–98.

Lavie, N., Hirst, A., De Fockert, J. W., & Viding, E. (2004). Load theory of selective attention and cognitive control. *Journal of Experimental Psychology: General*, *133*, 339–354.

Logan, G. D. (1978). Attention in character-classification tasks: Evidence for the automaticity of component stages. *Journal of Experimental Psychology: General, 107*, 32–63.

Logan, G. D. (2002). An instance theory of attention and memory. *Psychological Review, 109*, 376–400.

Lu, C. H., & Proctor, R. W. (1994). Processing of an irrelevant location dimension as a function of the relevant stimulus dimension. *Journal of Experimental Psychology: Human Perception and Performance, 20*, 286–298.

Miller, J. (1991). The flanker compatibility effect as a function of visual angle, attentional focus, visual transients, and perceptual load: A search for boundary conditions. *Perception & Psychophysics, 49*, 270–288.

Milliken, B., Tipper, S. P., & Weaver, B. (1994). Negative priming in a spatial localization task: Feature mismatching and distractor inhibition. *Journal of Experimental Psychology: Human Perception and Performance, 20*, 624–646.

Monsell, S., Sumner, P., & Waters, H. (2003). Task-set reconfiguration with predictable and unpredictable task switches. *Memory & Cognition, 31*, 327–342.

Oberauer, K. (2001). Removing irrelevant information from working memory: A cognitive aging study with the modified Sternberg task. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27*, 948–957.

Oberauer, K. (2002). Access to information in working memory: Exploring the focus of attention. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*, 411–421.

O'Leary, M. J., & Barber, P. J. (1993). Interference effects in the Stroop and Simon paradigm. *Journal of Experimental Psychology: Human Perception and Performance, 19*, 830–844.

Pashler, H. (1998). *The psychology of attention*. Cambridge, MA: MIT Press.

Pratt, J., & Hommel, B. (2003). Symbolic control of visual attention: The role of working memory and attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance, 5*, 835–845.

Remington, R. W., & Folk, C. L. (2001). Dissociation between attention and selection. *Psychological Science, 12*, 511–515.

Simon, J. R. (1990). The effects of irrelevant directional cue on human information processing. In R. W. Proctor & T. G. Reeve (Eds.), *Stimulus response compatibility: An integrated perspective* (pp. 31–86). Amsterdam: North-Holland.

Soto, D., Heinke, D., Humphreys, G. W., & Blanco, M. J. (2005). Early, involuntary top-down guidance of attention from working memory. *Journal of Experimental Psychology: Human Perception and Performance*, *31*, 248–261.

Ste-Marie, D., & Jacoby, L. L. (1993). Spontaneous versus directed recognition: The relativity of automaticity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*, 777–788.

Tagliabue, M., Zorzi, M., Umiltà, C., & Bassignani, F.(2000). The role of long term memory and short term memory links in the Simon effect. *Journal of Experimental Psychology: Human Perception and Performance*, *26*, 648–670.

Tzelgov, J. (1997). Automatic but conscious: That is how we act most of the time. In R. Wyer (Ed.), *Advances in social cognition* (Vol. X, pp. 217–230). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Tzelgov, J., Porat, Z., & Henik, A. (1997). Automaticity and consciousness: Is perceiving the word necessary for reading it? *The American Journal of Psychology*, *110*, 429–448.

Tzelgov, J., Yehene, V., Kotler, A., & Alon, A. (2000). Automatic comparisons of artificial digits never compared: Learning linear ordering relations. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26*, 103–120.

Wenke, D., & Frensch, P. A. (2005). The influence of task instruction on action coding: Constraint setting or direct coding? *Journal of Experimental Psychology: Human Perception and Performance, 31*, 803–819.

Wenke, D., Gaschler, R., & Nattkemper, D. (2005). Instructions induced feature binding. *Psychological Research*, *10*, 1–15.

Wheeler, M. E., & Treisman, A. M. (2002). Binding in short term visual working memory. *Journal of Experimental Psychology: General, 131*, 48–64.

White, I. M., & Wise, S. P. (1999). Rule-dependent neuronal activity in the prefrontal cortex. *Experimental Brain Research*, *126*, 315–335.

Woodworth, R. S. (1938). *Experimental psychology*. New York: Holt, Rinehart and Winston.

Yantis, S., & Egeth, H. E. (1999). On the distinction between visual salience and stimulus-driven attentional capture. *Journal of Experimental Psychology: Human Perception and Performance*, *25*, 661–676.

Yantis, S., & Johnston, J. C. (1990). On the locus of visual selection: Evidence from focused attention task. *Journal of Experimental Psychology: Human Perception and Performance*, *16*, 135–149.